The MARATHON 1500m Train Opening up new horizons in Rail Freight Transport in Europe

THE MARATHON HANDBOOK

© Sebastien Godefroy

TABLE OF CONTENTS

TABLE OF CONTENTS

1. INTRODUCTION 7

1.1 FOREWORD 7

1.2 THE MARATHON RED THREAD 7

2. TEC REC PROPOSAL AND MARATHON HANDBOOK 9

2.1 PROPOSAL FOR THE TEC REC: MARATHON TECHNICAL RECOMMENDATION 9

2.2 THE MARATHON HANDBOOK 9

3. MARATHON DEPLOYMENT PLAN 22

3.1 THE MARKET REQUIREMENTS (WP1) 23

3.1.1 BUILDING UP ON STRENGTH AND OPPORTUNITIES 26

3.1.2 THE MARITIME EVOLVING SCENARIO WITH THE DESIRED SERVICE PROFILE 29

3.1.3 THE OVERLAND EVOLVING SCENARIO WITH THE DESIRED SERVICE PROFILE 40

3.1.4 THE DEMAND/SUPPLY SIMPLIFICATION PARADIGM LEADING TO NEW BUSINESS MODEL 44

3.2 TECHNOLOGICAL DESCRIPTION (WP2 - WP3) 56

3.2.1 THE SPECIFICATIONS AND SYSTEM ARCHITECTURE (WP2) 56

3.2.2 THE APPLICATION OF TECHNOLOGIES (WP3) 83

3.3 BUSINESS CASE SIMULATION & EVALUATION (WP4) 142

3.4 PILOT TEST (WP5) 193

3.5 DISSEMINATION AND KNOWLEDGE TRANSFER (WP6) 194

4. CONCLUSIONS AND RECOMMENDATIONS 198

5. TABLES OF FIGURES & CHARTS, GLOSSARY, BIBLIOGRAPHY 207

Publisher:
NEWOPERA Aisbl
Rue d'Idalie 9-13 – 1050 Brussels – Belgium
www.newopera.org
Tel: +32 2 739 30 20
Fax: +32 2 743 15 50

Report Title:
MARATHON - THE MARATHON 1500M TRAIN OPENING UP NEW HORIZONS IN RAIL FREIGHT TRANSPORT IN EUROPE

Editors:
Franco Castagnetti
Armand Toubol

Design:
UNIFE The European Rail Industry
221 Avenue Louise – 1050 Brussels – Belgium
www.unife.org
Tel: +32 2 626 12 60
Fax: +32 2 626 12 61

Printed by Drifosett, Brussels
Layout by Orangemetalic.be

Orders: NEWOPERA Aisbl

Depot: September 2014 in Belgium

ISBN: 978-2-9601435-1-5

RECOGNITION

After **NEWOPERA** Project the precursor of the European Rail Network for Competitive Freight, **TIGER** and **TIGER DEMO** introducing new techniques and technologies for industrializing Rail Freight Transportation to/from the Sea Ports to the inland Dry Ports, the MARATHON Project with its 1500m trains opened up a completely new horizon on European Rail Freight scenario by operating a new generation of longer, faster and heavier trains.

The leadership of the **MARATHON** Project during the various stages of its development, the challenges, the problem solving, the technological achievements, the discoveries up to the train physical testing, delivered emotions and sense of achievement for having proved in a real market environment a technological conquest capable of changing the European rail Freight commercial game.

This Hand Book is dedicated to us the **MARATHON** Project initiator, to all the Project partners and the European Commission for having believed in this innovative and challenging initiative and for bringing it to a positive conclusion. The market exploitation results for Rail Freight will be far reaching contributing to the fulfillment of the EU Commission ambitious European Mobility policies.

A special recognition is due to the technology providers for developing the **MARATHON** Kit, the two equipment locomotive manufacturers and the French partners who were fundamental in organizing the operational theatre for testing these **MARATHON** trains. The **MARATHON** trains technological discoveries open up new horizon for Rail Intermodality and Rail Freight in general contributing to keep in EUROPE the Rail Global leadership.

NEWOPERA Aisbl

01. INTRODUCTION

European Commission

1.1 FOREWORD

The **MARATHON** Project developed around the concept of running a train of 1500 m length by coupling two classical trains of 750 m each with the second locomotive radio commanded by the front one, coincided with two basic market requirements:

- the need to reduce the rail freight operating costs for inducing in economic term the Shift to Rail in a sustainable and competitive way,

- The economies of scale generated at sea by the new gigantic vessels developed the requirement in the market place to move containers on land in quantities to be compatible with the maritime transport chain. The sea ports were indeed capable of handling these new giant CT vessels of 14000 TEU capacity through investments in lifting gears and equipment, only to discover that the crisis point had moved one step further along the line in the sea terminals/hinterland distribution area.

The **MARATHON** partners consortium realized that the sea ports have within themselves the economies of scale necessary for feeding continuously intermodal trains capable of dislocating CT in an industrial way to Dry Ports, Freight Villages, Mega Hubs, located in the Hinterland Traffic Attraction Zones. The **MARATHON** trains of 1500 m represent a unique opportunity for dislocating substantial traffic volumes from point to point in an industrial way at much lower operating costs. In addition the **MARATHON** trains generate extra capacity on the traditional rail lines by reducing the rail tracks occupancy hence maximizing the use of the existing resources at much reduced operating costs valued at no less than 30%. **MARATHON** Project is totally supportive of the European Commission White Paper objectives towards a more sustainable Freight mobility. The White Paper objectives of reducing 60% the GHG emissions by 2050 minimizing the dependency from fossil fuels can be achieved through a better use of the existing infrastructures, reduction of energy consumption and the adoption of environment friendly transport means.

1.2 THE MARATHON RED THREAD

The **MARATHON** "Read Thread" objective is to provide a synthetic explanation of the *MARATHON Project* Rationale which is instrumental for a better understanding of this Final Handbook.

The Final Handbook represents the conclusive document of the MARATHON Project summing up the proposal for a TecRec which is a joint effort UNIFE-UIC, the Handbook constituting an operating tool for managing these trains, the deployment plan describing both the accessible market for gaining the desired market share, the innovative system architecture, the deployed technologies, the simulation and evaluation, up to the Pilot Test executed respectively with electric and diesel locomotives. The dissemination and knowledge transfer has been executed on a Europe wide basis with ricocheting effects well beyond the Union borders. In order to perceive the correct value of the **MARATHON** Project and its future relevance on the European freight mobility evolution, it is necessary to explain in synthesis the whole Project development from its conception up to the project conclusion.

02. Tec Rec Proposal and MARATHON Handbook

European Commission

SEVENTH FRAMEWORK PROGRAMME

2.1 PROPOSAL FOR THE TEC REC: MARATHON TECHNICAL RECOMMENDATION

The **MARATHON** Project Technical Recommendation is coordinated by UNIFE and UIC together with all the Technological Project Partners. This document being related to a complete new operating situation of combining two trains of 750 m with the second locomotor in the middle of the convoy for a total train consists of 1500 m length, requires a series of cross check and validations. This process involves a number of contacts between the operators, the technology providers, UIC and UNIFE.

At the time of writing this report the Tec Rec proposal and recommendation are a work in progress not yet finalized.

2.2 THE MARATHON HANDBOOK

This chapter has not the ambition of being totally exhaustive but wishes to provide some operating guidelines utilized during the MARATHON Project development which led to test in full operating profile two trains of 1500 m length between Sibeling (Lyon) and Nîmes, one operated with two ALSTOM/AKIEM electric locomotives and the second operated with two VOSSLOH diesel locomotives.

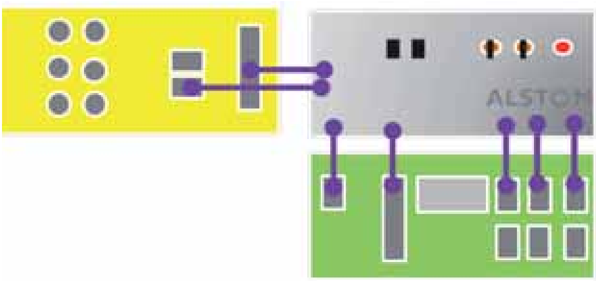
Driving operations of BB 37000 **MARATHON**

→ Figure 1: Alstom Locomotive BB 37000 in service with AKIEM.
Source: **AKIEM for MARATHON Project**

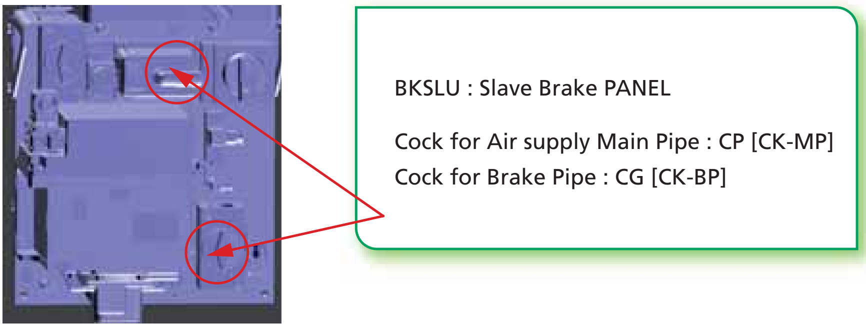
Available interfaces

→ Installation of Racks into System cubicle placed into the corridor technical room

Rack Radio [SCHEIZER Electronic]   Plate for Wiring & Configuration [ALSTOM]



Rack Distributed Power Control Unit [Faiveley]



→ Figure 2: Radio Rack & Slave Brake Panel.
Source: **MARATHON**

→ Front Face Plate dispatch with switches & circuits breakers for MARATHON configuration

→ Figure 3: Front Face Plate of MARATHON Configuration.
Source: **MARATHON**

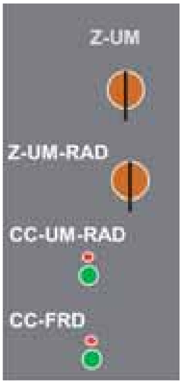
Z-RAD is the switch giving to the radio the configuration Master or Slave

Z-ORIENT is the switch giving the direction of orientation of the locomotive
BPL-DF-UM(RAD) Push button light for acknowledge of radio Multiple unit Failure

CC-DPCU Circuit breaker for protection of electronic DPCU

CC-BKSLU Circuit breaker for protection of electronic BKSLU

→ Other commands Existing on full stock locomotives



Z-UM is the switch giving the locomotive the configuration Master or Slave

Z-UM-RAD is the switch giving the locomotive the configuration Radio Remote control. It also put In/ Out service the MARATHON KIT

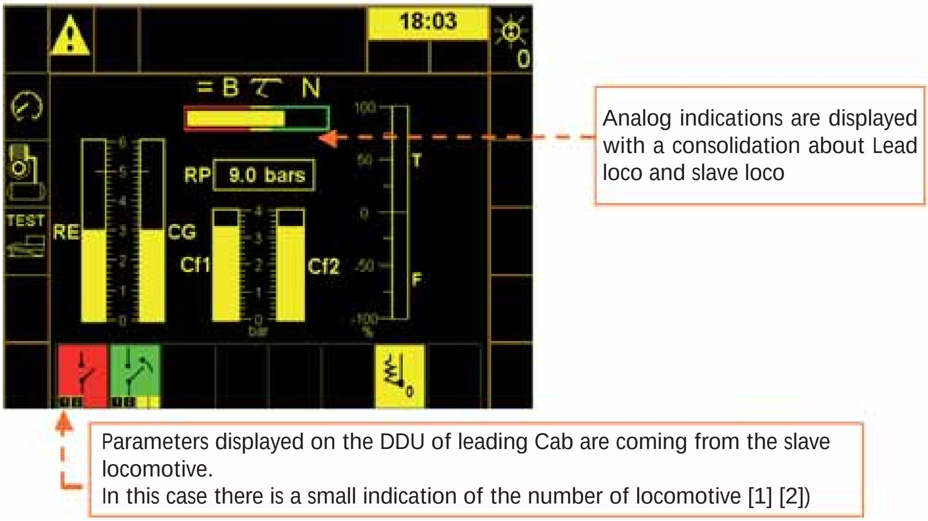
CC-UM-RAD Circuit breaker for protection of Command & control specific circuit for MARATHON

CC-FRD Circuit breaker for protection of electronic RDU

→ User accessible commands & control into the Cab with standard display

As HMI (Human Machine Interface) The driver has Driver Displays Units for monitoring of the States of the train. The different States are corresponding with the menu of the corresponding commands.

Some commands are available by touch switches around the display units.



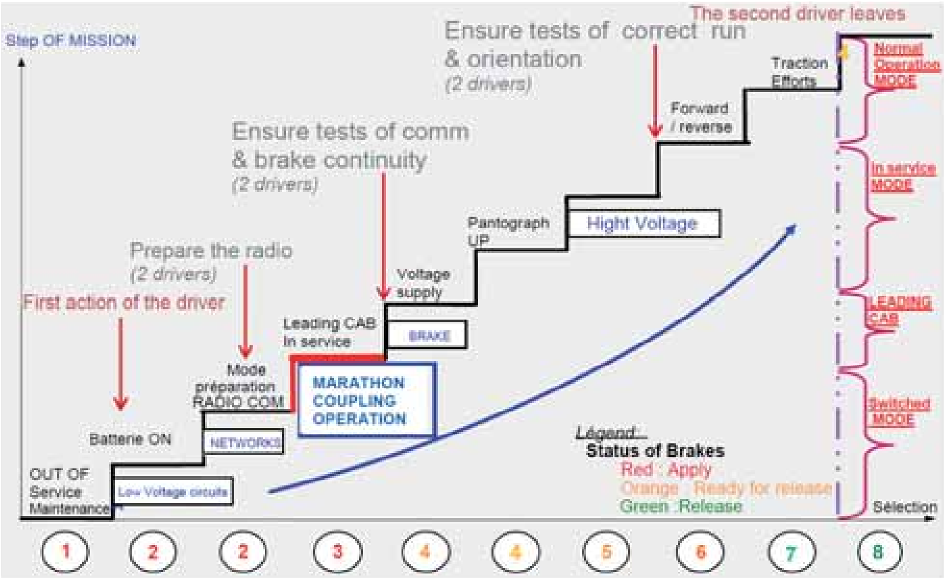
→ Figure 4: Command and Control into the Cab.
Source: **MARATHON**

➔ Scalability : Numbers of locomotives into a **MARATHON** train

The scalability of the design of wired multiple units BB 37000 is 4. (4 locos coupled). The scalability for **MARATHON** is 2 (point to point radio link). Consequently the scalability of the born design of **MARATHON** remote control is 2. It should be however extended in the future to 3 by connect 2 locomotives into the remote control set of locomotive with the first one connected radio and the second one in classical wired multiple unit.

Operations for Coupling two trains

The following Steps shall be executed in less than 15 minutes



➔ Figure 5: Operations for Coupling Two Trains.
Source: **MARATHON**

1. Configuration required Before Start operation initial phase

➔ Before the operation in distributed multiple unit both trains must have performed a complete brake test and both locomotive must have been undergoing current preparation.

The locomotive "put in service" is carried out in a classic way. It is executed on the system panel control box situated in the corridor near the cab.

BP-BA 1 to supply batteries and start the command and control of the locomotive
Ensure Z-UM is in the position MENANTE
Ensure the configuration of the brake system on "MARCHANDISE" (Goods)
Go into the cab & initialization cab in service by Z-MES

Boarding the second train must be performed according to the usual procedure by stopping a few meters from the second train.
After that, the operation connection could start.

→ Basic Status before configuration of the first locomotive MASTER :

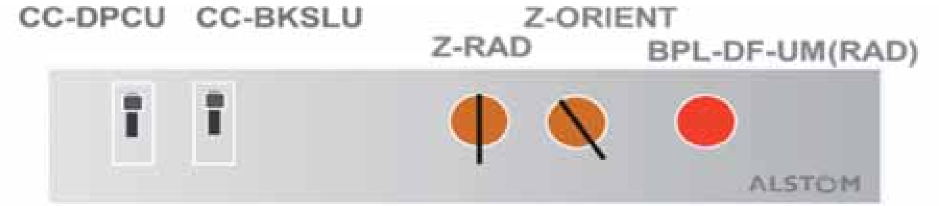
The master operative cabin must have the selector Z-MES on the radio system transmission voice
RST must be switched on
The pantograph must be in position down
The main circuit breaker must be opened
The service brake must be operating with a pressure drop of 1 bar
Driver's brake valve command by Z-NEU on 1 (NEUTRAL position)
The selector Z-UM is on MENANTE (MASTER)

2. Configuration of the second locomotive SLAVE:

The master operative cabin must have the selector Z-MES on 0
Place Z-UM on "MENEE" (SLAVE)
The on board radio is switched off
Emergency of the brake pipe CG=0 bar
Place Z-ORIENT in the position indicating the cab which is at the head of the train. The antennas od the head locomotive are sending/receiving by the cabin indicated as being at the front of the train.
Pay attention that for safety reasons the configuration must be achieved before putting the **MARATHON** Kit in service.
Place Z-RAD on "SLAVE" (chart 1)
Place Z-UM-RAD on Normal position on the locomotive has for action to put in service the **MARATHON** Kit.
Note "No master locomotive" on HMI of the Slave locomotive
Get in touch by radio with the driver of the locomotive at the front of the **MARATHON** train to inform him that his locomotive is now on SLAVE configuration.
Loco SLAVE configuration panel

2. Configuration of the first locomotive MASTER:

As soon as Slave configuration notification is received from slave locomotive driver
Place Z-ORIENT in the position indicating the cab which is at the head of the train
Place Z-RAD on MASTER (Chart 2)
Place Z-UM-RAD on Normal position on the locomotive has for action to put in service the MARATHON Kit. And has the both are now in service inauguration process start between the radios.
Pay attention that for safety reasons the configuration must be achieved before putting the **MARATHON** Kit in service.
Note the configuration UM on LOC STATUS of the HMI of the MASTER Locomotive
Authorize the physical coupling of the trains and of the Brake pipe
Close the SAFETY LOOP by BP-DJ.
Loco MASTER configuration panel

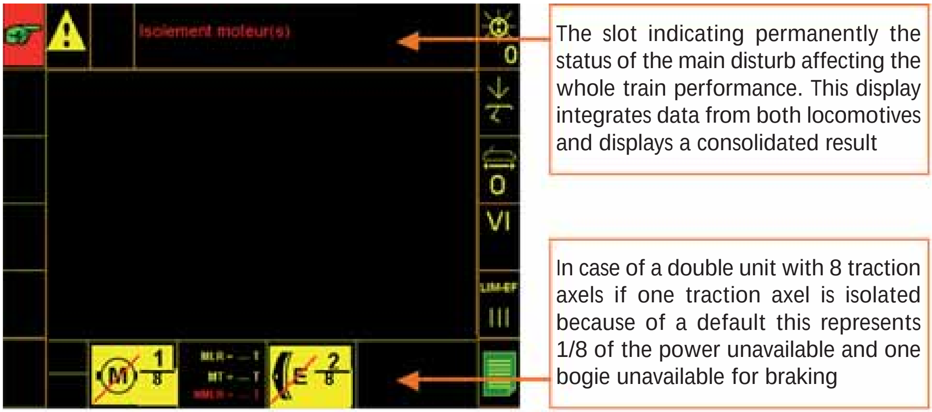


2. Brake configuration of the locomotive SLAVE:

Note there is no more message “No Master locomotive” on the HMI display of the Slave locomotive and the switch on of the light indicating “other cabin occupied”
Put in service BKSLU (slave brake panel) only in the Slave locomotive with the specific cocks CP (CK-MP) right in vertical position and CG (CK-BP) in Vertical position.
As the master loco done the close of the SAFETY LOOP in the previous step, it is possible to connect the BKSLU on the Brake pipe.
If the loop not closed, the Brake pipe will be vented by emergency valve of BKSLU.
Pay attention that in no way the Slave Locomotive configuration named DT must be in service.
The corresponding switch to check is near the brake control box
Both distributors must be on Goods position (notified on the panel “Merchandise”)
Get in touch by radio with the master Locomotive driver

3. Control of the status of the two Locomotives from locomotive MASTER:

At the end of the initialization procedure the slave locomotive informs the Master locomotive of its global status. It is displayed in a specific slot of the main screen. If that slot is totally empty it indicated to the driver of the master locomotive that the slave locomotive is in a “Leading Cab MODE”.

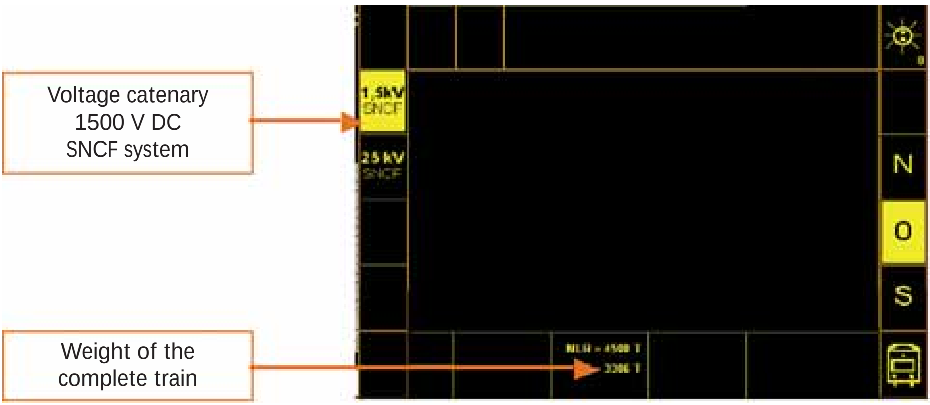


→ Figure 6: Locomotive Status from Master Locomotive.
Source: **MARATHON**

In case of failure (as following example) it is clearly indicated
Status of brakes is displayed on the screen of the Leading cab of Master locomotive. in the Menu called Locomotive Status, it is notified "M"

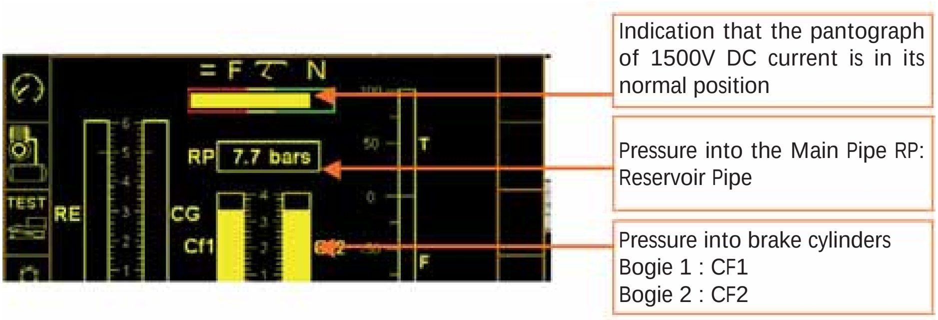
4. Entry of train data and selection of the voltage from locomotive MASTER:

Introduce the train data in integrating the maximal load authorized and tha real load of the double train. This action has an impact on the dynamic reaction of the locomotive in case of bad adhesion conditions. The selection of the type of voltage (AC/DC), and the type of pantograph to be use is made from the Master cab of the head locomotive.



→ Figure 7: Train Data Selection.
Source: **MARATHON**

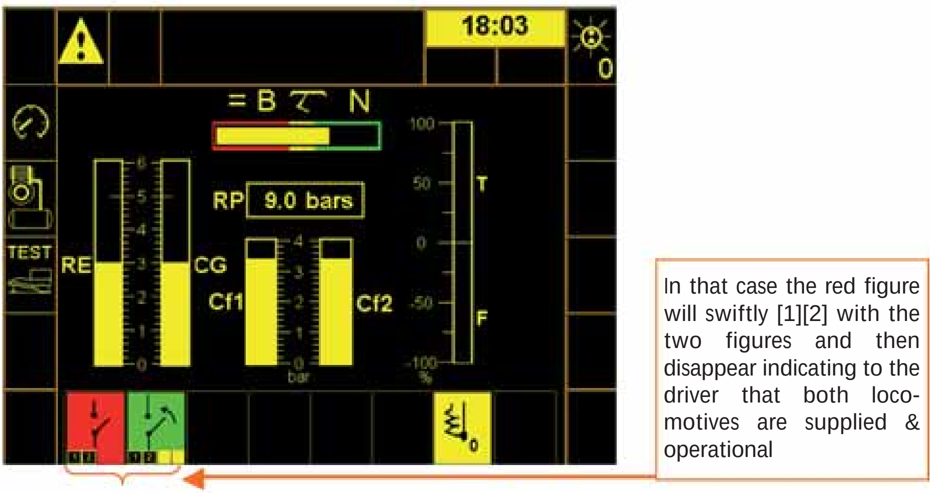
Following the simultaneous rising of the pantographs on the two locomotives (duration depending mainly on the initial values of the RP or of the use of CP-AUX) the voltage is displayed on the lead (Master) locomotive panel.



→ Figure 8: Pantograph and Locomotive Data.
Source: **MARATHON**

This indication only refers to the Lead locomotive catenary voltage only.
In case of ice on the catenary the Ice position is authorized but is only operative on the two pantographs of the Lead locomotive.

5. Electric power supply from locomotive MASTER:



→ Figure 9: Electric Power Supply.
Source: **MARATHON**

Data at train level are displayed in the leading cab at the head of the train with use of two index [1] for the Master and [2] for the slave locomotive for each picture concerned. To order the closure of the main switch (DJ) in the Lead locomotive (Master) only the green indicator is sufficient (index [1]). The other indicator (index [2]) will remain red to indicate that the slave locomotive main switch is still opened.

The closure of the main circuit breakers needs a specific authorization controlled by the current system selection devices and by the safety loops of the traction equipment. It is mandatory for the driver to maintain the button pushed until confirmation on the HMI of the effective closure. When high voltage supplied the both locomotives, red and green pictures disappear. The closure of the DJs enables the auxiliaries to become operational and in particular the compressors of the two locomotives. When the pressure is sufficient into the main pipe the driver's brake valve is available for raising the pressure in the brake pipe.

In case only one of the Dj stay open the picture red will stay with corresponding index ([2] for the slave loco not able to close its main circuit breaker)

5. Control of the brakes efficiency controlled from locomotive MASTER:

The MASTER locomotive Driver control the brake commands:
Made an overload pressure phase before the train departure. It raise the pressure of the main brake pipe at 5.4 Bars.
The SLAVE locomotive Driver use the display:
This visual check is done using the temporarily activated display panel of the no active Cabin of the Slave Locomotive. The deactivation of the panel will happen within a few minutes.
Check the increase of the pressure of CF1 and CF2.
Gives to the MASTER Locomotive Driver to refeed the Main Brake Pipe
Look the emptying of CF1 and CF2
Notify to the MASTER Locomotive Driver of the correct result of the coupling Test
During the regulatory brake tests performed by the two drivers, it is necessary that the driver of the Slave locomotive controls the pressure decrease in the RP and the starting of the compressor when the brake release phase is ordered by the driver of the lead cabin.
This action enables to check that the control box of the BKSLU is effectively ordering to the slave locomotive compressor to help the refilling of the Brake Pipe.

6. Check the movement direction when traction is ordered

The sanding command is twinned with the movement direction, the check to be done during the initialization phase is to have a look on the consistency of the sanding on the front axels.
In case of wrong traction direction the radio coupling procedure must be restarted with return of Z-UM-RAD on isolated (out of High Voltage). Then position correctly the Z-ORIENT (which was certainly wrong).
AT this STAGE the train is able to be drive only from the leading cab.

7. 8. Train Traction start-up operation

Starting the movement of the train with traction

Taking into account tha distributed traction and the weight of the train, it is necessary to start with sufficient power but smoothly because the execution of the order by the slave loco is slightly delayed by the radio safety procedures. It is suggested to activate the direct brake of the Master locomotive to avoid moving and to get the impulse on the train from the slave locomotive. Then the direct brake of the Master locomotive is released and the whole train starts to move forward slowly. take care that the effect of the push effect of the remote loco could take more than 5 second.

It is also preferable to sand manually BP-SA at the first departure to avoid any slippage. Then when the driver has acquired the whole of the train reaction the sanding remains available at discretion. In any case it is important to act smoothly with commands and to increase the traction power progressively by small steps stabilizing the train in between two successive levels of traction or reversely of direct electric braking.

The electric braking enables to reduce the train speed down to a very low level, and then the automatic brake command enables to stop it completely. This driving procedure enable to keep a slight compression of the train towards the front which is very favourable to restart the train as the couplings which are compressed gives to the locomotives the capacity to avoid dragging an extended trains and thus helping to increase speed without risks of slippage and excessive constraints.

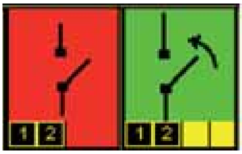
MARATHON DECOUPLING PROCESS

STEP 1] Stop the train in safety condition from MASTER locomotive:
Stop on the automatic Brake , the brake pipe is at 3 Bars
Open the main electric switch
Drop down the pantograph
Place Z-UM-RAD on Isolated

STEP 2] Deactivate the remote control on the Slave locomotive.
This step has to be done with two agents
Close CP and CG on BK-SL-U, valves in Horizontal positions
Place Z-UM-RAD on Isolated (the light on indicator of LS-UT-CAB and message on the HMI panel NO MASTER LOCMOTIVE.
Place Z-UM on MASTER
Place Z-MES on 1 in order to restart on board Radio (notify to the master Driver End of radio coupling)
Place Z-MES on 0

In case of failure of the radio system.
When the locomotive is in traction mode, from the third second of interruption of radio signal, the traction effort of the distant locomotive will be gradually returned to zero until 20s and finally the circuit breaker will be opened, then the pantograph will be lowered.

If the image index [2] comes back red it means that either the slave locomotive has not been able to close its DJ or that there has been a loss of communication over 20 seconds which obliges the Slave locomotive to reduce its traction power, then open its DJ and finally drop down its pantograph.



The locomotive will thus be considered as a vehicle. Its brake panel BKSLU will be autonomous and it will no more make release, the value of the Brake Pipe will be permanently checked.

The route continues with the locomotive Master alone and fully operational. When the train will be in a more favorable zone it will be possible to try again a cycle of traction delivery of both locomotives. If it is necessary to make a train braking when there is no radio communication: it will not be possible to modulate the braking effort, only the trigger point of the braking will be at the disposal of the driver. Indeed brake locomotive remote control unit will provoke a maximum service braking when it has received the information from drop in the brake pipe (about 4s).

To make the train available again, it will be possible to release only from the locomotive Master, the BKSLU the remote locomotive brake module is isolated. itself.

It will be again operational only when the radio will be again available.

The overall operation of the train provides both the phase of train safety and good availability because the train undergoes a momentary fault radio doesn’t stop. It still retains the ability to stop safely, and further to incident it is possible to make the track again available with only the first locomotive.

The electrical brake is however always available in any case.


akiem
37042
marathon

© Sebastien Godefroy

03. MARATHON DEPLOYMENT PLAN

3.1 THE MARKET REQUIREMENTS (WP1)

At the time of writing this report, introducing the Market Requirements task, the objectives and scope of this research have been reinforced by two important European Commission policy papers recently published which were not either envisaged or available at the launch of the **MARATHON** Project. These two policy documents are:

- "The European Rail Network for competitive freight" which was approved by the EU Parliament on November 9th 2010, setting up the long term objective of progressively creating in Europe a combination of corridors "the TEN T NETWORK" serving important freight traffic attraction zones where cargo could be transported effectively at competitive costs with long term environmental benefits.

- The recently published European White Paper on Transport which, while adjourning the modal shift towards rail avoiding traffic congestion on roads, is setting up a new ambitious objective of making the Rail Transport system in Europe competitive on distances of 300 Km or more. This indeed is a substantial step change since for decades rail freight was perceived as being competitive only for much longer distances.

In the light of the foregoing the **MARATHON** Project as a whole and its new business model become fundamental pillars towards the fulfilments of the policies set out by the EU Commission for the cargo mobility of the future. In fact the transport scenario for freight is evolving faster than anyone had expected. The transport industrialization at Sea generated by the world largest shipping lines deploying many vessels of over 14,000 TEUs with new orders for additional capacity increasing up to 18,000 TEUs, is facing a situation on land where both the existing road/rail infrastructures and the key transport actors in the chain, are caught unprepared to live up to this challenge. When the giant CTS vessels calling at a fewer number of ports, with an increased number of movements, reach the land in one of their ports of destination/departure, the crisis point is moving progressively from the ship to shore and from the quay terminals to the hinterland.

The economy of scale generated at Sea are not coherent with the transport organization on land and today more than ever before the inland distribution of single CTS carried by single trucks appears to be a very old and outdated practice. There is no transport industrialisation to/from ports to the hinterland destinations, exception made for inland navigation. However the barges system, if and when available, is suffering sometimes from the problems of the Sea port congestion having to use the same Sea port facilities which need to be decongested. The consolidation process between existing transport operators has yet a lot of progress to make and this is seen as a missing opportunity for traffic bundling and economy of scale generation. Besides the new traffic flows originating to/from the fast growing economies of the world such as China and South East Asia need additional capacity to be available in the transport infrastructures. The fact is that new infrastructures both road and rail as well as ports require a very long time to market in order to produce their beneficial effects whereas the additional transport capacity is required by the market as from now.

The answer to this paradigm which is further complicated by the need to implement transport industrialization at lower costs being this a key driver of competitiveness, can be addressed by the definition of a top railways official when declaring: *"we have to transport much more cargo with the available resources"*.

Road transport is limited by the truck dimensions and any efforts to change the existing rules in this general public awareness on environment, seems to go against history. Rail freight, on the contrary, has the ability to fulfil in practice the basic criteria of transporting more cargo at substantially reduced costs by managing longer, commercially faster and heavier trains on the existing infrastructures.

Longer faster and heavier trains are deployed in many areas of the world and also in Europe, particularly in Russia. The reasons why these trains have not developed in Central Europe which is the busiest area of commercial interchanges, is due to a number of reasons. One can indicate only few as examples: lack of technology, old rolling stock, braking and signaling to be upgraded, infrastructures to be upgraded, axel load limited to 22.5 Tons, psychological barriers and, last but not least, the lack of a clear policy in order to operate these trains on the existing lines.

Now the time for decision making has expired and most probably both the infrastructure managers and the rail operators, they are confronted themselves with what is probably today the easiest of the choices to be taken. There is in fact no alternatives to the choice of deploying longer, faster and heavier trains if one wants to generate the much needed capacity on the existing rail lines/corridors. This choice goes hand in hand with another impending market requirements of generating transport industrialization from the ports to the hinterland in order to have a transport system on land compatible with the economies of scale generated at Sea.

The decision making process is today facilitated by the availability of technologies capable of delivering the required technical standards needed for maintaining and increasing the safety requirements acceptable on the European rail network. The **MARATHON** original idea is to couple two existing trains with the second loco motor in the middle of the convoy connected by radio communication technology to the front one. By so doing the train stability should be enhanced and no additional major hazards are to be envisaged on the train dynamics. It goes without saying that these trains will be allowed to run on the existing infrastructures between ports, terminals to the hinterland where freight villages and mega-hubs have the required specifications to receive them. Equally these trains can run between two freight villages/mega hubs located in the hinterland where the traffic attraction zones reproduce the correct market conditions for having the traffic volumes capable of filling up these trains.

The implementation of this concept entails the application of a completely new business model. This is based on the selling of capacity and the production of regular services to be made available in the market place at a given timetable in order to achieve the proper reply to the paradigm of improving the service quality at lower costs. Therefore the objectives and scopes of this research are the following:

- to verify the market readiness for the adoption of these longer commercially faster and heavier trains. At the same time verify the validity of this innovative business model based on transportation of larger traffic flows at substantially lower costs, in order to attack the remaining 92% of the transport market which has eluded rail in the past 20 years;

- to stop the discussion on the existing 7/8 % market share which is probably the very residual percentage which cannot be transported without rail also in presence of a non-satisfactory services (chemicals, dangerous materials, steel, coal, etc.). If such a traffic is unable to find alternative means of transport it will certainly not be lost if a new business model is adopted. In fact what will happen is exactly the contrary. This existing traffic combined with the new one will contribute to the services improvement and to the costs abatement by implementing the transport industrialization concept;

- to simplify the production processes, particularly in the last mile. This should be possible when operating in inland terminals having the necessary economy of scale;

- to plan the distribution of the service in the market place through a multi-channel distribution concept where E/freight has a significant role;

- to envisage the adoption of enabling information technology capable of delivering resources optimization and on time information to the customers;

- to consider the adoption of a cooperative approach between all the key actors in the transport chain. Such a cooperative approach is generated by the sharing of benefits deriving from the lower cost-based production.

All these principles which appear to be revolutionary when applied to rail freight are indeed common practices in other modes of transport with no exclusions. Shipping lines are competing between themselves but through slot charter agreements they cooperate for filling up the capacity available on the ships. This happens not only in the liner CTS traffic but also on all other industrial fields. Chemical vessels carry in separate tanks products competing with each other in the same destinations. Cargo planes are filled up by the cargo being consolidated through the active co-loading efforts of forwarding agents, integrators, competing between themselves to the same destinations. Also in road transport it is very common the participation of different actors in the co-loading of trucks for optimising the space thus achieving reduction in transport costs.

The logic prevailing in such approaches is guided by the “selling of capacity” and “capacity optimisation”, being the driving force the cost reduction per unit transported, be such unit irrespective of its nature, be it 1 TEU, 1 Kilo, 1 TON, 1 cubic meter or any other weight/measurements. These practices and the cooperative approach needed to make this business model to work have hardly been recognized and implemented in rail freight be it conventional, intermodal or other type of traffic.

Additionally the scope of this research is to make also a market assessment on the marketing of these trains. Marketing in rail freight is a science which has never been used whereas marketing and merchandising are the fundamental pillars of any selling strategy. The standard definitions of freight trains opposed to passenger trains is becoming obsolete and is reflecting an old and conservative type of mentality. Already today on the European network there are several categories of trains requiring all of them different approaches and most probably different prices. This is the philosophy of service segmentation as elaborated in the **NEWOPERA** Project. Just to quote few examples, one can mention several categories of trains:

- tank wagons trains;
- IMCO class trains;
- Rolling motorways;
- Motor car trains;
- Intermodal trains;
- Steel trains;
- Coal trains;
- Cereals trains;
- Industrial trains (paper, mineral water, domestic appliances, consumers, etc.);
- Mixed trains;

Most definitely infrastructure managers, railway operators, service providers and together with all the other actors in the transport chain have to make the step change adopting this new business model based on transport industrialization by selling all the available capacity at reduced prices. Rail freight then by adopting the service segmentation approach will be capable of attracting new cargo to rail freight, reversing decades of market share decline and giving to rail the role which it deserves in Europe.

Europe needs rail freight at its best. This is the challenge to be won in the next decade.

3.1.1 Building up on Strength and Opportunities

If one wants to summarize the main elements of strength these are the following: transport industrialisation, production cycles on 24hours/365 days, cost reduction curve proportionate to progressive distance increase, time tabling ability, environment friendliness, energy efficiency, accident free, security, risk management easiness. All these elements contain both “cost reductions”, “services reliability” and “greening characteristics” which are vital ingredients for commercial success.

Likewise on the opportunities side one can summarize the following elements: market and societal readiness for cleaner, safer, sustainable transportation, driving hours regulations, Eurovignette implementation, road traffic congestion, truck drivers shortage, accessible market enlargement, maritime economy of scale availability, new accessing Countries entrance, longer, faster and heavier trains deployment, new technologies and ICT communications availability, maritime and overland traffic combination possibilities, traffic attraction zones knowledge, future traffic projections awareness, cooperation/partnership approach opportunity, customer supply chain innovative market requirements, Mega Hubs and freight villages availability as traffic multipliers, Logistics opportunities developments, multi-channel distribution approach exploitation, OSS or SPC strategy adoption, marketing, branding, time tabling as market penetration tools, wagons/rolling stock technology evolution, new business model introduction.

The strengths are encompassed within the Rail freight/intermodal nature itself whereas the opportunities which are indeed very many and representing a vast market opening must be seized by all actors involved for achieving the desired results. This should not be an impossible task since some of the opportunities are offered by the competing modalities suffering from effective limitations, incapable of offering transport industrialization being moreover penalized by negative costs evolutions and unfavorable societal environmental perceptions.

If one wants to build on the strengths and the opportunities opposed to the weaknesses and threats, one discovers that these represent indeed a limited lists where the rigidity of Rail freight being a closed system, its inferior accessibility, its element of complexity, its inability to provide equipment at a required time coupled with psychological barriers and labor blocking force, political interferences represent the major obstacles for Rail freight rejuvenation. However in every business there are elements of weaknesses and threats and it is difficult to see in the market place an occurrence of strengths and opportunities so vast at the same time. Such occurrence should justify a rapid development of Rail freight in very substantial terms with elements of sustainable growth for many years to come. It is up to the key actors for taking the initiatives and making the necessary investments coupled with the most opportune management decision for making Rail freight more competitive placing it in the heart of the European mobility scenario.

The visual representation of strengths and opportunities versus weaknesses and threats is reproduced in the following figures (see page 28):

STRENGTHS

- transport industrialisation
- production cycles on 24 h-365 days
- Cost curve reducing progressively with distance increase

OPPORTUNITIES

- Societal readiness for cleaner, safer, sustainable transport
- driving hours regulations & Eurovignette implementation
- road traffic congestion & truck drivers shortage
- accessible market enlargement & new accessing Countries
- maritime economy of scale & overland traffic combination possibilities

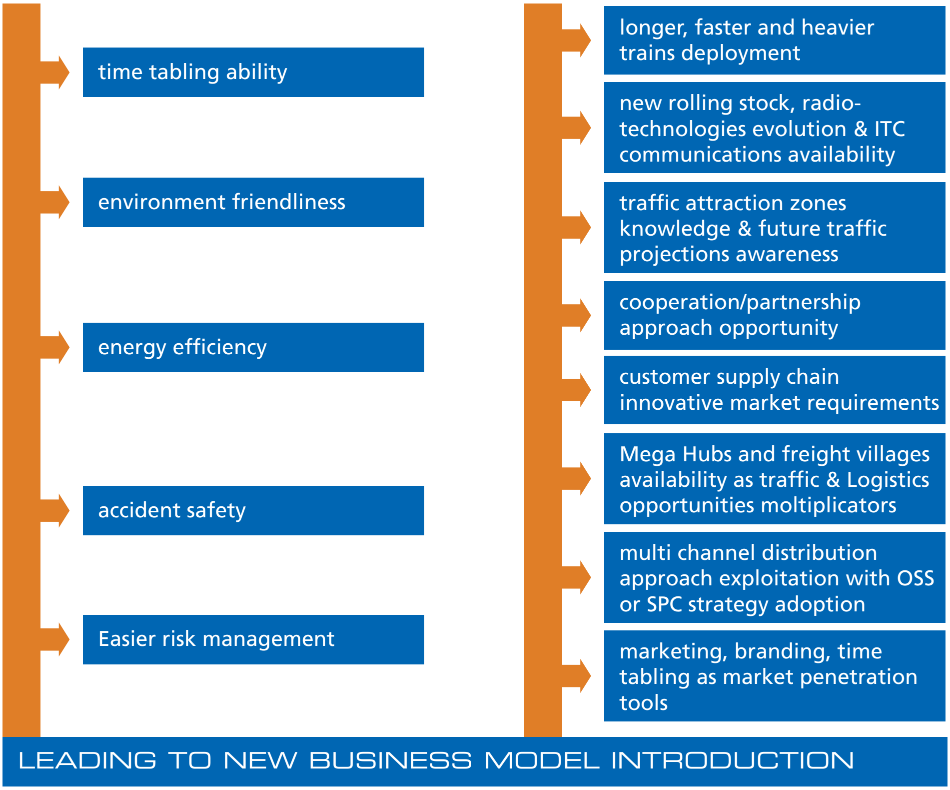
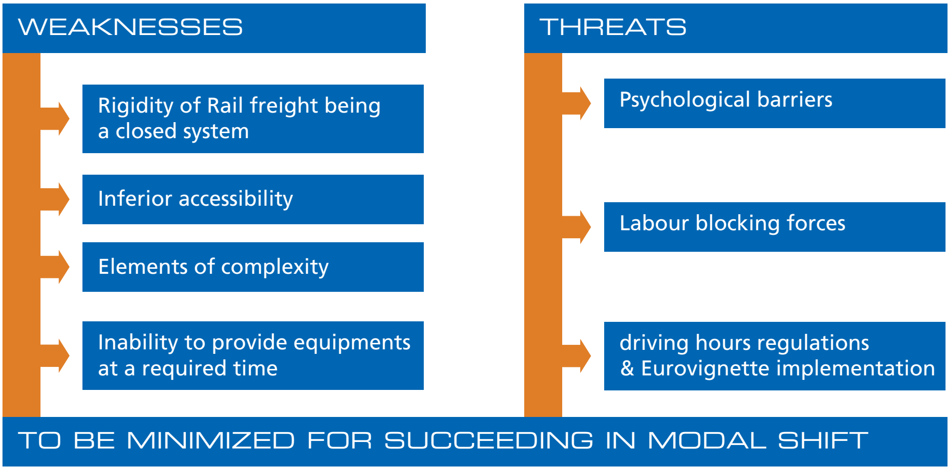


Figure 10: Strengths & Opportunities.
Source: **NEWOPERA Aisbl**

The previous graph summing up strengths and opportunities has to be put in direct connection with weaknesses and threats. The visual representation it is self-explaining. However in standard business strategy it is common practice to maximize the use of strengths and opportunities and minimize the weaknesses and threats which are the natural obstacles against the fulfilment of the modal shift, as reproduced in the following figure:



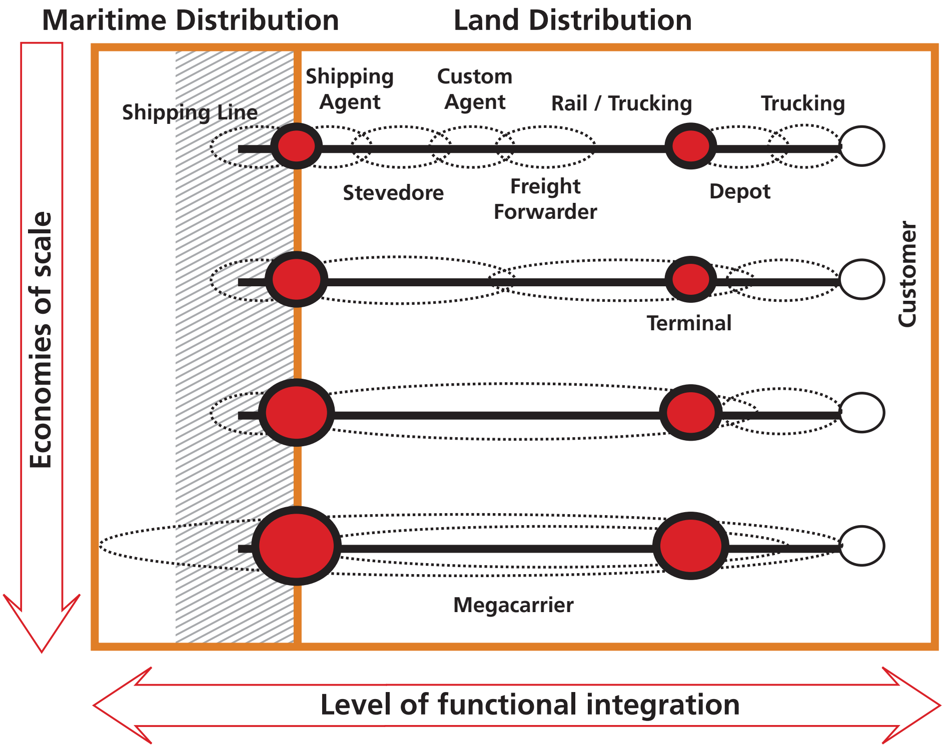
→ Figure 11: Weaknesses & Threats.
Source: **NEWOPERA Aisbl**

3.1.2 The Maritime Evolving Scenario with the Desired Service Profile

In the introduction of this document it has already been described that the new element which has given a completely different dimension in terms of traffic volumes to the challenges facing the maritime industry is the economy of scale generated by the new generation of giant CTS vessels. The new class of these vessels now fully deployed on the world sea routes reaching up to 14.000 TEUs capacity have optimized the operating costs (slot costs) while steaming at sea, but at the same time have produced negative effects when hitting land in the Sea ports.

The giant CTS vessels by definition call at a fewer number of ports where they generate a higher number of movements. By calling at a fewer number of ports the emerging result for the CTS handled is an inferior optimization of distances to/from their places of origin/destinations when compared to the natural traffic basin of each given port. The shipping lines while implementing these policies are not prepared to give away any traffic and apply to the proportion of CTS which due to increased distances appear to be penalized in costs, the principle of " equal access to the cargo "By applying this principle the shipping lines have invented a new Logistics/Transport concept which the great majority of people not involved in transport matters have difficulties to understand. This concept is known as "virtual distances", wanting to signify that according to market circumstances the physical distances are completely different from the virtual distances. The virtual distances concept generated another one called the "Sea port gravitational areas" or "Sea port competitive accessibility" to signify the ability of the port itself in combination with its shipping lines to attract cargo from geographical areas where physical distances would have justified the use of another Sea port nearer to the places of origin/destination. The virtual distances combined with the Sea port competitive accessibility are largely applied in everyday business practices and are indeed marketing and commercial tools in the market place.

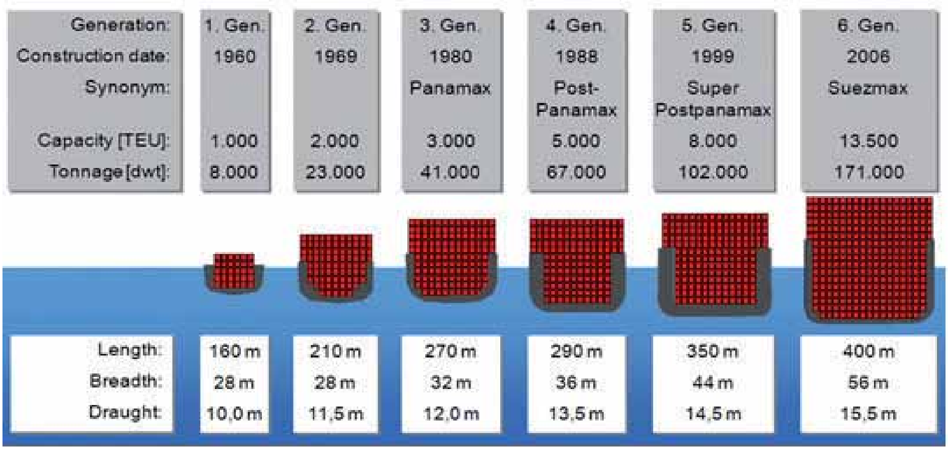
By calling at a fewer number of ports the quantities of handled CTS becomes greater and here is where the first problem arises for the giant vessels when meeting the land in the port. The port represents the link between land and Sea. The economy of scale generated at Sea do not find the same compatible dimension on land. The crisis point following the industrial dimension generated by the giant CTS vessels has moved from the Sea to the Terminal quays and from the Terminal quays to the hinterland where it becomes evident that the distribution cannot be fulfilled by road on a one by one bases, but has to be industrialized.



→ Figure 12: Functional Integration of Supply Chain (Adapted Model of Robinson).
Source: **Naples Port Authority**

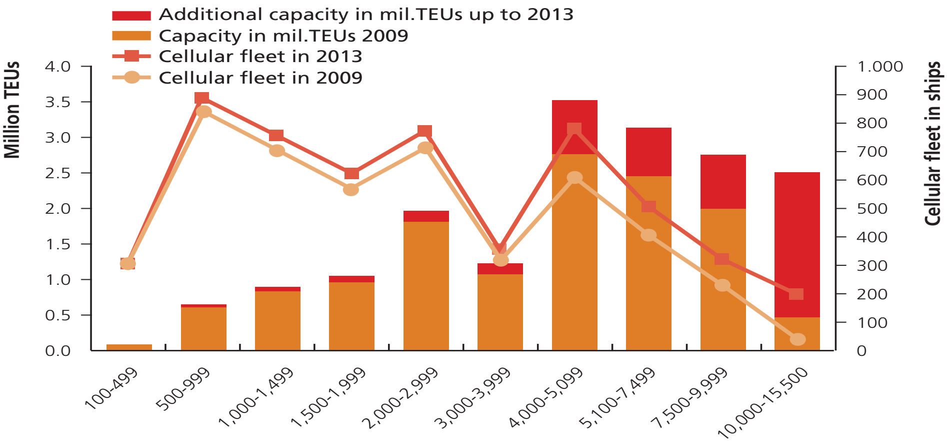
The above is representing the evolution of the industrialization process in the maritime traffic. The existing operational scenario is in the last stage represented by the Mega carrier. The graph is representing a production simplification of the maritime transport chain where the hey elements in the chain are represented by the ship, the Port terminal as well as the hinterland Mega Hubs/Freight villages.

The CTS vessels sizes have grown over the past few years providing a substantial increase in maritime carrying capacity. The following figure (Figure 4) illustrates the development of new CTS ships as from 1960. The largest of these ships are capable of carrying today 14,000 TEUs or more. Orders of new tonnage to a Korean shipyard have been passed by the World's largest shipping lines for 18,000 TEUs vessels. The delivery of these vessels is expected in about two years' time. This fast and phenomenal evolution in the maritime sector stands to indicate the Economies of scale which the overland operators and infrastructure managers will be confronted with.



→ Figure 13: Containers Vessel Size Groups.
Source: **Port of Hamburg Marketing**

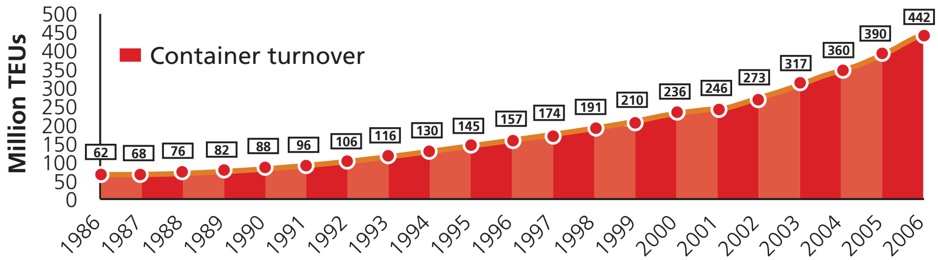
The next picture confirming the above trends shows that the additional capacity is provided by the introduction of the giant CTS vessels whereas the smaller vessels are no longer built.



→ Figure 14: Cellular Ship Delivery Program 2009-2013.
Source: **HHM, data: AXS-Alphaliner**

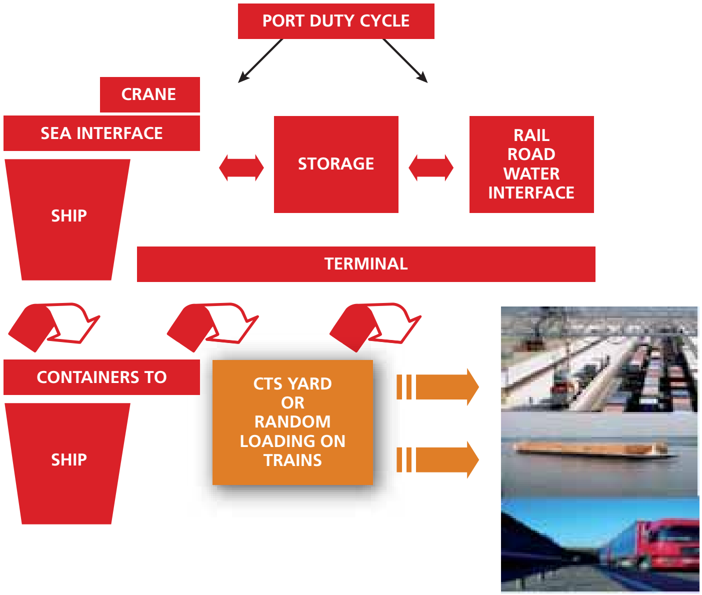
The following graph if one focuses the attention on the last 5 years from 2001 to 2006, it is possible to appreciate how quickly the maritime traffic has changed the World scenario. While it took 30 years to build the traffic up to 236 MM TEUs from the conventional time (the containerization process started in the 70ies while the statistics here reproduced starts from 1986), it took only 5 years from 2001 to 2006 to double this colossal containerized traffic.

With the advent of the giant CTS vessels this trend has started to grow even further and the traffic forecast indicate a further colossal jump from now to 2020. The Traffic forecast up to 2020 are reproduced in the following pages.



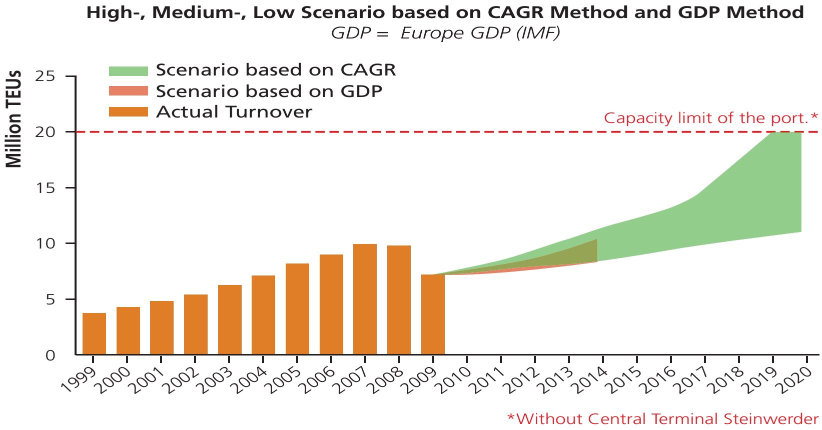
→ Figure 15: World CTS Traffic Evolution.
Source: **Port of Hamburg**

The next picture is showing how the industrialization process of the maritime sector is facing the bottleneck in the total production cycle. When the giant CTS vessels hit the ports due to a larger number of their movements they generate congestion on the quays which are the immediate storage areas and a new business model must be introduced to link the interfaces “ships to shore” and from “shore to inland destinations” in order to generate a seamless industrialization process to move immediately the traffic from the Sea Ports to the inland Dry Ports. In the inland Dry Ports it will be possible to combine the maritime traffic already managed in an industrialized way with the European overland traffic allowing Rail freight to multiply its chances for reaching additional inland destinations where in the past insufficient volumes could not allow the bundling of full trains. This process increases both volumes and frequencies contributing to the cost reduction & services improvements.

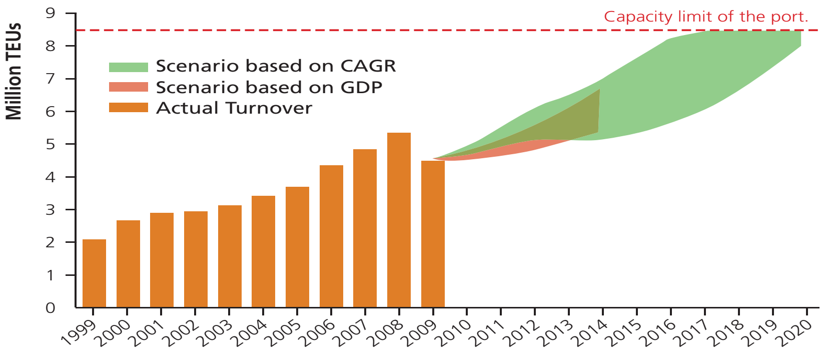


→ Figure 16: Port Duty Cycle Graphic Representation.
Source: **NEWOPERA Project**

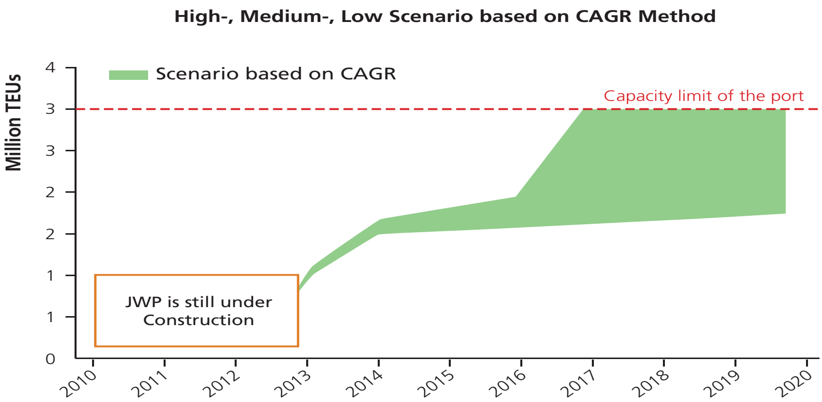
The following graphs show the Traffic forecasts from now to 2020 of major North European and Mediterranean Ports as emerged from a recent research elaborated by the TIGER Project (TIGER FP7). The Traffic forecasts stand to indicate that by 2020 the North European Ports will reach their technical capacity despite the investments which are in progress. The industrialized business model for moving traffic from the Sea Ports to the Dry Ports appears to be the only realistic solution to the challenge posed by the maritime sector. Longer, commercially faster and heavier trains represent the only way to generate additional capacity on the Rail lines indispensable for moving quickly the traffic handled by the new giant CTS vessels. The road option although forecasted on a growing trend, is unable to deal with this additional traffic.



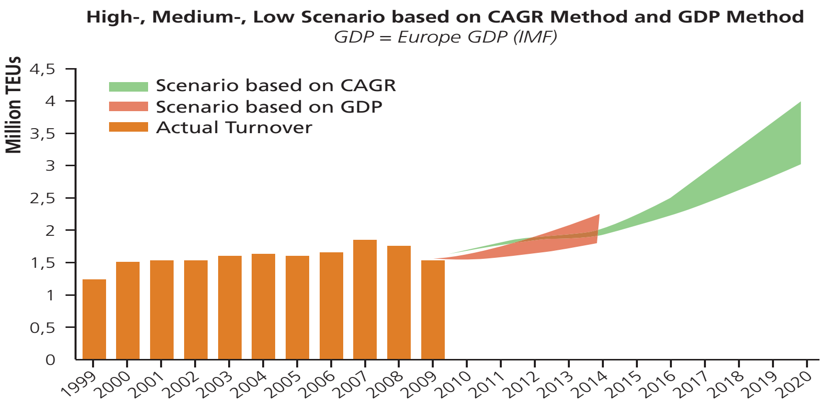
→ Figure 17: High / Medium / Low Scenario Based on CAGR and GDP for Port of Hamburg. Source: **TIGER Project**



→ Figure 18: High / Medium / Low Scenario Based on CAGR and GDP for Bremerhaven Port. Source: **TIGER Project**

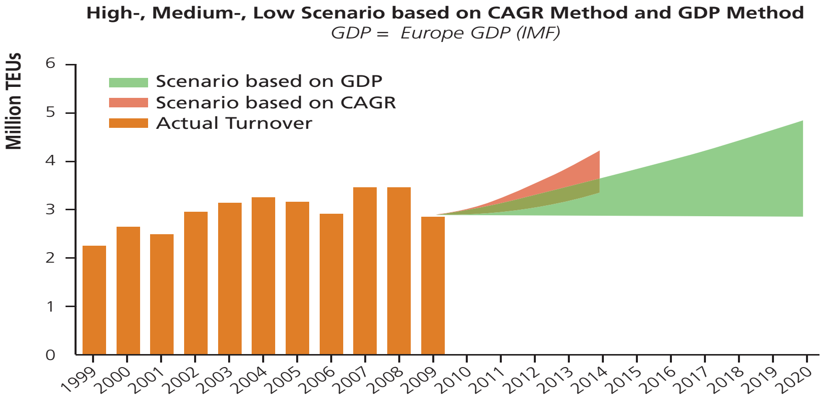


→ Figure 19: High Medium Low Scenario Based on CAGR Methodology for the Jade-Weser-Port. Source: **TIGER Project**

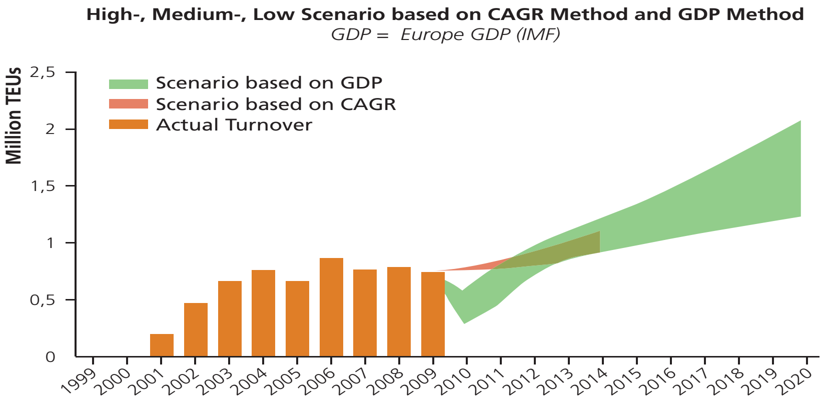


→ Figure 20: High / Medium / Low Scenario Based on CAGR and GDP for Genoa Port. Source: **TIGER Project**

A residual Technical capacity is expected to remain available in the European Mediterranean Ports due to the competition exercised by completely new Ports infrastructures in the North African Countries. In fact Traffic Market share is likely to be transferred from South Mediterranean Ports to North African Ports due to much inferior cost of labor.



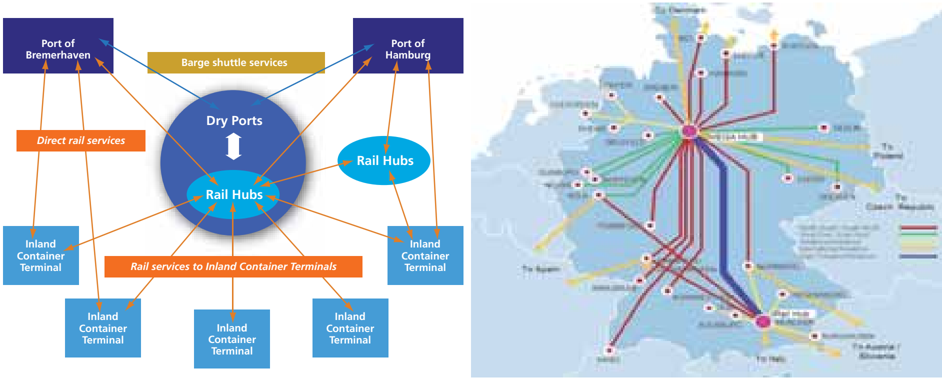
→ Figure 21: High / Medium / Low Scenario Based on CAGR and GDP for Gioia Tauro Port. Source: **TIGER Project**



→ Figure 22: High / Medium / Low Scenario Based on CAGR and GDP for Taranto Port. Source: **TIGER Project**

From the previous paragraphs it becomes apparent that the driving forces towards the Transport industrialization leading to MARATHON longer, commercially faster and heavier trains are the Economies of scale generated at Sea and discharged on land at Sea Ports and combined with the progressive technical capacity saturation of the same Ports. Consequently the need of the Sea Ports to sustain both their Traffic development, their economic growth and the consistency of a service quality performance to the customers is lying on their ability to keep moving the traffic to/from the Sea Ports to the hinterland destinations. This is a paramount paradigm to be resolved which will be pushing towards finding innovative Transport solutions. Infrastructure investments will take too long anyway to come to fruition apart from the budget constraints which themselves exclude this possibility. Therefore the operating alternatives must be found into the implementation of new work processes and the application of innovative business models based on technology improvements and better use of existing infrastructures.

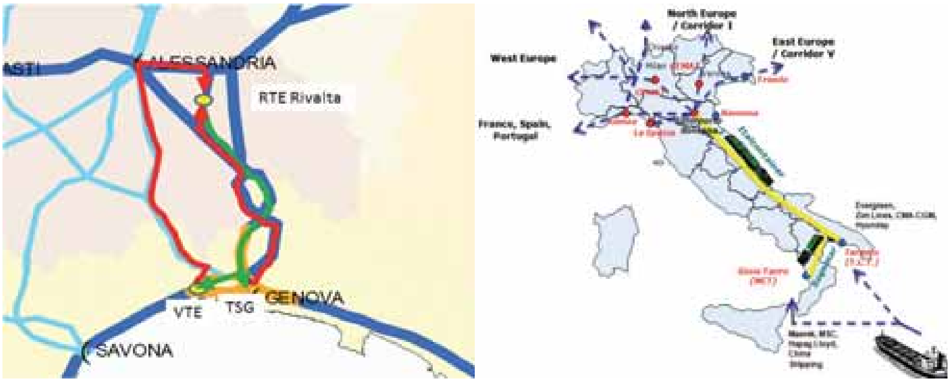
In the following Figure is reproduced how the German Ports are getting ready to resolve the overland service challenges posed by the maritime new Economies of scale. It is obvious that investments are necessary particularly in the Inland Dry Ports and Mega Hubs in order to equip them with the needed technologies and additional terminal facilities necessary to introduce the “extended Ports-Quays” approach. However such investments on land are much easier to be accomplished compared to investments at Sea with the additional benefits that Freight Villages, Terminals and Mega Hubs are managed by private investors or by public-private enterprises on pure competitive and economical basis totally Market driven.



➔ Figure 23: Mega Hub & Dry Ports Envisaged Service Solutions.
Source: **TIGER Project**

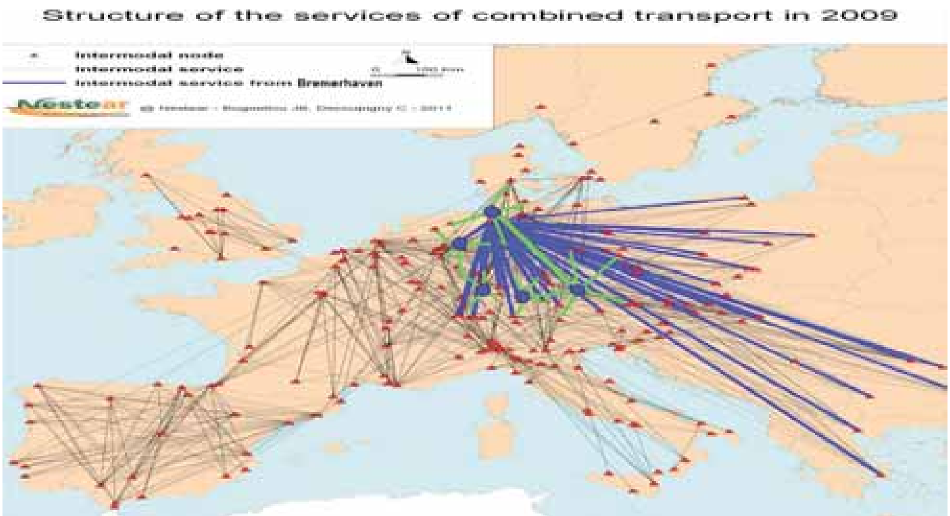
The prevailing philosophy here is based on co-modality where the best performances by each transport mode is put at the center of the envisaged solutions. All transport modes are used at their best. Rail, road and inland waterways are used in the Bremerhaven/Bremen Dry Port solution. Additionally for the Mega Hub two strategies are being implemented with the ”near approach” and the “distant approach”. Both solutions make visible how the seamless flows of traffic move from the Sea Port to the Hinterland in a continuous transport chain.

Likewise the Italian Ports as represented in previous figures have found sustainable solutions based on the same approaches. The Port of Genoa through the Mega Hub of Rivalta Terminal Europe fed continuously by shuttle trains from the Port overcoming the Apennines natural barrier. The Port of Gioia Tauro and Taranto, joining their traffic in Bari to route it to Bologna Freight Village via the Adriatic Rail line less congested than the Tyrrhenian Rail line.

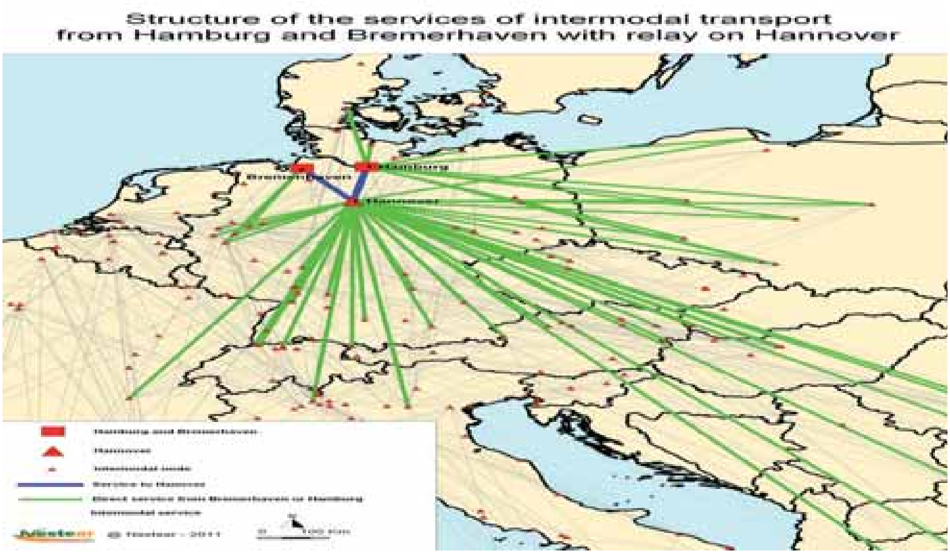


➔ Figure 24: Mega Hub & Dry Ports Service Solutions.
Source: **TIGER Project**

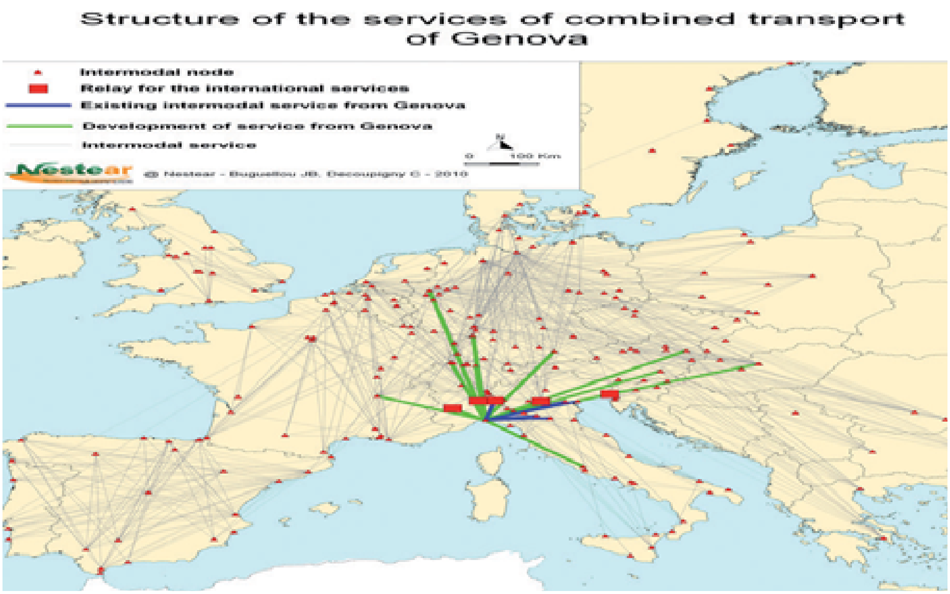
As a result of these innovative solutions the Sea Ports are able to manage in a sustainable way their continuous growth and Rail freight as a result is increasing dramatically its service performances and its market share on the maritime traffic. At the same time together with the costs reduction and service improvement the transport industrialization on Rail is conducive towards a more extended competitive reach of the Ports themselves improving the Ports accessibility helping them to extend their attraction areas. The gravity zones far away from the Ports due to these Rail industrial services are largely extended making it easier for the Countries not having any Sea front to be directly connected to more than one Ports. The following graphs are making this concept very visible.



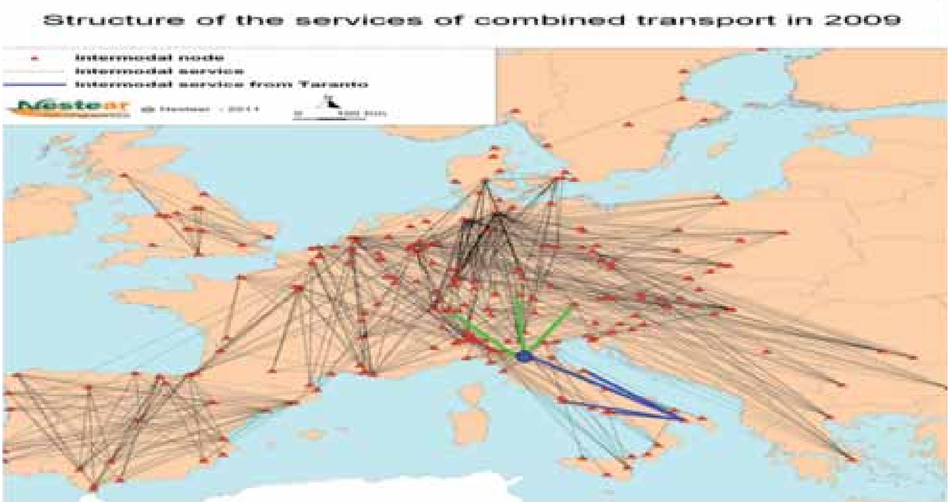
➔ Figure 25: Hamburg Rail Service reach & Dry Ports “Distant Approach”.
Source: **NESTEAR**



→ Figure 26: Hamburg Rail Services and Dry Ports “Near Approach”.
Source: **NESTEAR**



→ Figure 27: Genoa Rail Service Reach and Dry Ports Approach.
Source: **NESTEAR**

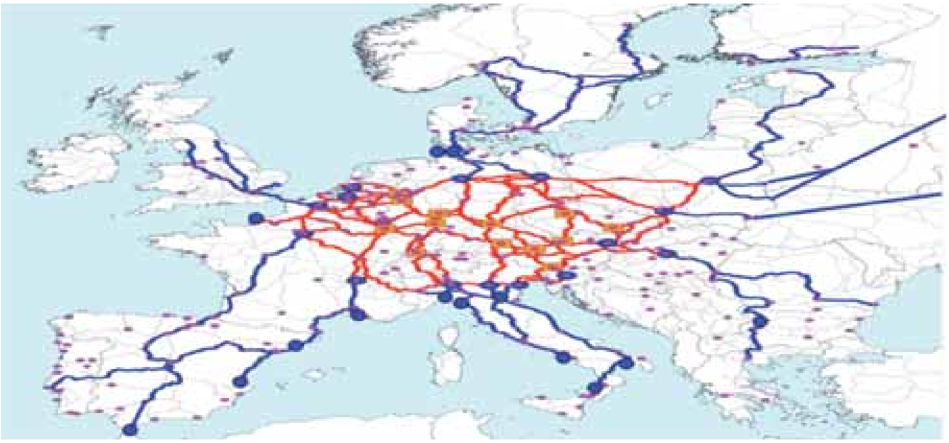


➔ Figure 28: Taranto & Gioia Tauro Rail Services and Dry Ports approach.
Source: **NESTEAR**

3.1.3 The Overland Evolving Scenario with the Desired Service Profile

Also the Overland sector has undergone in the last few years major structural changes. The Rail Network is not only a combination of Rail corridors but also a combination of Rail corridors integrated with a number of Freight Villages, Hubs and Terminals. The Hubs, Terminals, Freight Villages integrated on major European corridors constitute the Freight multipliers, represent the centers of traffic bundling and the structures capable of providing the additional tools for achieving Freight industrialization. It is obvious that longer, commercially faster and heavier trains up to 1500 m can run only between Point(Terminal)-to-Point(Terminal) giving an industrial dimension to that particular section of the transport chain. These Terminals must have the capacity and the Rail tracks of a length adequate to house such long trains or two semi-trains of 750 m.

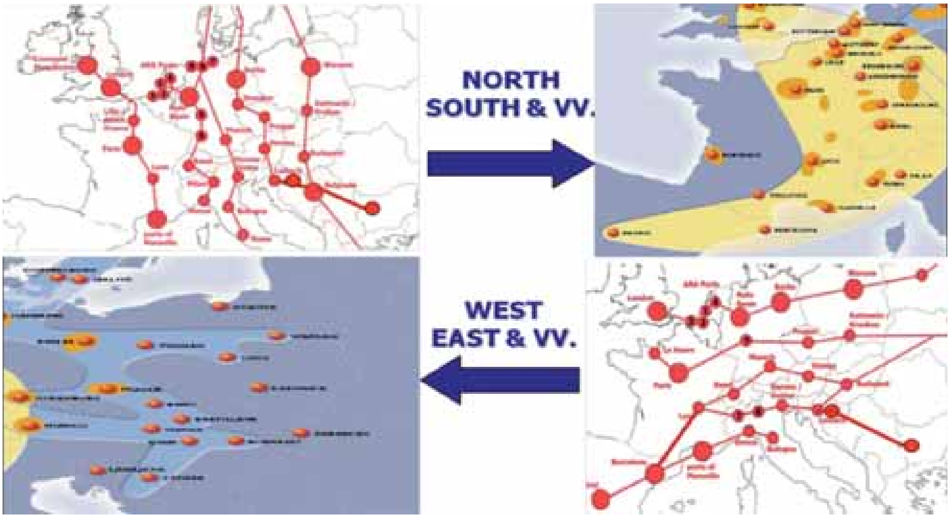
The following is reproducing the NEWOPERA Rail network which is encompassing the TEN-T corridors. The small pink dotted points are the existing Terminals and most of them are located outside the major corridors and very few are located on the corridors themselves or at the interchanges. This signifies that these Terminals have been constructed following either domestic prevailing logics or for political Decision Making obeying to parochial interests. The Terminals and Hubs of the future have to be planned according to the philosophy of a “borderless Union” and have to fulfil the requirements of traffic collectors and multipliers along major European corridors or at the intersections of such corridors. At the same time they have to be at the center of substantial traffic attraction zones to serve either important City centers or major industrial areas. The most successful Terminals/Freight Villages have already such characteristics and their successful developments indicate that such market requirements have been satisfied. Any new initiatives in this field have to fulfil these basic pre-requisites.



➔ Figure 29: NEWOPERA Rail Network & Intermodal Terminals.
Source: **NEWOPERA Project**

The structural changes of the continental European traffic were originated mainly by the new dimension of the West-East traffics generated by the European Union enlargement towards the East, by the emerging phenomenon of industry relocation in Countries with lower labor costs and by the consequential development of these Economies at higher GNP rates than Central Europe. Also the Russian economy which has transformed itself into a market driven one is influencing this mega trend. As a result the inter European interchanges which for decades have developed along the North-South axes both road and Rail, have been complemented and supplemented by the West-East improved trading conditions generating substantial traffic volumes in these directions. This is making international transportation more complex, the European logistics more sophisticated bringing further pressures on already constrained European infrastructures.

The new accessing Countries have started developing their infrastructures both road and rail. The next picture is synthesizing this situation where the famous “Banana” of the most industrialized European traffic zones is crossed by a number of trade lanes to and from the new emerging Countries. The commercial activities of these Countries are set to increase in the future making Rail Freight a key actor of their development.



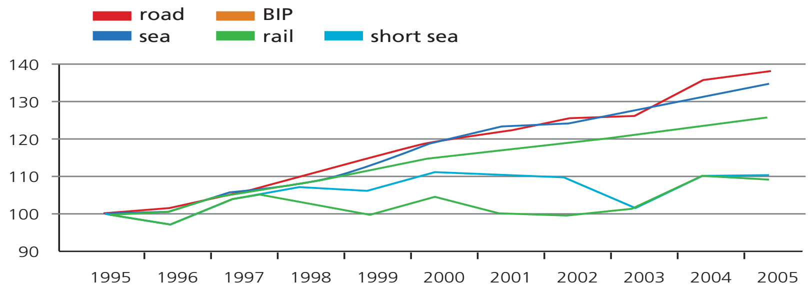
→ Figure 30: Traditional Flows North-South Supplemented by East-West.
Source: **NEWOPERA Aisbl**

As a result of such structural changes a number of commercial Rail connections have been established with regular services managed by old and new European Rail freight operators. Here below few examples are reported(not exhaustive)proving this evolution with various Rail Freight operators and customers responding to these new challenges posed by the market. In the next picture the VR Finnish Railways extending towards the Russian network is reproduced.

→ Figure 31: VR with PGK Rail Network towards Russia.
Source: **VR**

The next figure indicates the traffic evolution in Europe and the prevailing modal shift which the European Authorities are trying to correct. Road and Maritime modes of Transports are continuing their expansion together with Intermodality whereas Short sea shipping and rail are on flatter trends. The next picture is comparing the overland connections with Asia with the maritime sea trade lanes highlighting the difference in distances.

Several Rail Freight Operators are engaged on the Trans-Siberian and Trans Asia routes with regular services. One must say that the Rail connections are utilized for high value CARGO being the rail transport costs much higher than sea freight. Consequently it would not be realistic to project into the future the utilization of the overland routing to a large scale.



Note : Maritime = seulement transport domestique et intra-UE 25.
Route = transport national et international de véhicules enregistrés en UE 25.
Source : Eurostat, European Conference of Ministers of Transport.

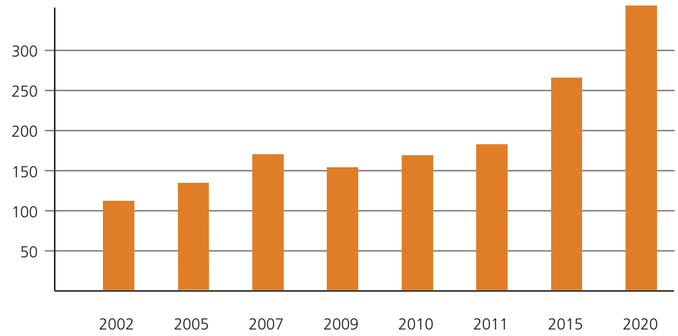
→ Figure 32: Transport Modal Split in Europe.
Source: **EUROSTAT**

→ Figure 33: ROUTE Asia-Europe.
Source: **TRACECA**

Another factor to be taken into consideration is the fact that on these overland corridors towards the East new industries are appearing because of the relocation phenomenon in areas of lower labor costs, generating new mobility needs. One of these much publicized connections is represented by the Beijing/Hamburg rail corridor operated by DB Schenker. The actual opening to the European market of these overland Trans Asia connections are favoring the progressive establishment of rail services between Central Europe and Eastern provinces where the industry relocation phenomenon is taking place.

The Intermodal traffic as a result of these new services integrating the North - South Corridors with the West – East ones is producing a substantial traffic overland increase making Rail Intermodality a true operating alternative capable of favoring modal shift. The Intermodal traffic projections are pointing decisively towards new records. The temporary setback suffered during 2009 because of the economic recession has been already recovered and the projections to 2020 are forecasting a doubling of the volumes as reported in the next chart.

Likewise the maritime the overland sector needs the transport industrialization business model in order to reduce substantially the operating costs giving substance to the TENT corridors which are providing new accessibility to the industrial and economic traffic attraction zones of Europe.



→ Figure 34: Intermodal Traffic Projections to 2020.
Source: **KV**

3.1.4 The Demand/Supply Simplification Paradigm Leading to New Business Model

The failure of Rail Freight in capturing market share has been caused by its inability in responding to market changes. In fact such inability has produced the effect of substantial losses in market share. The basic mistake occurred in the rail freight marketing approach has been not understanding the essential concept that in the "SERVICE INDUSTRY" the services must be readily available in the market place in order for them to be sold to the customers. If the services are not available they cannot be sold since the production of such services take such a long time to be organized that the prospective customers meantime had to find alternative solutions. The Customers sophisticated Supply Chains cannot wait for the time to market necessary for future services organization(Demand driven).The Demand driven approach is typical of physical products both consumers and durables linked to production lines. The transport and logistics services are more linked to time and space factors which constitute an essential VALUE component of the physical products which is being transported. The VALUE of the transported products is sustainable for the customers if available in the time and in the location where it is required. Therefore the Service offering must be concrete and available if one wished that the potential customers could purchase such services. This is the Offer Driven approach which Rail Freight has failed to exploit. Several examples are available in the service industry itself to prove this point. The Integrators have launched this approach industrializing the intermediate long haul section of the total transportation chain. DHL –UPS – FEDEX – TNT have been the first off the starting blocks followed by many others. The Maritime CTS industry is marketing its World shipping services based on timetables, regularity and consistency. The same applies to the airlines. More so the low costs airlines. The Rail High Speed services have reversed years of declines and by applying the Offer Driven approach, are conquering growing market share pushing progressively the airlines which were their original competitors out of the medium distances market segment. All these industries and operators have one common denominator. Their businesses are “CAPITAL INTENSIVE”. The CAPITAL rotation is essential for survival. Rail Freight has failed to interpret this basic economic requirement. If Rail Freight wants to be successful the traditional business approach must be reversed by implementing the OFFER DRIVEN PHILOSOPHY.

The Asset Based Business Model Driven by Transport Industrialization.

As indicated in the Methodology chapter of this document, Rail Freight Services are produced through the deployment of substantial equipment and infrastructures such as locomotors, wagons, trains, terminals, marshalling yards, Rail tracks, maintenance and repair facilities, etc., making them a very capital intensive activity. In order to secure a proper return on the capital invested the emerging asset based business model must be built around the proper rotation of assets so that they are capable to generate on 365 days and 24 hours round the clock activity the required productivity for securing services availability combined with cost competitiveness. Transport industrialization must be the necessary strategy for achieving these goals. May be one reason why this business model was not adopted in the past is to be attributed to the fact that the incumbents did not have a proper attribution of their costs to the correct sources. The monopolistic approach combined with the perception that the Rail infrastructures were belonging to the States, did not provide the necessary incentives to manage the business on classic and competitive economical basis. The liberalization process undertaken in the last decades by the European Commission through the various Rail packages with the privatization of the incumbents activities and the opening of the Rail market to effective competition, has generated the conditions for a complete change of philosophy. The market forces are now prevailing and the newcomers are imposing through their aggressive competitive profile new operating and commercial practices for the service exploitations. The traditional operators must become more efficient and competitive if they want to avoid their complete disappearance from the market place.

As indicated in other parts of this document, an unexpected help favoring new opportunities, is represented by the need of de-carbonizing the transport field and achieving at the same time energy savings. Several studies have been made in this field. A most recent one carried out for CEFIC. It goes without saying that such values are varying depending on individual supply chains, products and customer base. However the trend towards de-carbonising transport plays clearly in the hands of Rail Freight.

The services, as already stated, have to be readily available. The service availability or Rail Freight in order to be produced on a competitive basis must access the traffic industrial dimension of major traffic basins. This means that the service offering must become available where the industrial demand is being generated. The simplification of the offer driven approach must be produced between terminals which are located in substantial traffic attraction zones such as Ports, Freight Villages, Industrial or Consumption areas. This itself is a very old concept largely applied by the airlines and the maritime industries. One of the excuses largely adopted by Rail freight relied on the misconception of the "demand driven approach" where the customers wanted a "tailor made" service which the Rail operators were not able to offer anyway. The result of this misconception has been the loss of market share. The solution of this paradigm is the ability to produce a standard service on an intermediate portion of the transport leg while the service "customization" can be achieved in the so called "last mile". The maritime industry is producing this standard service on the "Quay to Quay" segment likewise the airline industry is producing the same standardized service on the "Airport to Airport" while the personalization of the customers' requirements is fulfilled in the total "door to door" transportation. The asset based business model driven by Transport Industrialization applied to the service industry must be based on a number of fundamental pillars:

- Nomination of a geographical network of reference;
- Standardization of service products;
- Utilization of economies of scale achieved through mass production on a given transport route between two nominated points (Terminals, Hubs, Freight Villages, Ports, etc.) having the characteristics of being traffic attraction zones;
- Identification of product service through easily recognized "market brands";
- Publication of timetabling coherent with the needs of the reference market;
- Assignment of the resources (equipment, labor, infrastructures, management, etc.) capable of sustaining the service quality performances;
- Nomination of equipment available to the customers (wagons, CTS, Intermodal units.) for satisfying their needs. Equipment and wagons must be standardized;
- Employment of advanced technologies and management systems coherent with the service industrialization objectives and cost/service competitiveness;
- Declaration of the strong points (the advantages for the customers) which the market should be relying on (why the customers should buy the service);
- Publication of transparent tariffs/pricing based for the basic service;
- Identification of payment terms;

- Nomination of innovative distribution channels. These could be direct (for major customers) or indirect (through forwarding agents, operators, partners, MTOs, integrators, etc.) or via the web through e-freight solutions;
- Application of One Stop Shop (OSS) or Single Point of Contact (SPC) combined with Concurrent Planning;
- Adoption of the Selling of Capacity policy being the full utilization of the trains the major task for being competitive assuring the required return of capital;
- Introduction in the terminal/terminals of the trains destinations of the same operating and commercial capabilities able to assure the return of these trains in full load capacity to the place of origin;
- Introduction of longer, commercially faster and heavier trains to reduce substantially the operating costs in order to be more competitive with other transport modes. This is the core objective of this MARATHON Project.

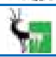
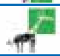
SEGMENTS	SYMBOL	Rail Market Share	Size of Market	Growing Potential	Customers Group
Raw Materials		High	Very Large	Linked to Growth	Heavy Industry
Durable Goods		Medium	Very Large	High	Large Shippers and LSP
Fast Consumer		Very Small	Very Large	Very High	LSP
Furniture, Toys, Household Ornam.		Very Small	Large	Very High	LSP
Process Industries		Medium	Very Large	High	Large Shippers and LSP
General Cargo		Negligible	Very Large	Very High	LSP, Optimisers, Consolidators
Specialities, Dangerous		Medium	Medium	Medium	Large Shippers and Specialised LSP
SEGMENTS	SYMBOL	Rail Market Share	Size of Market	Growing Potential	Customers Group
Green Logistics		Large	Very Large	Very High	Heavy / Process industries, Large Shippers, Specialised LSP
Web Star		Large	Very Large	Very High	Cross Section

Figure 35: Potential Products Description & Growing Potential.
Source: **NEWOPERA Project**

Intermodal operators have started to implement this philosophy through the adoption of the shuttle trains. Some of their efforts have been frustrated by the lack of capacity on the Rail network and the service disruptions emerging thereof. The generation of capacity to be achieved through longer, commercially faster and heavier trains is an important pre-requisite for implementing this philosophy.

The capacity must be available on the Rail tracks if the transport industrialization driving the asset based business model is to be successful. The target market is potentially enormous as it appears in Figure 35. In addition, one has to remember that on this figure the maritime sector to and from the Ports has not been considered which for the Rail intermodal industry is itself a huge market to be accessed. Numerous examples of success business cases both in Europe and overseas have already been quoted in other parts of this document.

The Selling of Transport Capacity

The offer driven marketing approach is clearly possible only if transport capacity is available on the Rail tracks in an industrial scale. The **MARATHON** Project through the adoption of longer, commercially faster and heavier trains, wants to generate the market conditions for this approach to become a real opportunity. By so doing, decades of demand driven approach which has generated only substantial decline in market share will be substituted by a proper offer driven approach based on the selling of transport capacity. The selling of transport capacity is the generator of the economy of scale driving itself the transport industrialization and hence force giving significance to the "asset based business model".

The traditional Rail Freight business approach adopted by the incumbents has been based for decades on the costs recovery basis of the service, on top of which an element of profit (margin) was calculated for reaching the selling price. This philosophy supported by the monopolistic situation has been very negative for Rail Freight since it never took into consideration the competitive market forces. Gradually but surely the customers abandoned Rail for more competitive modes of transportation. The asset based business model is starting from:

- The competitive market price obtainable from the customers for the services;
- The theoretical lowest cost denominator based on the maximum rotation of the resources and the maximum productivity for producing that particular service;
- The **MARATHON** Project through the adoption of longer, commercially faster and heavier trains is envisaging a reduction of the existing operating costs between 30% to 50% since it is paramount that the theoretical lowest cost denominator is at a level capable of assuring a return on the invested capital (asset based) offering in the market place a selling price competitive with other modes of transport. This is not the case today where the Rail Freight is not competitive compared to other modes of transport and the selling price generates for Rail operators very substantial losses. This means that the existing costs base is incorrect and must be lowered substantially;
- The theoretical lowest cost denominator becomes an achieved lowest cost denominator by filling up the trains capacity through the offer driven approach.

The selling of transport capacity equates to a revolution for Rail Freight. The reversing of decades of wrong practices is achievable through the adoption of a business model where services are "products" having the following characteristics:

- Service products must be available for the market to access them immediately according to customers' needs;
- The prices must be competitive when compared to other transport modes;
- The advertised service products must have the characteristics of regularity and punctuality. The transit time on the declared journey must be guaranteed;
- The transport capacity must be available for the market and is adequate for the traffic basins serviced by the transport links;
- The service products distribution is multi-channel using both direct, indirect and e-freight tools. These channels are capable of generating the required traffic volumes adequate for filling up the operating trains;
- The marketing techniques are adopted as tools for the service products selling;
- The approach of selling the service products through the multi-channel distribution network is pro-active and not re-active;
- The multi-channel distribution approach is achieved through a cooperation with all the key actors in the Rail transport chain such as forwarding agents, MTOs, logistics operators, integrators, consolidators, etc. Such cooperation is based on economic interests through the sharing of the benefits deriving from economy of scale generation and the traffic industrialization;
- The selling and the filling up of the trains capacity is a driving force of this industrialized business model. The filling up of the capacity is generating the lowest operating costs which is the fundamental pillar of service competitiveness. The standardized efficiency through the best rotation of assets secures the return of the capital employed.

The selling of capacity business model is adopted by maritime, airlines and integrators industry as well as in the Rail field itself by the High Speed services where standardization and services industrialization has been in execution for some time (Thalis, Frecciarossa, etc.).

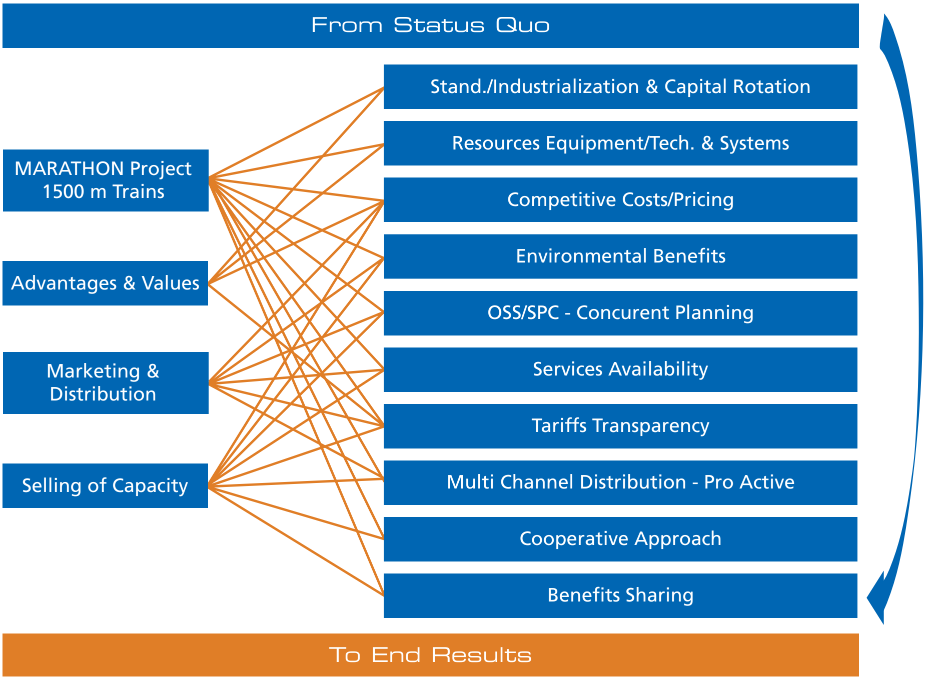
The Rail Freight Competitive Advantage Generation through the Asset Based Business Model

The objective of the **MARATHON** Project is to create the operating conditions for allowing Rail freight and the leading actors capable of undertaking the needed changes to exploit these favorable circumstances. However the fundamental pillar of the Asset based industrialized business model is the creation of the competitive advantage through the achievement of a lower operating cost base when compared to the existing situation. The **MARATHON** Project, through the introduction of longer, commercially faster and heavier trains, wants to resolve once and for all the paradigm of producing a "better service at inferior costs" by generating more transport capacity on the existing infrastructures. Intermodal operators have addressed this issue to the incumbents for some time without success. The resilience to changes was not instrumental but was the result of the difficulties in reducing the existing operating cost base. In fact the existing operating cost base is generated by a cost train/kilometer on a profile train length varying between 400 m to 750 m on average depending on which European Country is the operating theatre. Until this train length profile is overcome and standardized, it will be impossible to change drastically the components of the operating costs structure. The only way by which such cost structure can be pushed towards much lower denominators is the adoption of longer, commercially faster and heavier trains. The **MARATHON** Project wants to demonstrate the feasibility on a European part of the network, in France, of operating trains of up to 1.500 m on the existing infrastructure using double traction with the second locomotors in the middle of the convoy. It is not the objective of this document to describe the operating conditions through which this test will be fulfilled being this the specific task of technical researches and deliverables. What is important for this document is the confirmation that such train of 1.500 m will be capable of reducing substantially the operating cost base of percentages varying between 30% to 50% depending on local conditions. This is the much needed and still outstanding competitive advantage which the modern intermodal and Rail operators have been waiting for such a long time. There is now a growing consensus all over Europe by the infrastructure managers and Rail operators on the needs to achieve this “step change”. The decision making process all of a sudden appears to be rather simple since it has become an “obliged choice”. In fact the only other way to achieve capacity increase in the Rail tracks is through investments in new infrastructures which solution has two major disadvantages which are impossible to be overcome at the same level in the short term:

- Budget constraints;
- Very long time to market.

On the contrary the capacity on Rail is needed as from now both for providing competitive service to the industries and citizens as well as for fulfilling the environmental objectives of reducing the transport carbon foot print. The **MARATHON** Project is the generator of the operating conditions necessary for the Rail Freight competitive advantage generation which is the fundamental pillar for implementing the Asset based industrialized business model.

Figure 36: Basic Steps to MARATHON Asset Based Business Model.
Source: **NEWOPERA Aisbl**



➔ Figure 37: From Status Quo to End Results of MARATHON Asset Based Business Model. Source: **NEWOPERA Aisbl**

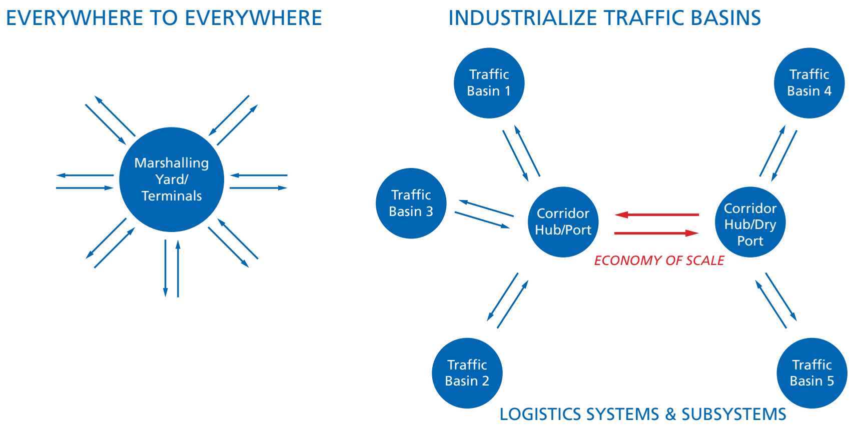
Once implemented in all its components the MARATHON Asset Based Business Model can be used for accessing the targeted market of reference as described and any other market segments where so far Rail freight has a negligible penetration. The Asset Based Business Model driven by the selling of capacity and Services industrialization is a complete revolutionary approach compared to the commercial strategy adopted by the incumbents during the last 40 years or so.

The Collaborative Approach Between The Key Actors

A basic step for fulfilling the selling of capacity driving the Assed Based Industrialized Business Model is the change of approach to be adopted by the traditional Rail operators towards all the key Rail actors in the transport chain. This change is again a revolutionary one. In the recent past the prevailing relationship has known phases of ups and downs but with the common denominator of the Rail incumbents wanting to occupy market segments already heavily crowded by transport and logistics operators. The emerging result has been a permanent situation of conflicts generating, in many cases, competition. The key transport and logistics actors with the continuous complication and sophistication of their customers' supply chains, have occupied a growing control over their transport needs also through outsourcing. Having these transport and logistics operators a conflicting market approach with the Rail incumbents have used alternative modes of transport in order to avoid passing to the Rail incumbents vital commercial information. By contrast such conflicting situation has brought great disadvantages to Rail freight with the multiplying effect that in the last 20 years incumbents have lost progressively the commercial know how of their traditional customers' requirements. So the detrimental effect has multiplied by two the negative impacts. The first time due to conflicts with the actors who had the cargo's control and the second time by the loss of commercial know how of their traditional customer's base. Such negative attitude has been sometimes adopted by incumbents toward their own intermodal daughter companies. In fact in the not too distant past the intermodal daughter companies of the incumbents were accused of cannibalizing the conventional traffic converted to intermodality. According to this wrong perception the incumbents were under the impression that their intermodal daughter companies were inducing conventional traffic to intermodality generating undue internal competition. Only in recent times the incumbents have discovered that their conventional traffic is the biggest source of financial losses due to the very high costs of production of this service which is not at all industrialized. This new awareness forced the incumbents to take very drastic measures for restructuring the conventional traffic by limiting the terminals and marshalling yards where this service is still available. They indeed have closed a substantial number of stations and terminals concentrating in very few locations the service accessibility in order to give it an industrial dimension. This however is not a simple process to be accomplished since the customers have to find different ways of routing their cargoes in the places where the service is still available. In this connection both the **MARATHON** Project and the key actors of the transport chain have a very important role to play for achieving the traffic bundling necessary for realizing the economy of scale for transport industrialization.

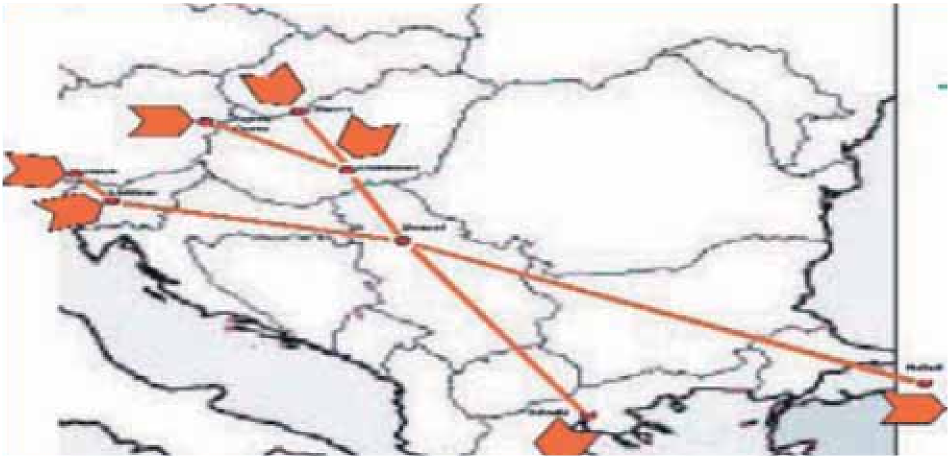
It goes without saying that to make this strategy of traffic bundling possible it is necessary to implement a policy of cooperation between Rail operators and transport and logistics operators. This policy cannot rely on generalized undertakings of goodwill but has to have its foundation on economic interests which can be generated by the sharing of the benefits deriving from the transport industrialization and the filling up of the full trains capacity. When one considers that for decades the relationship between incumbents and transport/logistics operators has been conflicting, one can imagine how relevant is the change of policy to be adopted in the future for generating the correct conditions of cooperation. The change of attitude is between being competitors to becoming partners in the transport chain.

Because the conventional traffic still constitute a substantial portion of the total Rail freight traffic, it is important to find an operating solution for this traffic through transport industrialization. In the following picture (Figure 38) it is reproduced in a very schematic way how the conventional traffic was handled up to recent times. The scheme is "Everywhere to Everywhere" with few Marshalling Yard acting as major collectors of traffic for subsequent train distribution to final destination or near-final destination requiring further handling activities. This system produces very high sorting costs, low productivity, long equipment rotation, long waiting and operating time, and unsatisfactory services. In the long run both the incumbents and the customers reached the conclusion that this system had to be overcome.



→ Figure 38: Old Conventional Traffic Scheme Compared to New Industrialized Approach between Hubs. Source: **NEWOPERA Aisbl**

The following picture reproduces a real business case where a group of forwarding agents were able to create a regular industrialized service from Central Europe across the Balkans to Greece and Turkey in a geographical area where such service was not existing. In one year the volumes increased from 300 trains to 1500 trains. This business case proved the validity of the industrialized regular service along a given corridor and the validity of the cooperative approach.



→ Figure 39: Industrialized Single Wagon / Group of Wagons Service Applied to Real Business Case. Source: **NEWOPERA Aisbl**

The advantage of this simple evolution is generated by the fact that in such Hubs/Freight Villages are concentrated already different categories of traffic allowing increased number of bundling possibilities and by so doing allowing the development of traffic in an industrial scale to destinations where it would be impossible to run full trains if the approach was "Everywhere to Everywhere". The directional corridors North-South/East-West or vice versa should constitute the backbone of the future European Rail Network for Competitive Freight (New EU legislation approved November 2010) along which the major European Rail traffic flows should be carried on a regular and competitive way.

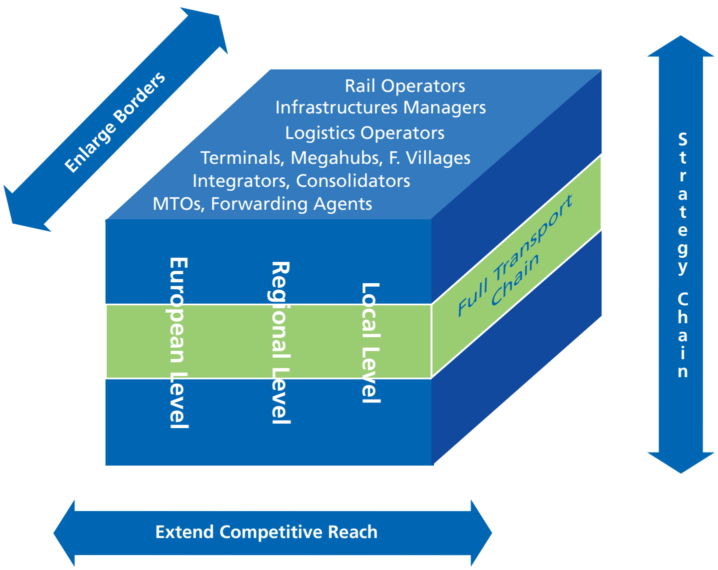
The **MARATHON** Project has to assume on the basis of the future traffic projections that the Rail traffic development will take place on the various corridors which are part of the **NEWOPERA** Network(basically the same as The European rail network for competitive Freight). Consequently the cooperation strategy will have to be implemented along the corridors of this network which includes already the Hubs, Ports, Gateways and connections. Therefore the selling of capacity for the economy of scale generation for filling up the 1500 m **MARATHON** trains has to take place to and from the Terminals, Hubs, Ports, Gateways of origin and destination indicated in this network. All the charts indicated above in this paragraph are related to conventional and intermodal traffic. These two types of traffic however reflect only a part of the Rail traffic. The different types of trains typology are indicated here below (not exhaustive) as already quoted in the introduction of this document.

- tank wagons trains;
- IMCO class trains;
- Rolling motorways;
- Motor car trains;
- Intermodal trains;
- Steel trains;
- Coal trains;
- Cereals trains;
- Industrial trains (paper, mineral water, domestic appliances, consumers, etc.);
- Mixed trains;

The cooperative approach developed around these Hubs/Freight Villages/Sea Ports/Dry Ports which are the new bundling points for industrialized traffic, multiplies to a greater extent the possibilities of services availability, frequencies, achieved at lower costs. Different types of traffic can be consolidated along the same corridor with the common denominator of realizing the complete fulfilling of trains capacity and the direction towards the origin/destination points leaving to the operators controlling the cargo to perform the services personalization in the last mile. What is described in these pages is not particularly new in the transport field since the shipping industry, airfreight industry, integrators and consolidators have been applying it for decades. Shipping lines achieved the filling of 14.000 TEUs vessels using the multi-channel distribution approach combined with cooperation strategies. The vessels are filled up to full capacity by shipping agents, forwarding agents, consolidators, integrators, logistics operators as well as the shipping lines themselves who control some very big institutional customers. The applied philosophy is that all those participating successfully to the achievement of the loading objectives become partners even if on some other field they could be also competitors.

The train likewise a ship or an aircraft represents the industrial risk and the assets base which is capital intensive. The train must be at the center of the whole transport concept and cooperation must be searched in the market place with all the shippers or other actors who, having the availability of cargo, can help the Rail operators to fill up the trains capacity. One has to understand that the service industry is not an ordinary industry. In fact the residual capacity not filled up has a “Zero value”. This common denominator is applicable to trains, planes, ships, trucks, CTS, etc. This is the reason why the selling of capacity is the only driving philosophy for an Asset Based Industrialized Business Model. Successful Business cases between shippers, logistics service providers, intermodal companies and Rail operators have already been implemented successfully as a “win/win” situation although within the existing train profile.

VISUALIZATION OF FUTURE COOPERATIVE STRATEGY



→ Figure 40: Visualization of the Advantages of the Future Cooperation Strategy in the Full Transport Chain. Source: **NEWOPERA Aisbl**

3.2 TECHNOLOGICAL DESCRIPTION (WP2 – WP 3)

3.2.1 The Specifications and System Architecture (WP2)

This research activity aimed at identifying those international trade lanes in Europe, apart from the proper **MARATHON** Project corridor, which – from the perspective of intermodal rail/roads services - should be considered for implementing longer and/or heavier trains if the appropriate infrastructure parameters and operational prerequisites were provided for. In order to achieve the above objective Kombiverkehr as a **MARATHON** Project partner has developed a distinctive methodology. It has comprised the following steps of work or considerations.

The paramount prerequisite for implementing longer and/or heavier trains is the existence of a "critical mass" of intermodal shipments on a trade lane. Only if the productivity of rail operations were improved it would be reasonable to operate "bigger" trains. This applies to trade lanes, which provide for sufficiently existing intermodal shipments, or for which an increase of transport volumes could be anticipated as soon as the infrastructure and operational conditions would be available. Since the existing infrastructure parameters concerning the maximum length and weight of intermodal trains may vary from corridor to corridor the comprehension of what a longer and heavier train means is distinctive for every trade lane. For the same reason the required critical mass of intermodal shipments enabling to run efficient longer and heavier trains also differs considerably. However one has to appreciate that in several leading European countries the operating train length is 750m. This train length has become - for Countries where the operating length standard is shorter - a driver for improvement. The same applies to weight differences. One has to appreciate that unfortunately the weaker segment of the corridor dictates the "corridor standard" until the correction has taken place. These constraints which were known before the **MARATHON** Project conception, must not constitute, or be perceived as a limit towards trains length and weight "modular" standardization in order to be fully ready when the existing weak link have been finally corrected.

Against this background, the extension of the length and weight of trains and the critical mass of intermodal volumes must individually be specified for every trade lane. There are some general requirements, which enable to determine whether a trade lane is suitable for implementing longer and heavier trains.:Looking at history some cases are quoted as examples which the **MARATHON** Project should overcome because of the new economy of scale:

- An intermodal service provider is operating two or more daily trains between two terminals (a single origin/destination). In this case, the bundling of two train departures into one train would enable to produce the rail traction more efficiently. This benefit, however, has to be traded against the potential disadvantage of the customers facing a reduced service flexibility (no differentiation of departure and arrival times).

- An intermodal service provider is operating two or more daily trains on several terminal-to-terminal trade lanes (origins/destinations), over the same rail section for a part of the entire journey. In this case, the trains could be bundled and moved together over this rail section without jeopardizing the service quality and competitiveness.. An example for this set-up is included in the scope of the **MARATHON** corridor cases, described in the next chapter. It refers to Kombiverkehr's intermodal trains Köln - Port Bou and Ludwigshafen -Port Bou, which are travelling on the same rail section in France between Metz and the French-Spanish border terminal at Port Bou. In this category are falling all the trains originating to/from the Sea Ports interconnecting at intermediate terminals (being them dry-ports or other kind of inland terminals) with other trains going to the same direction and which could be coupled together for part of the journey. It has to be reminded that in **MARATHON** train concept, trains could be coupled in 10 minutes because the two locos remain in action and because the trains are already in running conditions also when they are coupled.

- Another case for coupling trains appears when several operators are servicing the same origin-destination or when using the same rail section on their journeys. If we look at the common situation of "power" intermodal corridor in the recent past, it was less likely to find service providers prepared to co-operate and join trains if the time-tables allow doing so at all. If they served the same market segment, either the maritime or continental business, they were due to competing for the same customers and shipments. They would have neither tended to share gains of productivity nor facilitated the competitor to identify the customer base in question. Competition between intermodal service providers is less intense if their services are not linking the same origin and destination and trains just travelling on the same rail section.

In D1.1, the future traffic evolution scenario 2020 both for the maritime traffic (assessed in TIGER Project) is reported, integrated by information from market independent sources such as Drewry. According to that survey, the economy of scale generated in maritime transport and the shortage of train paths/capacity due to hinterland infrastructure congestion, make the trains bundling almost compulsory. The market will force the migration from usual obsolete practices into a new market layout characterized by the generation of traffic bundling and economies of scale compatible with those generated at sea.

New mega hubs and dry ports are being constructed where the combination of maritime traffic and inland European traffic both Intermodal and conventional is possible. This is conducive towards traffic bundling and longer, heavier and commercially faster trains, optimizing both services and costs. In addition, such optimization in these mega hubs allows to link peripheral terminals which today are outside the rail freight network for insufficient traffic.

Based on the above premises Kombiverkehr has analyzed its market knowledge and other sources for defining trans-European corridors, which are suitable for enforcing "bigger" intermodal trains. The sources of this market research were as follows:

- Results of the FP6 project NEWOPERA
- UIC: DIOMIS Evolution of intermodal rail/road traffic in Central and Eastern European Countries by 2020. Paris 2010 (prepared by KombiConsult and K+P Transport consultants).

- UIC: DIOMIS - Agenda 2015 for Combined Transport in Europe. Paris 2008 (prepared by KombiConsult and K+P Transport consultants).
- UIC: Trends in Combined Transport in Europe by 2015. Paris 2007 (prepared by KombiConsult and K+P Transport consultants).

The following proposal for international corridors, on which a sufficient current or future market volumes is recognized, suitable for operating intermodal trains that are longer and/or heavier than the current services, took into account both main intermodal markets:

- The primary intra-European trade lanes for continental cargo.
- The major international container hinterland routes connecting sea ports and cross-border inland locations.

In this respect it is suggested to consider the feasibility of operating longer and heavier trains on the following trans-European corridors (see Figure 2):

- Gothenburg – Hamburg – München – Verona/Bologna
- Hamburg – Ludwigshafen – Lyon – Barcelona
- Hamburg – Prag – Wien
- Rotterdam/Antwerpen – Duisburg – Prag – Bratislava – Budapest
- Rotterdam/Antwerpen – Duisburg – Poznan - Warsaw
- Rotterdam – Duisburg – Ludwigshafen – Basel - Milano
- Antwerp – Ludwigshafen – München – Ljubljana - Istanbul
- Manchester – London – Paris – Lyon – Milano
- Le Havre – Paris – Ludwigshafen – Wels – Wien –Budapest - Constantza

It should be kept in mind that this concept is designed for international freight flows and was not supposed to take into account domestic trade lanes even though there might be a substantial potential for “bigger” trains as well. Yet, in addition to this corridor concept we do suggest that, in a medium-term perspective, the intermodal and railway actors should not only aim at running longer and heavier trains separately along certain corridors but also develop hubs or turnpikes for “bigger” trains so that, potentially, the resources such as rolling stock and engine drivers could be employed more efficiently.

➔ Figure 41: MARATHON Proposal of Trans European Corridors for Longer, Commercially Faster Heavier Trains. Source: **MARATHON**

MARATHON operational cases

In this section selected cases to build **MARATHON** operational scenario will be described. In accordance with the railway undertakings and other industrial partners of **MARATHON**, selected intermodal and conventional rail freight connections have been selected in order to simulate the suitable characteristics of longer and heavier trains in terms of:

- ➔ Number of wagons
- ➔ Length and gross weight
- ➔ Capacity in number of intermodal loading units (swap bodies, containers).

Hence the first part of the section describes the assumptions of proposed trains and corridors, with sections where trains could be coupled. The goal is here to assess the capacity (TEU/swap bodies per train) and define capacity scenarios, according to the wagons used. It has to be reminded that selected cases and corridors have been based on available services, in order to be consistent with the current rail freight transport market and with services/connections having already showed technical and operational feasibility.

In the second part of the section the same corridors have been considered. The train characteristics have been scanned in details in order to prepare the simulations to be conducted for assessing the longitudinal efforts appearing in **MARATHON** trains. For that reason a preliminary analysis of the various constraints to be respected in the train composition have been performed. This analysis could not be done without the intervention of drivers' experiences to introduce realistic actions to be undertaken by the train driver, in the various situations that could be met during the running of the train. Of course, the disrupted situations in term of radio remote control interruption of the slave locomotive needed to be taken into account.

The two parts of the section are interdependent, being the second the logical evolution of the first. The capacity assessment made in the first part assumes no technical constraints to the composition of longer trains, in this outlining the "market scope" of **MARATHON** Project and assessing the need for rail freight traffic demand necessary to activate longer trains on selected corridors. In the second part the technical features are transformed in data for real simulations, integrating all technical clues on train composition necessary to perform tests for longitudinal efforts.

The need for a sufficient demand for organizing longer trains, and the need for building the operational scenario from data available from the market, have led to a survey of existing intermodal and conventional connections, where:

a) The existence of sufficient traffic
b) The absence of infrastructure constraints, in terms of slope, low profile tunnels, differences between operational modules, make the composition of longer trains possible. Some existing connections on domestic and international corridors have been identified by SNCF among the currently operated trains, and existing flows of traffic have been spotted.

These flows could be interesting for **MARATHON** cases, as they are sufficiently frequent and volume demanding to justify long trains by coupling two of them. Nevertheless, they are interesting because they were using for a part of their routes the same corridor where they could justify the coupling of two trains carrying these flows.

The following train cases were selected:

- Combined transport trains on Lille-Marseille corridor. The case proposes the coupling of two of SNCF domestic services Dourges (Lille)-Marseille, Dourges-Venissieux (Lyon), Paris (Valenton)-Marseille (Miramas) in their common route. The trains are coupled in their section where no evident technical or capacity barriers have been identified. The trains are composed of 30 to 40 wagons. Assuming a standard train length of 630 meters, a standard composition of 32 wagons have been assumed, with a gross weight of 1500 tons.

- Combined transport trains on Le Havre/Paris-Milano corridor. The case proposes the coupling of two of SNCF (Novatrans) international services Le Havre-Torino-Milano (Novara Boschetto) and Paris (Noisy)-Torino-Milano in their common route between Paris and Lyon (Ambérieu). The trains are composed of 26 wagons, with a total length of 550 meters and a gross weight of 1350 tons.

- Combined transport on Ludwigshafen/Köln-Port Bou corridor. In this case the coupling of two SNCF international services Ludwigshafen-Port Bou and Köln-Port Bou in their common route, between Woippy (Metz) to Perpignan, is proposed. The trains are composed of 20 wagons, with a total length of 430 meters.

- Figure 42: Geographical Position of the 3 Corridor Case.
  Source: **SNCF**

Besides the corridor cases based on existing intermodal connections, two corridors covered by conventional trains are also proposed.

- Conventional (cereal) trains on Bourgogne (Dijon) - Strasbourg (Beinheim)
- Corridor. The coupling of two domestic conventional block trains is proposed. According to SNCF information, the train is composed in Dijon by single/group wagons having origin (destination) in several yards in Bourgogne region. The trains are composed by 22x15 m long wagons, with a length of 350 meters and a gross weight of 1800 tons. A standard gross weight per wagons of 83 tons is assumed, made by 25 tons of tare and 58 tons of payload.
- Conventional (cereal) trains on Morcenx (South-West France) - Antwerp corridor. The coupling of two domestic conventional block trains is proposed. The trains are composed by 22x15 m long wagons, with a length of 350 meters and a gross weight of 1800 tons. A standard gross weight per wagons of 83 tonnes is assumed, made by 25 tons of tare and 58 tons of payload.

The following assumptions were made on wagons and capacity:

- "Baseline scenario": combined trains with SGNSS wagons (or similar)
  - 19 m. length
  - Coupling 85T

- Capacity assumptions (loading units/wagon):
    - 3 TEU,
    - 2 Class C (7.45 m.) swap bodies
    - 1 Class A (13.60 m.) swap body
- “104’ scenario”: combined trains with SGGMRSS (104') wagons (or similar)
  - 33,5 m. length
  - Coupling 135T
  - Capacity assumptions (loading units/wagon):
    - 5 TEU,
    - 4 Class C (7.45 m.) swap bodies
    - 2 Class A (13.60 m.) swap body

The elaboration of two scenarios allows a better assessment of potential capacity of longer trains. In the “baseline” scenario the capacity is exploited more densely by containers, whilst “104’” scenario is more suitable for assessing the number of swap bodies potentially transported by each longer train, considering the use of 104’ wagons. Those assumptions lead to the calculation of the total capacity on the selected corridors. The results are resumed in the following tables.

Corridor	Terminals	Train length	Wagons	Wagon length	Weight (tonnes)	Capacity (Loading units)
#1: Lille-Lyon Paris-Marseille	Dourges-Venissieux Valenton-Miramas	1260	64	19 m	3000	192 TEU 128 Class C SB 64 Class A SB
#2: Paris-Amberieu (Lyon)	Le Havre-Novara B. Noisy-Novara B.	1100	52	19 m	2700	156 TEU 104 Class C SB 52 Class A SB
#3: Metz-Perpignan	Woippy-Perpignan	860	40	19 m	2200	120 TEU 80 Class C SB 40 Class A SB

Figure 43: Capacity Assessment on Selected Corridors – Baseline Scenario.
Source: **MARATHON**

Corridor	Terminals	Train length	Wagons	Wagon length	Weight (tonnes)	Capacity (Loading units)
#1: Lille-Lyon Paris-Marseille	Dourges-Venissieux Valenton-Miramas	1260	64	19 m	3000	180 TEU 144 Class C SB 72 Class A SB
#2: Paris-Amberieu (Lyon)	Le Havre-Novara B. Noisy-Novara B.	1100	52	19 m	2700	150 TEU 120 Class C SB 60 Class A SB
#3: Metz-Perpignan	Woippy-Perpignan	860	40	19 m	2200	115 TEU 92 Class C SB 46 Class A SB

➔ Figure 44: Capacity Assessment on Selected Corridors – 104 Scenario.
Source: **MARATHON**

The results of capacity assessment made on intermodal train cases led to significant results: in the baseline scenario, coupled trains show a capacity of up to 192 TEU per train, i.e. almost 1000 TEU per week per direction on daily connections. The capacity offered is almost triple than the available capacity on intermodal trains in other European power corridors, e.g. Gotthard[1].

In the "104'" scenario, coupled trains show a capacity of up to 144 swap bodies (Class C) per train, i.e. more than 600 per week per direction on daily connections. As expected, the "104'" scenario is more suitable for swap body transport, since this kind of loading units exploits the capacity offered by longer wagons better than containers. Moreover, almost all types of 104' flat wagons allow the transport of high profile swap bodies and semitrailers.

A general assessment of the freight volume carried on the loading units leads to a general assumption on the freight volume necessary to foster the economic viability of the longer trains on the corridors: assuming a standard loading factor of 85% (loaded wagons / total), and the weekly TEU capacity assessed in the baseline scenario, longer "**MARATHON**" trains are assumed to fulfil a yearly transport demand of 425 000 tons per year per direction.

The demand can obviously be lower if the train set is composed by wagons loaded with both loaded and empty boxes. The situation is suitable (see longitudinal effort tests) in order to meet safety standards for braking and other limitations in the network more easily. In this case, **MARATHON** longer trains are also suitable for meeting the necessity of empty container repositioning requested by forwarders and logistic operators.

The assessment of both intermodal and conventional train cases enlightens another opportunity given by the establishment of MARATHON trains: the capacity of the longer trains could be exploited

[1] According to Gruppo CLAS/D'Appolonia study for the Italian National Logistics Plan, the current average capacity of intermodal trains on "Genoa-Rotterdam" rail corridor is 62-64 TEU/train.

by coupling intermodal and conventional block trains on the same corridor, or wagons, or different kind of conventional wagons. However the practice is already being tested by the market, the technical feasibility of the train composition mix has to be investigated. The following development of scenarios for longitudinal tests make a step towards this goal by foreseeing the composition of longer trains made by different types of intermodal (flat wagons for unaccompanied combined transport and Modalohr wagons for accompanied combined transport) and conventional (cereal tanks + petrol tanks) wagons.

The Tolerable Hazard rates

The activity and the results shown in this document has been carried out with the objective of identifying the concepts and the requirements underling the feasibility to couple and run safely two trains on a trackside signaling subsystem and railway infrastructure. For this reason, the safety concept of the **MARATHON** Case Study is based on the demonstration that the are safely managed do not introduce any new hazard at system level.

The methodology of the present activity has been set up with the objective of developing the safety concept above declared and feeding it with the level of analysis appropriate for the current stage of the project.

Hazard Analysis

The activity detailed in this document has been set up and carried out to develop the safety concept illustrated in the sections above resulting from the first stages of the project. Accordingly, the modifications have been studied from the safety point of view, the relevant hazards analyzed and the appropriate set of mitigations or countermeasures has been generated to reduce the risk level into an appropriate level. The following risk analyses have been carried out:

- a functional analysis of the safety scenarios relevant to possible hazards deriving from the new aspects of the **MARATHON** train,
- a specific Interface Hazard Analysis to select the level of safety for each signal to be transferred from train to train.

In the following sections the methodologies pursued for the two analyses are illustrated whereas in the next section the results of the analyses are detailed. As a general guideline for the task, in order to explore the real possibility of success of the project, the analysis has been conducted with the objective of trying to minimize the generation of SRACs exported to the signaling system and to the infrastructure.

The possibility of exploring the safety of **MARATHON** trains in absence of request of modifications to the interfacing railway system is, in fact, one of the determining aspects for the success of the project. The generation of SRACs would translate into requests for modifications to the railway infrastructure managers and this would lead to a bad effect in the market interest.

The same concepts would apply if too intrusive solutions are considered at train level to justify the safety of **MARATHON** applications, so that the modifications would overcome the economic advantages and possible uptakes introduced by original logistic idea of the project. For these reasons, the safety studies and the associated justifications shall converge into a safety concept focused as much as possible in the capability of the functionalities to ensure an acceptable level of performances and integrity. On the other hand, the safety concept has been developed with the possibility of ensuring the availability of the line and the service. Accordingly, the solutions and the safety measures issued during the analysis have been checked if they are not too intrusive with respect to the availability of the line.

The objective of this task is to analyze the possible new scenario which would be introduced considering the **MARATHON** system in considerations of its interfaces with the pre-existing infrastructures and signaling interfaces. The analysis has focused on the system functionalities and, following a brainstorming approach, have studied the deriving scenario and, eventually, hazards due to the new aspects of **MARATHON** configuration.

Considering input information of the concept design phase, the innovative aspects in the scope of **MARATHON** Project and, thus, analyzed in this task have been the following:

[INN_01] increase of length, up to 1500 m in joined composition,
[INN_02] increase of weight, up to double the average weight of the trains used in the conventional European Lines,
[INN_03] new digital interface between the two trains in joined configuration, which is produced by Schweitzer Electronics with the following characteristics [MTH_SR_05]:

- a SIL3-compliant interface using a radio support,
- a SIL2-compliant interface by means of digital bus interface,

[INN_04] new integration stage of the two separate braking subsystems.

The impact on safety descending from these aspects have been with respect to the following general scenario:

[F 1] Speed and Distance Supervision (Infrastructural aspects and signaling functionalities)
[F 2] Braking
[F 3] Traction
[F 4] Pantograph management
[F 5] Driver Interface
[F 6] Fire (or more generic) Alarm
[F 7] Coupling/Uncoupling

In the following Figure 45: Cross Matrix: Modifications Impact towards System Functions.

A matrix is presented which aims at evaluating the impacts on each of the above system functionalities of the presented innovations.

Innovations (➔) vs. Functions (🡓)	[INN_01]	[INN_02]	[INN_03]	[INN_04]
[F 1]	X		X	
[F 2]	X	X	X	X
[F 3]		X	X	
[F 4]			X	
[F 5]			X	
[F 6]			X	
[F 7]	X			

➔ Figure 45: Cross Matrix: Modifications Impact towards System Functions.
Source: **MARATHON**

Considering the results of this allocation matrix, each functional scenario has been studied to analyze the new aspects generated by the applicable innovative aspects of the **MARATHON**. The analysis of each innovation is reported in the following sections.
Case 01: Increase of Length up to 1500 m(INN¬_01)

The increase of length impacts on the following functionalities:

- Speed and Distance Supervision (Infrastructural aspects and signaling functionalities)
- Braking
- Coupling/Uncoupling

Here below the relevant scenario are analyzed in detail.
Scenario 01.01: 1500m train within the existing infrastructure and signaling system.
The possibility to embed safely a longer train within pre-existing signaling system and a railway infrastructure has been analyzed. More in details, the signaling system shall tolerate within its rules and regulation body a vehicle of such length. The hazards, associated to the signaling system, concern the following aspects:

- the presence of continuous devices for the detection of track occupancy by the train,
- the possibility to manage the speed restriction zones with the whole train length

The new train dimensions impacts also in the integration with the infrastructure.

The associated hazard has to do with the possibility to support safely the curvatures and the associated trajectories of the track (e.g. maximum tolerated radius of curvature). As a result of the analysis shown in this section, the following Safety Related Application Condition have been highlighted.

MTH_SR_06: MTH trains shall ensure the safe integration with the existing signalling system.
MTH_SR_07: MTH trains shall ensure the safe integration within the existing infrastructure.

Scenario 01.02: Coupling and Uncoupling of the joined trains

The main hazard which could arise due to this scenario concerns with the fact that the new train shall allow the safe brake and traction management, considering the new composition due to the coupling of two independent trains. In order to overcome this hazard, an appropriate set of dynamical analyses and simulations is carried out to define the safest way to couple the two trains. In particular, the output of the simulations studies the longitudinal dynamics of **MARATHON** trains, verifying which are the most suitable configurations to compose and joins the vehicles within the new architecture. The parameters concerning the mass distributions along the train and the strategy adopted to manage the decelerations by braking shall be tuned to ensure that the composition of the train remains safely within its structural margins.

The main hazards emerged by the WG discussions relates the derailment risk due to the fact that an excessive pressure is carried by the slave train against the first train (due, e.g. to a not appropriate braking intervention or effort between the two vehicles or due to a wrong distributions of the loads within the whole train). The following preliminary safety measures have been issued to prevent this hazard scenario.

MTH_SR_08: MTH train composition shall be carried out to reduce as much as possible the load on the bumpers between the two trains.

Another hazard concerns with the criticality introduced by new composition of the two trains and it could be due by the fact that, for any reason, the slave loco stops the traction while it is on a down-slope. The risk is that the rear train could slip down. The core of the safety against this risk is to understand the possible causes of such failure. If the scenario is caused by a failure in the radio communication, the mitigation shall be found in the safe management of the radio protocol. It will be detailed in the next sections of this report. The hazards arising from other kind of failures are due to intrinsic causes of each train and, for this reason, they are not introduced as new by the **MARATHON** case study. For this reason, this set of hazards are closed by the assumption of the MTH_SR_01.In addition, the residual risk due to the idle time necessary for the **MARATHON** system (i.e. safe radio link supervision plus eventual mechanisms internal to the rear train) to secure against the negative slopes shall be managed by the following countermeasure.

MTH_SR_09: Coupling of the two trains shall be realized to ensure the integrity of the whole vehicle, also against the stresses which could be credibly introduced by the condition of rear train slipping down on a slope due to the loss of traction.

Finally, the general risk scenario concerning the interaction of the new trains with the procedures have been discussed.

According to the new train configurations, taking into account the new length new procedures shall be defined to operate the train in the following scenario (MTH_SR_10):
nominal scenario, couple and uncouple operations, degraded modes.

These aspects concerning with the procedures will be investigated and analyzed during the project development.

Case 02: Increase of weight(INN_02)

The increase of weight impacts on the following system functionalities:
- Braking
- Traction

Scenario 02.01: New Braking Curves of the heavier trains
The change of train configuration will bring a modification in the braking distances, due to the variation of the Braked Mass Percentage. Preliminary simulations have noticed that the new mass distribution would improve the braking performances, whereas, as degradation to the braking system, would lead to a worsening in the stopping distances. For this reason, the braking performance shall be assessed ex-novo accordingly. The hazard related to this scenario is strongly related with the integration with the signaling subsystem. A variation in the braking performances could affect the capability of the train to stop before the red signal or the End of Authority. In order to protect against this hazard, the following safety requirement shall be fulfilled.

MTH_SR_11: The braking performances of the **MARATHON** Train shall not be worse than the ones of the two separate vehicles. For the situations in which the braking performances are less performing than the original separated vehicles, the safety of the associated performances of the train shall be assessed again.

Scenario 02.02: New Traction Performance of the heavier trains
No new hazards have been found related to this scenario.

Case 03: New Train to Train interface(INN _03)

One of the key aspects of the innovations introduced by **MARATHON** Case Study concerns with the interface with the two trains. The relevant case study represents one of the more challenging aspect for the project and, at this stage, it has carried into the discussion technological partners, the railway authorities, the operators and the safety experts. The engineering proposal for **MARATHON** Application is to implement this interface via radio and bus communication, choosing a technological solution proposed by Schweitzer Electronics.

This solution consists in a master and a slave units to communicate each other via a radio channel and a bus channel. Each one of the two logical units is capable to have a direct interface with the train signals. In addition, at product level, the equipment can ensure the following minimum safety targets:

- EN 50159-1 [Ref. 3] SIL 2 compliance for bus interface,
- EN 50159-1 [Ref. 3] SIL 3 compliance for radio interface.

According to these input requirements, the **MARATHON** Working Group has deemed this solution the suitable candidate to support the interface communication between the two vehicles. At **MARATHON** application level, the architectural and functional configuration of this device has been established, following the outputs of the working groups.

Due to performance and installation reasons, it has been established that the two logical units for transmission and reception of the interface signal shall be installed on the top of each front locomotives ([MTH_REQ_01])[2].

By this way, the two boxes can be easily interfaced with the train inputs and outputs, located in the front locomotive and, in addition, can ensure the minimum allowable distance each other. A specific preliminary test campaign has been carried out with this subsystem to verify the reliability of the radio channel at different frequencies. The tests have been carried out on different environmental conditions; the campaign has considered straight, curved, uphill and downhill routes and the presence of physical barrier between the two transmission/reception points. Analyses of the results showed that, in order to target a widely accepted level of reliability (and thus also of safety), the radio communication shall be based at least on one channel under 1GHz ([MTH_SR_12])[3].

For a complete description of the technologies surveyed to support the train-to-train functionalities, refer to the deliverable [Ref. 9].

Interface Hazard Analysis

Standing this input requirements, as a first step of the analysis, the detailed Functional Breakdown Structure with the associated train signals have been studied by the WG. As a preliminary basis, the FBS accepted from MOD-Train EC Project has introduced and widely reviewed according to the needs of **MARATHON**.

For each function, then, the associated input/output signal list has been determined. This list has constituted the starting point for the detailed Interface Hazard Analysis carried out.

The interface hazard analysis has been carried out with the following objectives:

- determining the appropriate time sequence of reactions for the safe management of the radio protocol to be put in place by the whole train system against radio disconnection scenario,
- apportioning the appropriate safety level to each signal as a consequence of a systematic hazard analysis,
- contributing to the selection of the signals to be transmitted via SIL 3 radio support as the associated radio protocol is limited to 8 bits,

[2] This is not a safety requirement and for this reason it has not been tagged as MTH_SR_xx. Such requirements emerged from the analysis have been anyhow traced, with the label MTH_REQ_xx.

[3] Moreover an optional additional channel over 1GHz could provide more data rate capacity and open perspectives to provide added value services for a quicker return on investment.

- defining the safety requirements and the SRACs which contributes to determine the safety of the whole **MARATHON** Application.

The detailed results of the Hazard Analyses are reported in Annex A.

The interface hazard analysis has been reported according to the following template:

- ID_FUNC reports the progressive number of the functionality,
- Macro function reports the macro-class of train functions analyzed (e.g. Radio Communication, Brake Control, ...),
- Function reports the specific function analyzed,
- Function Description reports the description of the function,
- Safety Related defines at preliminary level if the function concerns or not with safety; defines the progressive number of the associated signal to the function,
- Associated Variable reports the variable name associated to the function,
- Flow Direction reports the direction of the associated data flow and it can be:
  M->S, if it goes from Master to Slave,
  S->M, if it goes from Slave to Master,
- Guideword reports the guideword used for the analysis. The list is based on the one defined by the yellow-book and it is:
- NO, if no data is transmitted,
- More, if higher value data are transmitted (applicable only to quantitative data flux),
- Less, if lower value data are transmitted (applicable only to quantitative data flux),
- Other Than, if the data is unduly transmitted (wrong value or in wrong moment – this last case includes the case of “before”),
- Delayed, if the value is sent with delay,
- Hazop_ID reports the ID of the Hazop analysis,
- Failure Mode reports the associated failure mode,
- System Effects reports the effects on the system caused by the failure,
- Hazard identifies the relevant hazard,
- Severity Level defines the associated Severity Level in compliance with the Risk Matrix defined by CENELEC EN 50126 Errore. L'origine riferimento non è stata trovata,
- Mitigations reports the list of safety measures (MTH_SR_xx), safety procedures (PROC_xx) or Rules (RULE_xx) to be implemented to reduce to an acceptable level the Severity of the relevant scenario,
- Final Severity Level defines the final severity level considering the list of mitigations,
- Interface SIL highlights the necessary minimum Safety Integrity Level for the associated signal to reduce to Negligible or Tolerable the Final Severity Level,
- Notes and Remarks reports eventual additional notes and remarks.

Finally, it shall be remarked that once the safety integrity levels of the train functions and the associated interfaces have been allocated, the internal interfaces between the radio unit and the train signal shall be realized in compliance with the Safety Integrity Level associated to the relevant train functionalities and the relevant train-to-train interfaces ([MTH_SR_16]).

Safe Timer Management of the Radio Communication

In this section, the timers for the safe management of the Radio Communication are highlighted with the respective reactions at system level, emerging from the results of the interface hazard analysis reported in the Annex A.

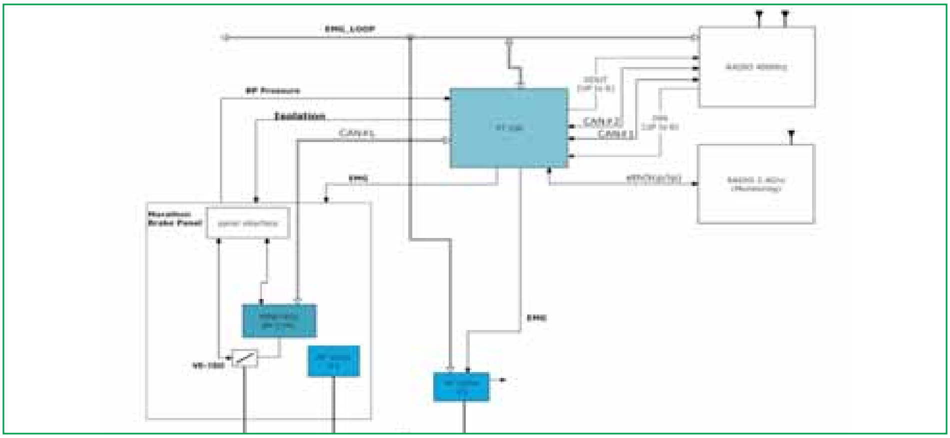
CASE 04: New Braking System(INN_04)

The configuration of **MARATHON** trains forces to reconsider and review the braking system. The joining of the two braking systems within a unique braking system shall ensure safe braking performances as a consequence of the [MTH_SR_06]. In addition, the definition of the new braking system shall support and be compatible with the relevant safety measures issued during the Interface Hazard Analysis reported in section § 3.1.3. The solution proposed by Faiveley Transportation leads to the definition a modified braking panel for the management and the control of the brake pipe. It is based on the following points:

- on the remote locomotive a gateway will interface the radio equipment on one side and traction and braking equipment on the other side,
- a new brake panel will be developed for the remote locomotive to react according to the commands of the gateway,
- the gateway, in its turn, will forward commands from the leading locomotive or will take local decisions in case of long communication losses,
- the gateway in the remote locomotive will perform a rough control, in order to avoid instabilities (due to interferences) in controlling the brake pipe,
- during a relatively long communication losses, an emergency brake triggered by the leading locomotive will be detected by gateway that senses the brake pipe pressure and the flow of compressed air introduced in the brake pipe. A preliminary scheme of this brake architecture is detailed in the next Figure.

As a consequence of the requirement [MTH_SR_01], it shall be observed that the new brake panel and the relevant interfaces with the brake pipe, the train and the gateway shall be realized with at least the same Safety Integrity Level than the substituted one ([MTH_SR_13]).

The analysis carried out on the differences with the single train configuration has shown that the whole new brake system introduces a new hazard scenario due to the breaking of the braking pipe. The generic risk derived from such scenario is the loss of the correct braking functionality of the train. In general, the braking in two of the pipe should lead to no consequence on safety, as the lowering of the pressure in both parts of the pipe would lead the train to brake almost immediately.



→ Figure 46: Preliminary Brake Architectural Overview.
Source: **MARATHON**

To overcome the residual risk due to a not-completely linear behavior of the pressure specific simulations shall investigate the train dynamic to study if residual risks arises due to the braking in two of the braking pipe ([MTH_SR_14]).

In case analyses and simulations cannot exclude the residual risk due to the breaking in two of the braking pipe, an additional device shall be introduced for the continuous monitoring of the pipe integrity with a safety integrity level compatible with the braking functionality itself ([MTH_SR_15]).

Results of the Safety Analysis

As results of the whole set of safety analyses carried out at preliminary design stage for the **MARATHON** Project and detailed in this document:

- a specific set of safety requirements/SRACs have been issued (collected in section § 4.1),
- a complete allocation of the SILs on the interface signals between train to train has been performed (summarized in section § 4.2).

The Technical Specification

This Task deals with Function/System interfaces

- INPUT OUTPUT extract from the functional list
- Interface between radio and system locomotive
- Interface for HMI (DDU)
- Interface with DAS driver assistance (DGN) diagnostic system

This section describes normal orders for the function and back-up value to take into account in the Command & Control system in case of Loss communication of more than 3 seconds (loss of communication < 20 are considered as maintain of the current situation by the radio system). After that it is an automatic slave power reduction down to 0 unless a breaking indication arrives through the pressure detector in the slave.

Organization of the requirements for Function/System interfaces; Orientation of the locomotives; Driving Orders TRACTION I_Traction_Level; Driving Orders TRACTION C_DynBrakeEnable; Driving Orders TRACTION: C_DynBrakeRequest; Driving Orders TRACTION C_TCUTraction_Cut Off; Driving Orders TRACTION C_TCUTraction_enable; Driving Orders DIESEL ENGINE CONTROL; Driving Orders TRACTION I_TCUTraction_enable; Driving Orders TRACTION C_Traction_Level_minus; Driving Commands Sanding management; Monitoring & Diagnostic I_ALARM_Fire Signalling; Driving Orders Traction I_ALARM_Impact_Mission; Driving Orders TRACTION I_ALARM_Oil_Temp; Pneumatic interfaces; Electrical interface; Communication interfaces; User accessible commands & control.

Details of the considered function. This specification describes the states of the locomotives in the following MODES.

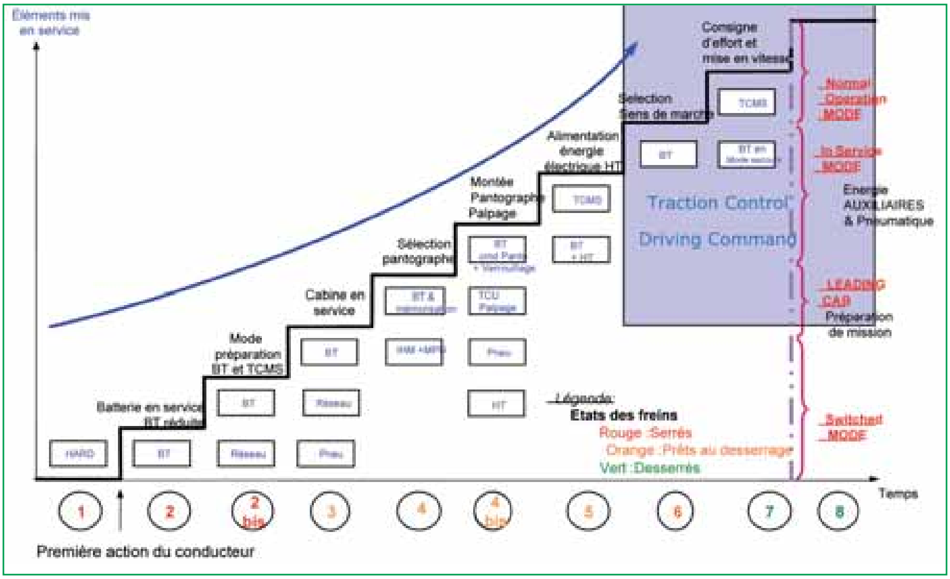


Figure 47: Conductor Actions.
Source: **MARATHON**

Operation in Degraded Mode
Processing in case of conflict of communication in MU

Case study no. 1: Loss of communication 3 < tloss < 20s by radio with a train in full operational mode Generic Breakdown of the sequence.

In case of loss of communication < 3 s between locomotives, the status transmitted are not refreshed.

Following back-up status are described in the detailed description of each signal.

If a conflict is detected in a leading locomotive, no order of driving operation will be positioned to lead locomotives (all the orders of driving operation are issued with their default value).

If a conflict is detected in a slave locomotive, the orders of driving operation from the leading will not be interpreted. In that case, the locomotive will use the default value of the exchanged data.

Case study no. 2: Loss of communication between locomotive > 20S Failure

Time of loss 20 s is justified by:

Distance between 2 locomotives < 500 m; Max speed in operation 100 km/h.

The second locomotive will reach the same point (PK) 20s after the first one.

Generic Breakdown of the sequence.

In case of loss of communication > 20 s between locomotives, the status transmitted are not refreshed and there is default value defined for each signal in order to favor operation without any damage for safety.

If a conflict is generated in one of the locomotives of the train, it will systematically be displayed on the screen in the leading locomotive.

Specific Breakdown of the sequence loss of communication with xxxxx commands.
In this case the value of transmitted data.

It has for consequence to (safety).

After retrieve favorable (availability).

Case study no. 3: Failure on the function of the slave locomotive

Generic Breakdown of the sequence.

It shall be mandatory to be able to interrupt voluntary the communication between the both locomotives in order to save certain unfavorable situation.

In this case after do this command from the leading locomotive the slave locomotive will be in an identical status than in loss of communication > 20s. A conflict of communication in MU will be processed locally in the locomotive where it is declared. This conflict is processed in the Function "to generate the information to be transmitted in MU".

Consequently the operational scenario after that will be the same has described in § loss of communication > 20s. If a conflict is generated in one of the locomotives of the train, it will systematically be displayed on the screen in the leading locomotive. Tests to be done before Departure. There is no specific tests before departure for this function it correspond to the normal configuration of the train. At standstill and before normal operation it is recommended to proceed to a command of tests to be done in Full operational MODE (after Departure). There is no specific tests to proceed. These are tests mandatory for a diagnostic of the function before operation.

General Architecture description

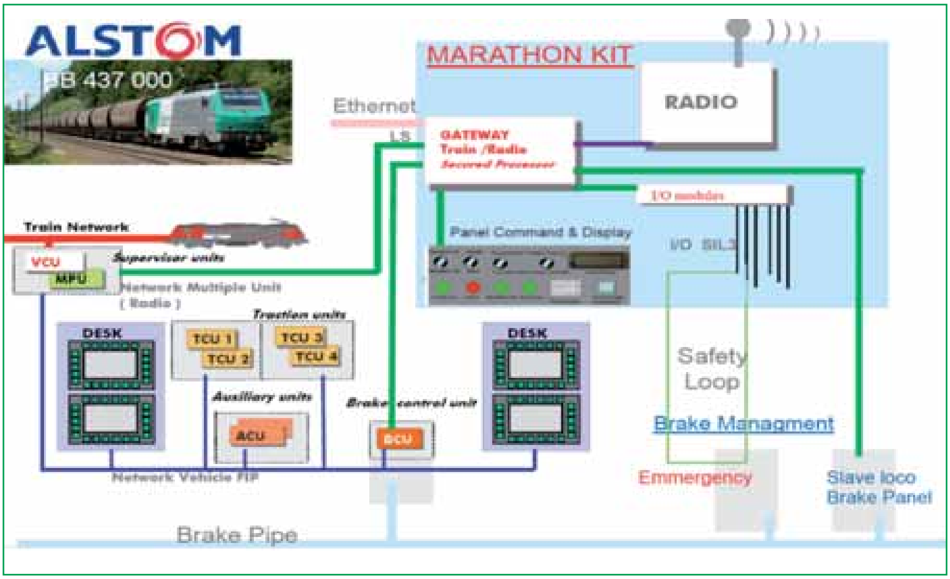
Adaptation of the MARATHON KIT into the Complete system. The impact of the KIT MARATHON into the complete system has been designed for a minimal impact into existing locomotives.

- First step put the complete KIT in an existing locomotive.
- Second step, make an optimized design should be in the future incorporated directly into the native design of locomotives without any impact on the brake system and the command and control system. Only add the specific devices for radio communication and Command and control for distributed power and activate dedicated software part for interfaces. This document is dealing with the FIRST SOLUTION adapted to the BB 437000 locomotive. The diagrams concerning the optimized phase are given for information.

System functional architecture At Train LEVEL

The System Architecture is done for two locomotives operating at the same distributed power or radio multiple Unit. Consequently there is a LEAD (or MASTER) locomotive in the front of the train & SLAVE locomotive placed in the middle of the train. The link is done by radio.

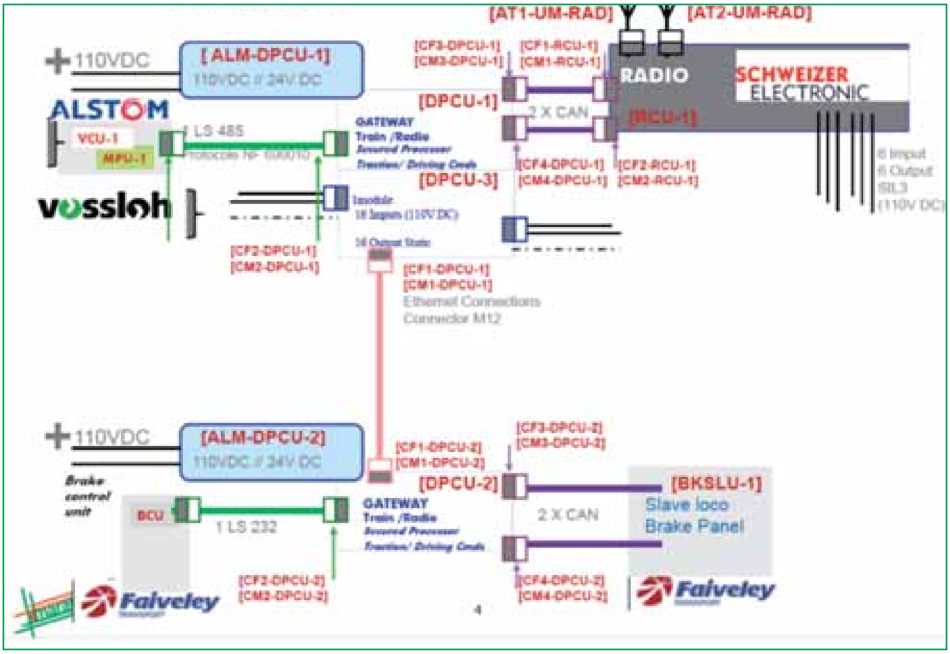
The MARATHON KIT is based on three main components



→ Figure 48: A Radio System RCU: Communication between Two Trains Sections. A Distributed Control Power Unit DPCU in Charge of Ensuring a Gateway between Existing Locomotive Certified & Radio Data Transmission System.
Source: **MARATHON**

→ A Slave brake Panel in charge of supply of vent the brake pipe of the slave locomotive.

The DPCU link with the radio is ensured by a CAN link between the main module



→ Figure 49: Electrical Interfaces between Sub-systems. Interfaces Between Radio RCU-1 and DPCU. Source: **MARATHON**

DPCU-1 and the radio Rack RCU-1.

The link is doubled (2 CAN) for availability of the function.

Internal interface of the DPCU

The DPCU is made by 3 modules linked with an internal Ethernet network.

As the modules DPCU-1 and DPCU-3 are installed in the cab cubicle at the same area then the radio rack, the link is native of the modular architecture of such modules.

The DPCU-2 module is installed in the area of the brake system (near the brake panel and the pneumatic bloc). This disposition is done because of physical proximity between Brake Panel and slave brake panel. Consequently it needs to put in place an Ethernet specific cable connected with M12 connectors between the DPCU-1 and the DPCU-2. (placed for minimize CEM perturbations).

Interface between VCU and the DPCU

The VCU is a part of the TCMS of the locomotive BB 437000 . It is physically ensured by the MPU (main processor unit supervisor of the locomotive) and a RIOM (remote input output module) equipped with a serial link type LS 485. This serial link ensure the interface between VCU and DPCU-1 module.

The protocol is type NF 690010.

Interfaces Between Brake Panel BCU and DPCU

The DPCU link with the main brake panel is ensured by a serial link type LS 232 placed on the existing BCU of the locomotive and the module DPCU-2. This serial link use the maintenance available port of the BCU.

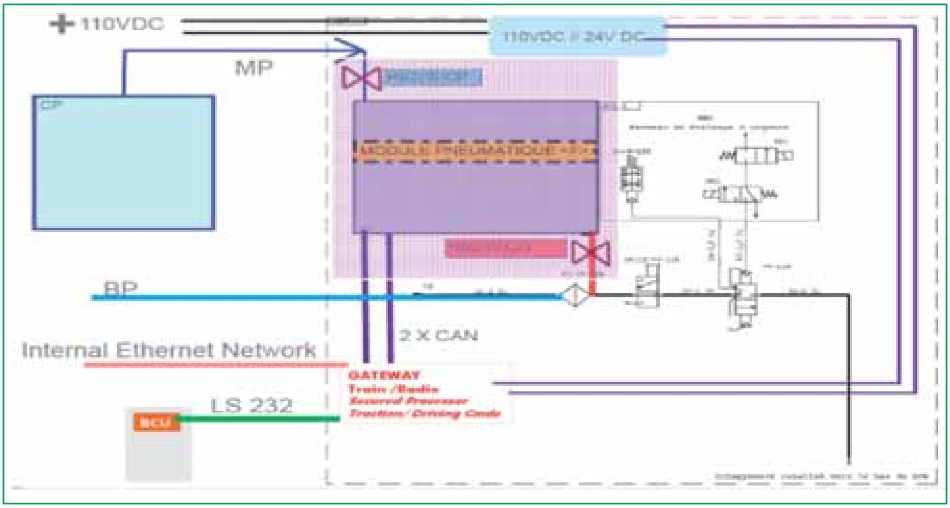
Interfaces Between Slave Brake Panel BKSLU-1 and DPCU

The DPCU link with the added slave brake panel is ensured by a CAN link between BKSLU-1 and the module DPCU-2. The link is doubled (2 CAN) for availability of the function.

Interfaces of the BKSL (BraKe SLave panel)

Only the slave Brake Panel need a dedicated pneumatic interface. This module is connected to the Brake Pipe in order to ensure the supply. It is connected to the brake pipe in order to be able fill it to 5 bar or drain it to 3 bar or 0 bar in case of emergency. The piping should be done by rubber connections.

The electro pneumatic diagram is as per following figure:



→ Figure 50: System Attributes (RAMS).
Source: **MARATHON**

Safety

The Safety level have to be considered like the following diagram.
Remark ALSTOM MPU & VCU software are done SIL 0.

→ Availability

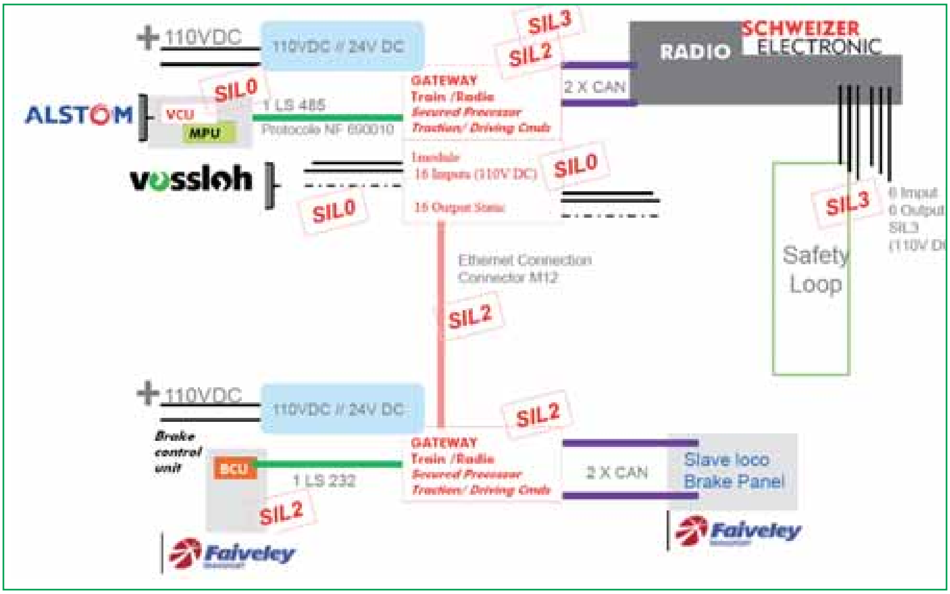
CAN link with radio RCU-1 & DPCU-1 is redundant.
CAN link with Slave brake panel BKSLU-1 & DPCU-2 is redundant.

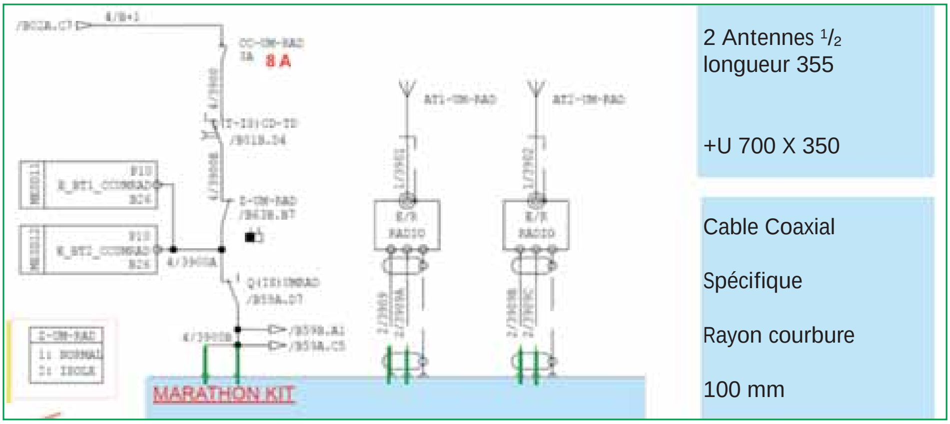
→ Maintainability

A specific tool is designed for Interface monitoring.

→ Reliability

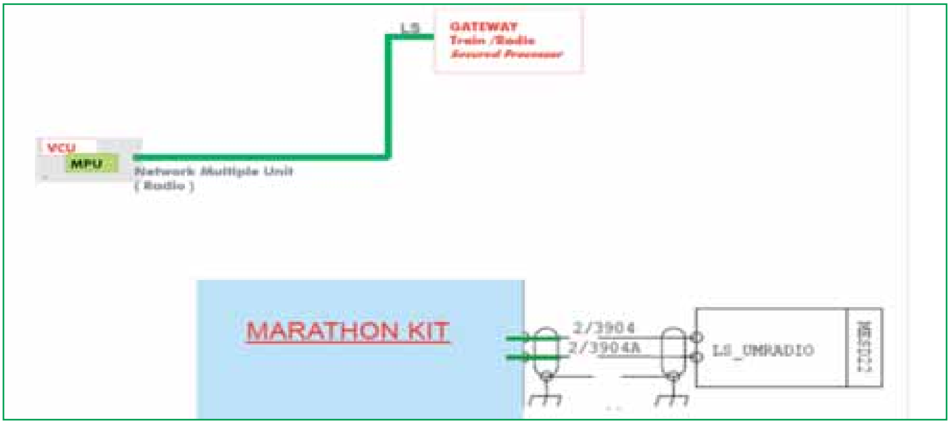
Life cycle Cost has been minimized in the design of the complete system with use of maximum existing components.





→ Figure 51: The Antenna connections.
Source: **MARATHON**

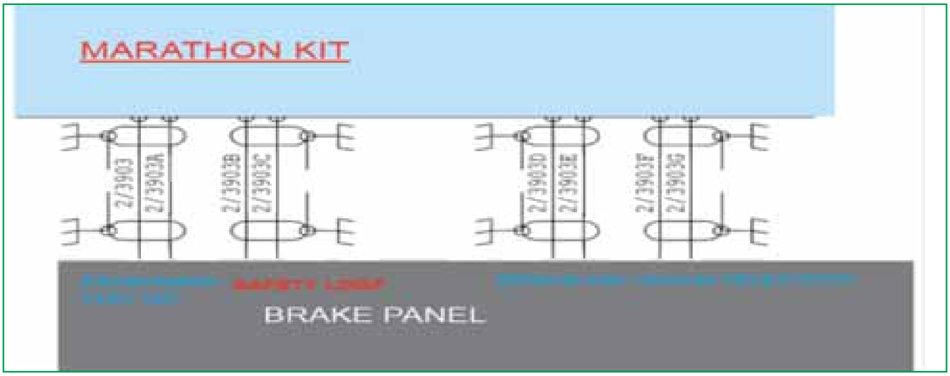
Serial Link for Cmd & Control LOCOMOTIVE



→ Figure 52: Serial Link for Cmd & Control LOCOMOTIVE.
Source: **MARATHON**

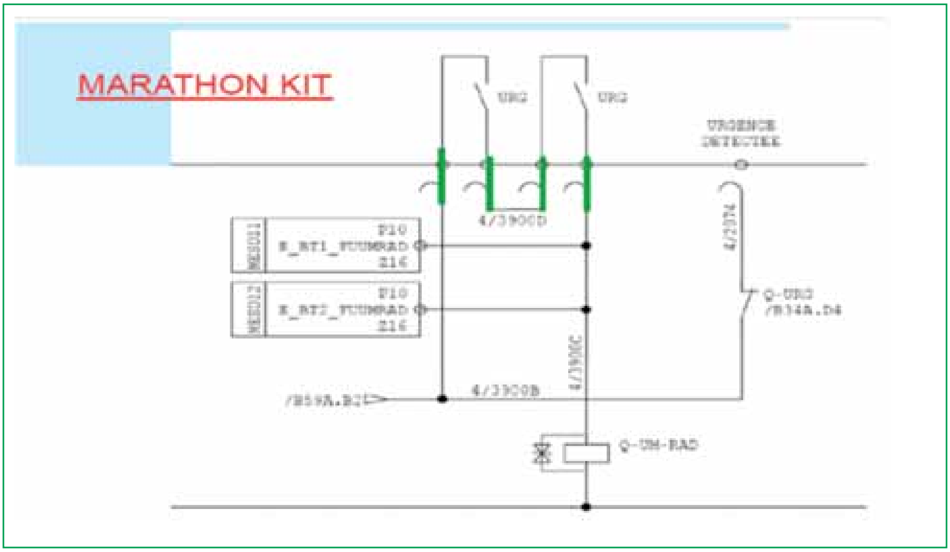
The Serial Link for Cmd of Brake system

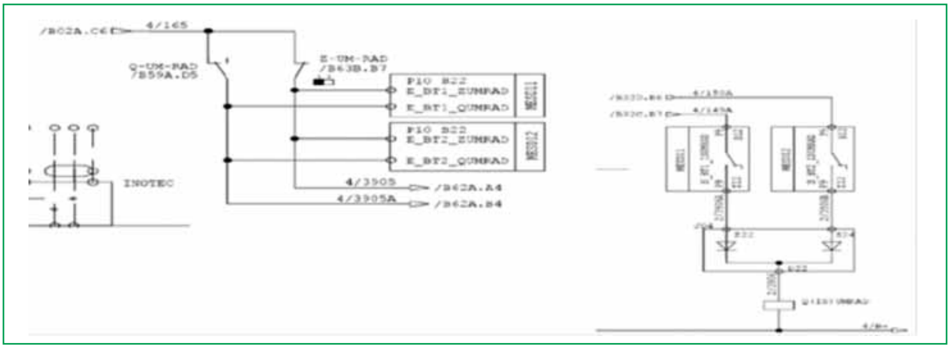
The Serial Link for Cmd of Brake system has to be adapted with a specific Ethernet cable between DPCU-1 & DPCU2 modules with M12 connection



→ Figure 53: The Serial Link for Cmd of Brake System Adapted with Specific Ethernet Cable between DPCU-1 & DPCU2 Modules with M12 Connection.
Source: **MARATHON**

Safety Loop



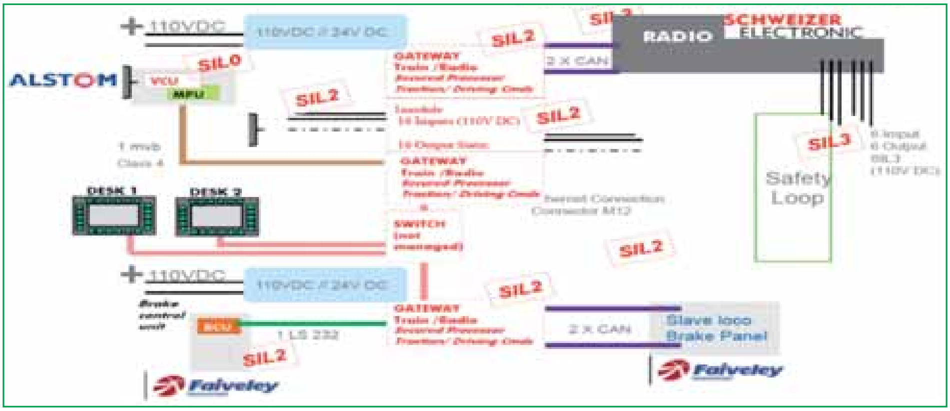


→ Figure 54: Safety Loop.
Source: **MARATHON**

Others sub function for Monitoring & Control locomotive

System Evolution

The Architecture shall be adapted to the actual generation of locomotives equipped with mvb. Case of PRIMA II. The Architecture shall be adapted to the new generation of locomotives equipped with Ethernet.



→ Figure 55: System Evolution.
Source: **MARATHON**

3.2.2 The Application of Technologies (WP3)

The Candidate Communication Technologies

Regarding communications, the basic need for MARATHON is to get a reliable radio data link to exchange command- control data between 2 locomotives in a freight train running across Europe.

The solution proposed by MARATHON shall be:

- Fulfilling the European railway norms EN50126, EN50159-2, EN50239, EN50155, EN300113
- ready to operate at the end of the project,
- economically viable,
- suitable to operational constraints,
- maximum operational availability

To increase the chances of success of the project, WP3 considers pragmatic scenarios and voluntarily dismiss exotic or complicated use cases witch would bring too much complexity.

The communication scenario considered in this document consists in point to point bidirectional communications between 2 locomotives located in the same train. The maximum distance between the two locomotives is 750m. This means that a **MARATHON** train can for instance be made of 2x 750m long coupled trains with one locomotive in the lead and another in the middle of the train.

The maximum speed of the train is 120Km/h. It has to be noticed that the relative speed between the 2 locomotive is 0 km/h, since they belong to the same train. But this is the speed at which the train "discovers" propagation obstacles such as tunnels.

The communication system shall be able to cope with several **MARATHON** trains operating in the same area. This is for instance the case when 2 trains cross each other in line or when several trains are parked in the marshalling yard of the same station. The retained scenario considers up to 5 simultaneous running trains in the same geographical area (being defined by the radio coverage around the train).

The communication shall work in the various and heterogeneous radio propagation environments that can be found along a train line. This includes for instance free space (field), tunnels, canyons, urban, vegetation, curves, slopes, weather conditions (clear, rain, fog, thunderstorm….). Another way of saying is that the system shall be suited for use non in line of sight and harsh environments (multi path, noise…).

In order to be economically viable, the solution shall be easy to use by train operators. For that purpose the following requirements are taken into account by **MARATHON**.

Equipment shall be installed on locomotives only. This discards by hypothesis solution based on equipment installed on wagons. This also discards deployment of additional infrastructure on ground. Note that solutions relying on already existing infrastructures (deployed for other use) can be acceptable providing that the lines where **MARATHON** is intended to be used are correctly covered by this infrastructure.

If such infrastructure should be used, the safety level (in this case SIL3 for some signals) and the norm EN 50159-2 must be guaranteed.

The proposed equipment shall be suited to railway constraints. This of course includes environmental constraints (for instance EN50155) but also logistics (maintainability, supervision…) and operational requirements. It is for instance obvious that the antennas shall not exceed train gauge or that there shall be an HMI on the system to configure it (locomotive association…) and to supervise it. It is also clear that the system shall be compatible with usual interfaces of a locomotive traction unit.

One of the **MARATHON** goals is to operate pan-European trains. So, the system shall be usable in all European countries. Regarding the data communication system, this means that the operating frequency shall be allowed in each country. **MARATHON** approach of this problem is dual. One solution is to get allowance for a dedicated radio frequency band throughout Europe. Such kind of authorizations already exists but it is not guaranteed that they are the same for whole Europe. So the second way is to be able to work in various frequencies (and optionally in various bands) and to select the allowed frequency in operation.

The problems related to differences between ways of operating trains in the various European countries are supposed to be resolved by work-packages in charge of defining unified functional needs for **MARATHON**. This should be included in the handbook to be produced at the end of the project.

The Communication performance Requirements

In **MARATHON**, the communication system is used to transfer data for a real time automation control process. This results in constraints on the system in terms of data rate, latency and availability (maximum tolerable link interruption). The corresponding requirements are issued from the functional analysis made in other work packages of the project by the locomotive manufacturers and the company in charge of the braking system . After joint analysis of the requirements and the effective capabilities and performance in the real environment of the candidate practical communication system, choice is made of communication system as well as the functional behavior in case of communication interruption/failure.

As an example for LocCom 102 RS, the possible performance and behavior of a system in the 400/500 MHz range, STD (Synchronous Time Division); 12.5 kHz bandwidth is:

- Maximal latency delay: 695 ms with 13 time slots (5 trains – 10 locomotives in the same area).
- Maximal communication interruption duration before being considered as a failure: 4s (loss of maximum 5 telegrams)

- Behavior in case of radio data link disruption:
  after 4 seconds → soft braking is applied during 15 s. During this 15 s the radio link tries to re-establish (same type of locomotives, same braking behavior of the two locomotives).

  a) radio link re-established → locomotives goes to traction constant during 30 seconds if there is no further radio-link interruption during this 30 seconds the two locomotives go to the desired speed

  b) if after the 15 seconds the radio link is not re-established → emergency braking procedure of the two locomotives is launched.

Existing Technologies

This chapter provides a survey of technologies that could serve MARATHON communication needs. Reflecting the market state, this chapter is divided into 2 sections.

- First section describes technologies issued from standards of the telecommunication domain. These technologies are currently the basic components for the deployment of wireless internet services for professional and mass customer markets.
- The second part of this chapter merely focuses on transparent data link modems and on locomotive communication systems based on this kind of devices.

Standard Technologies from the Telecoms World

The technologies depicted in this section are issued from standards designed for mass communication. Historically, standards for this world are written by 2 major organizations: 3GPP and IEEE. ETSI also provide standardization work at European level. Originally, 3GPP was interested in mobile voice communication network (for instance GSM from which GSM-R derivate), and IEEE in data packet networks (for instance 802.11 Wi fi). With the convergence between voice and data, both organizations now work on integrated networks like UMTS and LTE for 3GPP or 802.16 and 802.20 for IEEE. Most of these standards rely on a static infrastructure on ground. Others are either ad-hoc capable or simple enough to embed infrastructure devices on board the train so they don't need any device on ground to work. A last paragraph concludes on how these technologies could be used from **MARATHON**.

Mass telecom market solutions

The common point between the solutions presented in this paragraph is that they are all based on a static infrastructure on ground to manage mobile devices. Mobile to mobile communications are generally routed through this ground infrastructure.

In general, theses architectures aim to put complexity in the base stations on ground in order to get mobile devices as simple and economical as possible. Complexity then relies on telecom operators whose role is to finance and manage infrastructure by selling out of the box communication services to customers. This is for instance the classical scheme of 3GPP solutions being of 2nd generation

(GSM), 3rd generation (UMTS, WCDMA, HSPA…) or 4th generation (LTE). This is also the case for IEEE WMAN (802.16) and WWAN (802.20) standards.

The big advantage of these technologies is that they are quite simple to use for the final customer (i.e. for **MARATHON**). Indeed, it is simple and cheap to find communication devices compliant to these standards and the customer only have to subscribe to the service from a telecom operator. But the main drawback is that the end user (i.e. the train operator in the case of **MARATHON**) is dependent on the actual coverage and service offered by the latter telecom operator. Very often, rail operators and telecom operators have divergent economic interests. Telecom operators are generally willing to maximize the number of their customers when rail operators are more interested in getting an exhaustive and reliable coverage of their lines. This problem is one of the reasons why railway operators deploy and operate GSM-R networks by themselves.

Typical data rates offered by this kind of technologies vary between several 10kb/s (2nd Generation) to some 1Mb/s per mobile.

PMR

In order to avoid the incompatibility between a commercial service and a professional use, solutions exist for the end user to deploy and manage its own network. This family of solutions is called PMR (for Professional Mobile Radio). TETRA, which has been normalized by ETSI, is the most famous example of this technology. In a way, GSM-R can also be considered as a member of this family. PMR are well suited to provide complete and reliable radio coverage of an area and they generally offer joined services of voice and data communication. Typical data rates offered by this kind of technologies vary between several 5 and 50kb/s per mobile. Deployments generally cover an urban area . The advantage is that it is possible get coverage of singular points such as tunnel or canyons by the addition of base stations. Typical users of such solution are mass transit operators (rail, bus, tramway…) or institutions like police of fire brigade.

Except GSM-R, which only covers a small number of high speed tracks, no PMR service is currently accessible to railway operators along main line tracks. The usability of such kind of network for MARATHON is then impossible for the moment without dramatic investment. Note that the question could be re-evaluated later if GSM-R coverage increased significantly for other reasons.

SOHO oriented technologies (WiFi, pico & nano BS)

This category regroups small and low cost devices that are targeting to offer centralized communication services in a reduced area. Typical application of these products is to provide wireless connectivity for home and offices (SOHO). In such devices, the hardware of both the base station (also called access point) and the terminal is very simple and makes possible to package them in small and low cost standalone units. This kind of devices can then be embedded in locomotive to build data links that don't rely on any ground infrastructure.

Most famous example of this technology is Wi Fi (IEEE 802.11). But there is also emerging product from the 3GPP philosophy known as pico, nano or femto Base Stations. The goal of these devices is to implement a very light base station to extend mobile phone network coverage inside buildings. Pico, nano and femto base stations products are not sufficiently mature to be used for MARATHON. So, this paragraph will focus on 802.11.

802.11 is actually a collection of standards. Most famous are the 802.11b (1 to 11 Mb/s, DSSS, in the 2.4GHz ISM band), 802.11g (6 to 54Mb/s, OFDM, in the 2.4GHz ISM band), 802.11a/h (6 to 54Mb/s, OFDM, in the 5GHz ISM bands) and 802.11n (6 to 600Mb/s, OFDM and MIMO, in the 2.4 and 5GHz ISM bands). Other addendums normalize additional features such as security (802.11i for WPA2), mobility (802.11r for fast roaming) or QoS (802.11e). Note that 802.11 can be either used in cellular mode (like all technologies presented above) or in ad-hoc mode. In this mode, the protocol doesn't require any access point and all communications happen in mobile to mobile mode. The very large diffusion of 802.11 has created a complete eco-system around 802.11 chip vendors and led to the creation of a large number of data link solutions based on these chips. These products re-use the WLAN physical layer in OFDM (802.11a, g, h or n) or even DSSS (802.11b). Some chipsets are even capable to work outside the public band (for instance at 5.9/6GHz). Products can also re-implement the MAC layer to optimize the data link for a particular use.

There are currently many examples of use of WLAN products or derivatives in railway environment for various applications (maintenance, supervision, video surveillance, CBTC for metros…). This technology could be used in MARATHON communication system but it probably supposes to complete 802.11 modems with additional devices such as amplifiers or frequency translators. In these conditions, available data rate would vary between 1 and 10Mb/s. This overcapacity pushes to imagine additional services which could be useful to create added value and share the costs.

Another 802.11 initiative worth to be quoted in this document is 802.11p. Its goal is to provide a communication standard for Intelligent Transportation Systems (ITS) and road applications in particular. This covers both mobile to mobile and mobile to infrastructure communications. The similarities between rail and road needs (for instance long linear topologies) are very promising because rail could benefit from the R&D investments made by road industrials. Moreover, the quantities of production for the road market will lead to very low per unit device costs. Another interesting point in 802.11p is the targeted frequency band. Indeed this standard operates in the 5.85-5.925GHz. Initiative is currently being led by road industrials to ask European Union for the attribution of frequencies in this band. This request could interact with railway one's who also ask for a frequency in this band and lead to a common allocation of frequencies for railway and road safety. 802.11p prototype products are already available and serial products are currently under finalization. This means that products will hardly be available before the end of **MARATHON** Project and so, 802.11p can't be retained as a solution for the moment despite it is very promising.

Conclusion on standards from telecom world

As a conclusion to this chapter it can be said that:

- Infrastructure based networks are not adapted to MARATHON economic model. Some (like PMR) are too expensive; others (from private operators) don't offer sufficient coverage and availability.
- GSM-R could constitute a good solution but it not widely enough deployed to enable usage all over pan-European trips.
- 802.11 based devices can be used as standalone data link units to build a dedicated communication system. They are already used in railways but not for loco to loco communication for the moment.
- 802.11p is especially interesting due to the synergy between ITS and railway transportation. Economic power of the road market is also an advantage that could result in quick allocation of dedicated frequency in the 5.9GHz band.

Data link oriented technologies

Description

In this section are described proprietary radio modems providing point to point or point to multipoint radio communication. These devices are generally integrated into more complex communication systems.

Due to the variety of modulation, frequencies and bandwidth, the market offer for this category is very large. Solutions working over 1GHz either have already been studied in §0 or offer so high throughput that they are not interesting for MARATHON. At the opposite, frequencies below 400MHz don't enable enough data rate. So, this part of the document focuses on radio modems operating between 400MHz and 1GHz. Due to regulatory constraints, market offer in this part of the spectrum generally target either the 400-500MHz or the 750-950MHz bands. This covers both licensed and unlicensed channels.

Most implementations rely on narrow band modulations not exceeding 25kHz bandwidth. This small spectral footprint results in numerous channels in the same frequency band. This enables several communications at the same time with no interference. These communications being used either by various applications or by the same application but with independent channels (for instance 2 trains can use 2 different channels). Of course, the counterpart on the narrow band operation is that the available throughput (data rate) is reduced in proportion. In general one transmission channel can provide 1 to 25kb/s.

Due to the large panel of existing modulations, implementations of these devices are very various. Analog modulations tend to be replaced by numeric ones. Analog transmission is general only used for voice transmission. Data are more and more transported by numeric modulations (in amplitude, frequency or phase). Indeed, this solution brings more spectral efficiency, more scalability and more availability. But complexity (and by so, the cost) of these devices remains low because modulators come under the form of simple to integrate widespread single chip solutions. The quite low operating frequency is also a factor of simplicity and robustness. Note that RF losses are reduced at low frequency resulting in better link budgets.

Regarding the data interface, market offer is also very various. Basic products offer a serial communication interface (typically RS232 or 422) with basic on the fly transmission when others embed more evolved bus interface stacks like USB, CAN or CANOpen.

The radio modem can also implement a MAC layer over the radio. This stack controls access to the radio channel in order to avoid interference between the emitters thus enabling multi user topology. This layer can for example implement half duplex communication between 2 or more communicating nodes on the same channel or even implement addressing functionalities (unicast, multicast, broadcast). Thanks to such functionalities, the applicative devices only have to focus on their added value applicative functionality. Many implementations of such MAC layer exist on the market. They are in general proprietary and incompatible with each other.

Already existing communication systems

As explained in the previous paragraph, market offer of wireless modems is very wide and various. In general the modems are integrated in a more complex system to provide a customized and turnkey communication service for a specific application.

For railways, this integration effort is quite important since it has to comply with many requirements regarding environment, availability, maintainability, regulation issues, operational rule, etc. For that reason, re-designing a new system from scratch for **MARATHON** seems difficult and might not be cost effective. A more pragmatic approach is to look at existing locomotive communication systems ensuring functions quite similar to **MARATHON** need and check if they could be modified to fit all **MARATHON** requirements. With this intention 3 systems are presented bellow.

LOCOTROL® from GE TRANSPORTATION SYSTEMS

LOCOTROL® is a distributed power system with functionalities equivalent to **MARATHON**. It is built by GE Transportation Systems who says to have sold 6000 of these units over the world.

In general, this system is used to operate very long (> 1km) and heavy trains. Due to these characteristics, this kind of train can only run on tracks dedicated to freight lines. This constitutes a huge difference with MARATHON trains that are supposed to run on standard European lines where passenger traffic is mixed with freight and thus are submitted to dramatically stronger operational constraints. For instance, it is generally accepted that a LOCOTROL® loses radio communication for 30 seconds when MARTHON would only tolerates 4 seconds interruptions.

An opportunity could be to re-parameterize the system according to **MARATHON** specification but it is very difficult because the performance gap is to too important between the 2 specifications. Another idea was to only re-use the communication subsystem of LOCOTRL® but it also seems impossible because it's a closed system and it was not designed for that. But the major problem with LOCOTRL® is that it does not fulfil European norms as EN50126, EN50239 and EN50159-2 and therefore will not be accepted by any European Railway authorities (like EBA, EPSF, BMVIT or others). In conclusion this system proves the feasibility of distributed power control by radio but is hardly usable for **MARATHON**.

LocCom102 RS from SCHWEIZER ELECTRONIC

Schweizer Electronic has developed in 2002 – 2004 a product with the name "REDACOM". This product is successfully in use by the ÖBB since 2005 on the Brenner line. In 2005 Schweizer Electronic started the development of the technology platform "LocControl" with the radio remote control unit for shunting "LocControl100RS" as a first product. LocControl100 RS was introduced to the market in 2008 and is now in use in several European countries eg by DB-Schenker and SBB. LocControl100 RS fulfils all relevant European safety and radio norms. Based on LocControl100 RS Schweizer Electronic started in 2010 the development of SafeLink S and LocCom102 RS. SafeLink S is suited to control ie unmanned shunting locomotives. The first project was finished in September 2011 in Hansaport Hamburg. 4 unmanned shunting locomotives are controlled permanently 360 days / 24 h per year.

LocCom102 RS (under development and in certification process) is especially designed to link 2 locomotives in multi traction mode. LocCom102 RS is a further development of SaveLink S. The following properties were added in LocCom102 RS:

- Output Power of the radio system up to 5 W ERP, improved input sensitivity
- Multi – frequencies management up to 32 channels (channel space and channel bandwidth 12,5 kHz), Frequency range 410 – 470 MHz
- Input keyboard to program
  - RFID – key of the slave locomotive
  - pre selection of the radio – frequencies for the planned train journey
  - start – up tests of the train in multi traction – mode
- Synchronized radio – link interruption detection on master and slave locomotives

LocCom102 RS is particularly adapted to **MARATON** communication scenario. It enables loco to loco communications in the 400MHz (and/or 800MHz) band. It is capable to manage up to 5 trains with two locomotives in the same area thanks to robust and efficient STD (Synchron Time Division) channel allocation. It also natively manages diversity functions by duplicating data on 2 independent radio channels. LocCom102 RS is capable to select 32 different radio – channels (channel space and bandwidth 12.5 kHz).

LocCom102 RS data communication is certified but the product also proposes to replicate I/O from one end to the other with a safety level of SIL3 for 6 black & white signals and SIL2 for CANopen bus interface. This out of the box facility could dramatically simplify design of **MARATHON** safety critical functions by limiting safety related development on existing locomotives.

This Work Package has decided to perform a field test campaign of these products in order to validate their usability in **MARATHON** conditions. These tests are described later in this document (cf. § Errore. L'origine riferimento non è stata trovata.).

End of Train devices (EoT)

End of Train devices (EoT) are not systems for loco to loco communication but set a communication between a locomotive and a device attached at the end of the train. The purpose of EoT is to enhance brake behavior along freight trains. EoT can also be used to verify the integrity of the train consist in real time. Some EoT products are currently emerging in Europe but, they are more often used in the rest of the world. The similarity between EoT and distributed power is that EoT (except its European implementation) rely on a radio link which covers the whole length of the train. This is, once again, an example of radio usage in a railway safety critical application.

In the European EoT, brake control doesn't transit thought the radio link but an optional GSM (or GSM-R) link can be set between the locomotive and the device. In this case GSM is used to bring added value functionality such as system monitoring or freight/fleet tracking. Providing there is extra communication resource, this example of additional service financing the core function can be an interesting business model for **MARATHON**.

Conclusion on data link based products

The conclusions of this chapter are:

- Market has a plethoric offer of radio data modems. These devices have to be integrated into more complex systems to provide "ready to use" communication solutions for railway application.
- 3 solutions of locomotive to locomotive communication have been indentified by MARATHON: LOCOTROL®, REDACOM and LocCom102 RS.
- LOCOTROL® has been designed for trains running on dedicated track. It is a closed system and is difficult to modify it in order to cope with **MARATHON** requirements.
  LOCOTROL® doesn't fulfil the European safety norms.

REDACOM is already in use in Europe for similar use as **MARATHON** objectives but on 500m long trains running only on the Brenner line. Twenty locomotives equipped with REDACOM are used daily.

SafeLink S is in use in Hansaport Hamburg. The distance between the control tower and the locomotives is up to 1 km. There has been no interruptions since the beginning of the operation.

- Field tests of SafeLink S (LocCom102 RS) (cf. §5.2) have proven that the system range can be enhanced up to 750m with an acceptable availability. Corresponding developments are under progress to reach these goals.

- EoT device is another example of safety train automation involving radio communications. it does not answer **MARATHON** problem but presents interesting similarities. This example also shows that and on board radio communication networks could be shared by several applications.

Frequency bands

The selection of the frequency band is important because it governs the performances of the systems, especially in terms of data rate and link budget (range and availability). According the state of the art presented in the previous chapter, it is clear that a classical product offer does not cover the entire spectrum and only operates in a reduced number of frequency bands. Some are working in one band only while others work in multiple bands. According to previous chapter analysis, choice has to be done between the following possibilities:

400/500 MHz	allowed output power on licensed bands up to 10 W ERP
400/500 MHz	allowed output power on ISM bands up to 500 mW ERP duty cycle 100%
800/950 MHz	allowed output power on licensed bands up to 10 W ERP
800/950 MHz	allowed output power on ISM bands up to 500 mW ERP duty cycle 10%
2.4 GHz	no licensable bands available, public bands up to 100 mW ERP
5-6GHz	no licensable bands available except possibly around 5,9 Ghz as licensed in some places for Metros , public bands up to 1000 mW ERP

Another very important criteria in frequency choice is to determine if it is reserved (ie licensed) or public. At one end using a public band is simple because it does not need authorization and gives access to more channels (private allocation is restrictive in channel bandwidth). At the opposite end, licensed channels have to be negotiated (and in general paid) but allow for more power and provide a guaranty of immunity which results in a better availability. At this stage of the project it seems that the safety level of MARATHON application justifies using a dedicated band. This will be confirmed by the safety analysis made by other tasks of the project. It has to be noticed that numerous professional products offer to operate in both public and reserved bands providing they are close enough.

In this chapter frequencies are studied under theoretical aspects. Due to the complexity of the propagation theory it is worth to validate this analysis with the experimentation. This complement is developed in chapter 0.

The current theoretical analysis is developed in the next two paragraphs. The first one deals with frequencies bellow 1GHz. The second paragraph focuses on bands over 1GHz. This division into 2 groups reflects similarities that can be found inside theses 2 categories.

Frequencies below 1GHz

This paragraph focuses on frequencies between 400MHz and 1GHz. This part of the spectrum is often referred as the “gold frequencies” since it presents a very interesting compromise for ground to ground communication. This band is for instance massively used for TV broadcasting or mobile phones. Most frequencies in this range are already allocated. Some are unlicensed (like radio amateur or ISM1 bands) but most are reserved. Due to their very interesting performances these frequencies are very coveted as it has been shown by the recent example of re-allocation of the “digital dividend” left free by switching to digital TV broadcasting.

The major interest in the relatively low attenuation observed in this band. Free space attenuation law indicates that attenuation variation versus frequency is -20dB when the frequency is multiplied by10. For instance, this law gives an attenuation of 41dB for 1km at 400MHz and of 61dB (20dB more) at 4GHz. Attenuation under 1GHz is not only minimized in the air but also in electronics. So, receivers’ sensibility is generally better bellow 1GHz than in upper bands. For example, usual sensitivity level of a 400MHz receiver is around -115dBm when it is approximately -95dBm for 5.8GHz ones. The joined low channel attenuation and better sensitivity of receivers naturally leads to improved link budget allowing more margins to cope with sporadic interferences.

The counterpart to working at “low” frequencies is that the ratio between the carrier frequency and the bandwidth is much higher. By consequence, channel bandwidth allocation is very restrictive. Channel bandwidth is typically of 12,5kHz at 400MHz, 25 kHz at 800MHz and 20 MHz at 2.4 or 5GHz. By consequence, data rate available per channel is lower below 1 GHz.

Another drawback of these frequencies is their propagation characteristics. Due to their wavelength (75cm at 400 MHz, 33cm at 900 MHz), these frequencies have difficulties to penetrate inside buildings or in confined spaces. For MARATHON, this could become a problem in environments such as tunnels, especially for the lowest frequencies (around 400MHz) and when one end is in the tunnel and he second end is out.

Here are examples of frequency bands in this range:
433,05-434,79MHz: ISM public band
467,275-468,325 MHz: reserved for railway communications
876–880 and 921–925MHz: reserved for GSM-R
902-928MHz: ISM band in America, reserved in Europe

Frequencies over 1 GHz

For this category, the document focuses on 2.4 and 5GHz bands. The first band is exactly between 2.4 and 2.485MHz and is a public ISM band often used by WLAN (802.11b, g and n). At 5GHz, public available bands are 5.15-5.35GHz, 5.47-5.725GHz and 5.725-5.875GHz (limited to some regions). This band is also widely used for WLANs (802.11a, h and n) A little part of the spectrum between 5.9 and 6GHz is also likely to become a reserved band for transportation applications and could be interesting for **MARATHON**.

As mentioned in previous paragraph, channel attenuation at theses frequencies is higher than for ones below 1GHz. But, due to the shorter wavelength, for an equivalent size, the higher is the frequency, the higher the antenna gain is. But this only partially compensates losses in channel attenuation and sensibility so the link budget is generally worse over 1GHz than below. For **MARATHON**, concrete consequence is that radio link interruptions are more frequent and longer than below 1GHz. This results in the fact that these frequencies will hardly reach **MARATHON** availability requirements.

The short wavelength (12,5cm at 2.4GHz and 6cm at 5GHz) reduces the impact of obstacles on the wave propagation which can then be compared to linear propagation in optical geometry. The consequence is that these frequencies are well adapted to LOS (line of sight) communication but also for indoor coverage. It has to be noticed that, indoor coverage is acquired thanks to reflections. This of course, has an impact in terms of attenuation (due to refraction) and necessitate that the modulation enables multi-path reconstruction. Current state of the art numeric waveforms (for instance OFDM or DSSS+RAKE) ensure this function. For MARATHON use cases, such indoor coverage capacity could be very interesting to treat tunnel cases and come in complement to a lower frequency channel.

Channel bandwidth in WLAN bands is 20MHz in general. It can be reduced to 10 MHz for private bands. Depending on the modulation used, available data rate vary between 1 and 54 Mb/s. Of course, in MARATHON conditions, most robust modulations will be kept leading to a throughput between 1 and 6Mb/s.

MARATHON experiments reports.

The whole report shows in the document:

"Measuring report for radio link reliability in a multi traction (2 Locos) arrangement"
is part of attachment 1 (to be included in final version of current MARATHON report)
The summary and main conclusions are shown in chapter 5 below
General environment of the tests

From the 16th August to the 31st August 2011 10 train journeys to measure the different radio links were performed.

The place of measurements was the "autoroute ferroviaire Bettembourg-Le Boulou" which runs over 1000 km and which was tested south of Lyon to Le Boulou.
http://www.rail.lu/lorryrail.html
The railway track is from LU-3217 Bettembourg to FR-66160 Le Boulou.
The time of travel of the cargo train is about 14 h.
The locomotives for these cargo trains are (just as information) http://fr.wikipedia.org/wiki/BB_37000
The wagons are supplied by http://www.modalohr.com

Conclusions SafeLink S / LocCom102 RS

Nº	Conclusion	Measures	Situation
	The two systems A and B influenced each other. By Run 10 we turned off one of the systems.	Directive antenna Band pass filter Improving Blocking capabilities of the radio modules	Directive antenna work in process Improved radio module with output power 5 W work in process Band pass filters are available on the market.
	Works acceptable in free field	Directive antenna Band pass filter	Work in process, prototypes end 2011 available
	May be disturbed in free field	Directive antenna Band pass filter	Work in process, prototypes end 2011 available
	Is disturbed in tunnels	Directive antenna Output power of transmitter will be increased to 5 W (automatic power regulation)	Work in process, prototypes end 2011 Work in process, prototypes end 2011

The Task will concentrate all our efforts to the improvement of LocCom102 RS.

Conclusions REDACOM

Nº	Conclusion	Measures	Situation
	Works acceptable in free field	Directive antenna	No work is planned
	May be disturbed in free field	Directive antenna	No work is planned
	Is disturbed in tunnels	Directive antenna	No work is planned
		Output power of transmitter will be increased to 5 W (automatic power regulation)	

REDACOM works in ISM – Frequency Band with 10 channels switched.

It is not possible to get 10 frequencies assigned.

Conclusions SafeDat2 2,4 GHz FHSS

Nº	Conclusion	Measures	Situation
	Works acceptable in free field	Use circular antenna Bandpass	Further measures will be decided later
	May be disturbed in free field	Use circular antenna Bandpass	Further measures will be decided later
	Works acceptable in tunnel	Use circular antenna Bandpass	Further measures will be decided later

→ Figure 56: Experiments report.
Source: **MARATHON**

SafeDat2 is only SIL3 in combination with PSS (Siemens, PILZ, Hima, Schneider Electric others).

Regulations for output power are different in different countries.

Conclusions SafeDat2 5,7 GHz WLAN

The product used was not tested enough (first series samples): no conclusions could be drawn, further tests will have to be performed.

Conclusions of experiences in the past and tests in project **MARATHON**

Availability of the safe control radio link.

Service availability must be ensured by at least one channel less than 1GHz.

The output power must be in minimum 5W ERP (radio module under development). The antennas on the locomotives must be directive antennas especially designed for this application (under development).

Redundancy of the safe control radio link.

The stalling in line of a long "**MARATHON** type" train (having only one driver on board the master locomotive and a second unmanned remotely controlled locomotive) should be an extremely rare occurrence: as line may, in such case, be obstructed for a significant time due to longer than usual recovery (eg. send a second driver , split the train and run two separate trains if remote control is out of service). Some redundancy in the communication system between the two locomotives will therefore most probably be necessary, to prevent total loss of control of remote locomotive in case of permanent communication failure.

Multichannel (multi frequencies) equipment mandatory.

The radio equipment for the safe radio link must be a multichannel equipment because it will be impossible to coordinate the frequencies between the different countries in Europe. The channel selection may be done manually or automatically.

Equipment for the safe control radio link must fulfil all relevant European norms and the defined SIL – level.

The relevant norms are:

→ EN 61508	(general safety industrial applications)
→ EN50126	(general safety railway applications)
→ EN50128	(Software for railway control and protection)
→ EN50129	(Railway applications - Safety related electronic systems for signaling)
→ EN50159-2	(data transmission)
→ EN50155	(railway environment)
→ EN50239	(railway radio control shunting and multi traction)
→ EN 45545	(railway fire protection)
→ EN 300113	(radio)

Other norms may also be important.

The equipment for the safe control radio link must pass an expert opinion. The equipment must pass an expert opinion from a notified body like TÜV SÜD Rail GmbH or a similar company. The equipment for the safe control radio link must be accepted by the country authorities.
The equipment must be accepted at least by the EPSF (France) and the EBA (Germany).

Information radio link.

A second channel (not safe) could be used in complement in order to get better performances in tunnels, increase availability and get better throughput capacity. If implemented, this second channel could be chosen in one of the over 1 GHz bands in order to take advantage of the significantly higher data transmission capacity offered at these frequencies and get benefit of better tunnel propagation characteristics.

In conclusion the current technology state of the art enables to solve **MARATHON** communication needs with no requirement of ground infrastructure. This can dramatically simplify **MARATHON** deployment and market uptake since equipment costs and maintenance are only supported by train operators and loco manufacturers.

Radio communications technologies are still under development. Significant innovation should occur in the next years. Some of them could simplify **MARATHON** system design or improve its functionalities. But these technologies are too recent to be straightforward usable by **MARATHON** in the short term. They could also involve the infrastructure which goes against the simple “loco only" deployment mentioned just above. To reach the availability requirements, it is clear that the system shall include at least one communication channel under 1GHz. Moreover an optional additional channel over 1GHz could provide more data rate capacity and open perspectives to provide added value services for a quicker return on investment.

Theoretical and experimental approaches confirm that one existing locomotive to locomotive communication system, namely the LocControl product family from SCHWEIZER ELECTRONIC, could be able to answer **MARATHON** communication requirements providing slight design adaption and enhancement. The FUNCTIONNAL REQUIREMENT ANALYSIS PHASE under progress will have to confirm that feasibility.

MARATHON architecture is sufficiently opened regarding radio communication system to let other suppliers develop alternative communication solution when **MARATHON** market will be sufficiently developed to justify the effort.

MARATHON WP3 recommendation is, for those reasons, to specify communication interfaces compliant to current SCHWEIZER ELECTRONIC solution and to use this system for **MARATHON** demonstrator.

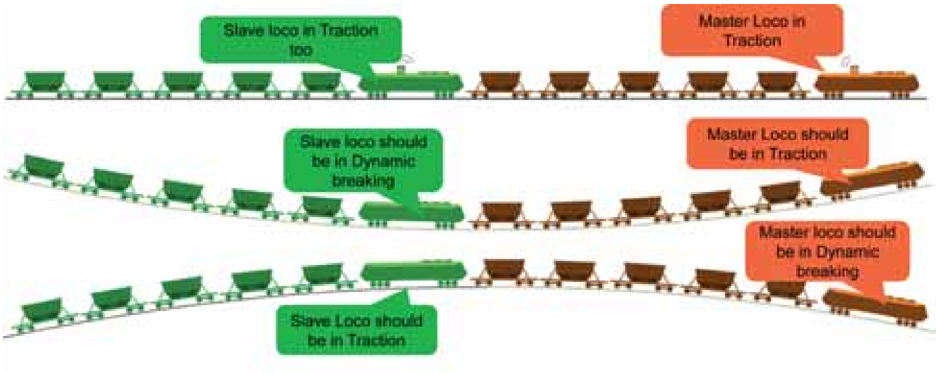
The Interface Development and Safety Requirements

As a part of the development of the equipment, the interfaces between the communication/synchronization system and traction and brake equipment has to be identified. The interfaces define the information to be exchanged between the two locomotives in order to perform the multiple traction function.

The resultant interfaces will be categorized in three types in order to allow the system to work with different types of locomotives: general interfaces, those related exclusively to electric locomotives and those exclusive of diesel locomotives. The interfaces have been defined taking into account the next requirements: first and principal, to keep the same safety levels of the actual locomotives following the European standards in force and, second to allow the maximal functionality and availability for the operators of the long trains. One main issue in the safety aspect is to reduce the longitudinal forces along the train. In terms of functional groups, the interfaces can be split in four groups:

1. Traction command Interfaces
2. Brake command Interfaces
3. Put in service & manage MODES; those interfaces related to the put in and out of services of the train and the management of the communication system
4. Control High Voltage Power Supply; control and synchronization of the pantograph in electric locomotives. These interfaces are exclusives of electric locomotives.

Information of previous or even parallel task of WP2 has been taken into account for the definition of the interfaces and its safety requirements. The next figure shows in a very schematic way different cases that can occur in the multiple traction operation and that were discussed during the working group meetings: the locomotives will not always be in the same operation mode. These situations are taken into account in the next Task. The Calculation of Longitudinal Dynamics.



→ Figure 57: Examples of Different Transmission Commands in a MARATHON Train. Source: **MARATHON**

As an approach to the definition of the signals this chapter will explain the process followed by the **MARATHON** partners to arrive to the final interfaces list.

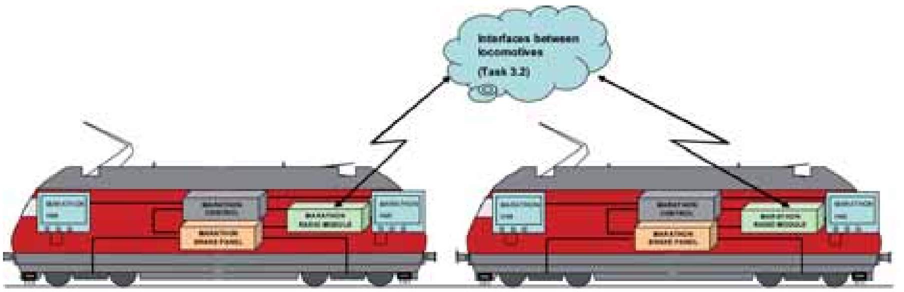
The first work performed by the partners in the task of the researching for the interfaces was to set down a first list according to the experience of the different partners as locomotive builders, safety experts, brake system suppliers, radio communication suppliers, operators and rail agencies. As a matter of conclusion for this first approach it was agreed that the system will be defined for long trains using the same type of locomotives either two electric locomotives or two diesel locomotives.

Next step in the way to define the interfaces and to complete the definition of the whole system was the functional description. As a base the results of MODTRAIN project were used. The FBS of MODTRAIN containing all the possible functions was the perfect choice to identify the so called '**MARATHON** functions'. Every partner according to its knowledge area, identified the functions needed by the long trains to perform a safety and proper operation from all the involved points of view.

An agreement was accorded for the FBS of **MARATHON** after some meetings and discussions.

As the last step prior to the definition of the interfaces a functional description of the **MARATHON** FBS was needed. The work was split in the four functional categories described in point 1. From each category a functional description document has been developed, each document describes the functions and its interfaces.

The results of the different functional descriptions are summarized in the next chapters and annexes.



→ Figure 58: Example of communication between two locomotives via MARATHON. Source: **MARATHON**

Traction Command Interfaces

The next table identifies all traction command interfaces that will be taken into account for the communication of the 2 locomotives operating in multiple traction.
M: identifies the Master Locomotive
S: identifies the Slave locomotive

Name	Description	Application E: Electric D: Diesel	Signal Direction (M→S, S→M)	Safety Level
C_Traction_Level	Traction request by the driver	E D	M → S	2
I_Traction_Level	Traction apply level report from S	E D	S → M	2
C_DynBrakeEnable	Dynamic brake enable	E D	M → S	2
C_DynBrakeRequest	Dynamic brake request	E D	M → S	2
C_TCUTraction _CutOff	Traction_CutOff	E D	M → S	2
C_TCUTraction _enable	Traction enable to Loc S	E D	M → S	2
C_TCUTraction _enable	Inverter pulses authorization	E D	S → M	3

C_Traction_Level _Plus	Traction plus to Loc S	E	M → S	2
C_Engine Run	Status of the diesel engine in the slave locomotive	D	S → M	2
C_Engine Stop	Request to stop the engine of the slave locomotive	D	M → S	2
C_Engine Start	Request to start the engine of the slave locomotive	D	M → S	2
I_TCUTraction _enable	Available power on the Slave (report) (2.2.8)	E D	S → M	2
C_Brake _Emmergency	Emergency brake apply to Loc S	E D	M → S	3
C_Brake_Apply	Service brake apply to set level	E D	M → S	2
I_Traction_Slipping	Slipping detected report from S	E D	S → M	2
C_Traction_Level _minus	Traction minus to Loc S	E D	M → S	2
C_TCU_diagnostic	level of effort [notch position report]	E D	S → M	2
C_SandManual _control	Sand to Loc S	E D	M → S	2
I_Sand_Status	Sanding status from Loc S	E D	S → M	2
C_SandAutomatic _control	Sanding inhibit	E D	M → S	2
I_ALARM _FireSignalling	Fire alarm from Loc S	E D	S → M	3
I_ALARM_Impact _Mission	ALARM condition report from loc S	E D	S → M	2??
I_ALARM_Oil_Temp	Over temperature alarm report from Loc S	E D	S → M	2

→ Figure 59: Traction Command Interfaces.
Source: **MARATHON**

Brake Command Interfaces

The next table identifies all brake command interfaces that will be taken into account for the communication of the 2 locomotives operating in multiple traction.

M: identifies the Master Locomotive

S: identifies the Slave locomotive

Name	Description	Application E: Electric D: Diesel	Signal Direction (M→S, S→M)	Safety Level
C_Brake _Emmergency	Emergency Brake Request	E D	M → S	3
C_Brake _Emmergency	Emergency Brake Request	E D	S → M	3
C_Power_CutOut	Locomotive Power CutOut requested	E D	S → M	3
C_Brake_Apply _Release	Service brake apply & realase to set level-Norminal range (0 – 100%) equivalent to (5.0 – 3.0bar) (8 bits)	E D	M → S	2
C_Brake _QuickRelease	Brake Quick release	E D	M → S	2
I_BK_Mode	Brake Status Report (8 bits)	E D	M → S	2
I_BK_Mode	Brake Status Report (1 bit)	E D	M → S	2
I_MRTH_TRL	MRTH Train Length (1 bit)	E D	M → S	2
I_BP_Pressure	Brake Pipe Pressure report (0.0-6.0 bars) (8 bits)	E D	S → M	2
I_BC1_Pressure	Brake Cylinder Pressure -Report from LocS(0.0-6.0bars)(8 bits)	E D	S → M	2
I_BC2_Pressure	Brake Cylinder Pressure -Report from Loc S(0.0-6.0 bars)(8 bits)	E D	S → M	2

I_Friction_Release	Air Flow operational condition Report from slave Locomotive. Quantity of air sinked by the BP(8 bits)	E D	S → M	2
I_Brake_isolated	→ Slave Brake Panel CutOut status from Loc S (OK/not OK) → DBV Isolation BP status from Loc S (OK/not OK) (2bits)	E D	S → M	2
I_Air_Flow	Air Flow operational condition Report from slave Locomotive (4 bits)	E D	S → M	2
I_MR_Pressure	Slave Locomotive Main Reservoir Pressure report (0.0-10.0 bars) (8 bits)	E D	S → M	2

→ Figure 60: Brake Command Interfaces.
Source: **MARATHON**

Put into Service and manage Modes

The next table identifies all command interfaces that will be taken into account to configure and start the service of the radio communication of 2 locomotives operating in multiple traction.
M: identifies the Master Locomotive
S: identifies the Slave locomotive

Name	Description	Application E: Electric D: Diesel	Signal Direction (M→S, S→M)	Safety Level
C_RadioStatus	Radio OK / not OK	E D	M → S	3
I_RadioStatus	Radio OK / not OK	E D	S → M	3
I_TrainCuopled _Orient	Locomotive orientation (8 bits)		M → S S → M	3

→ Figure 61: Put into service & manage modes.
Source: **MARATHON**

Control High Voltage Power Supply

The next table identifies all command interfaces of the pantograph control system that will be taken into account for the communication of the 2 locomotives operating in multiple traction.

M: identifies the Master Locomotive

S: identifies the Slave locomotive

Name	Description	Application E: Electric D: Diesel	Signal Direction (M→S, S→M)	Safety Level
BURPTO	Emergency Pantograph Fall down /(+open Circuit breaker to cut the traction current)	E	M → S	3
N_TTR	Selection of the network voltage (8 bits)	E	M → S	2
B_NTTRFC	Correspondence network voltage	E	S → M	3
N_SPT	Selection of pantograph Pantograph Loc S up / down Leading (both) (4 bits)	E	M → S	2
N_TAP	Type of adaptation of power (4 bits)	E	M → S	2
N_SPT_R	Pantograph Status Report from Loc Slave Selected pantograph & Up/ Down (4 bits)	E	S → M	2
N_TAP	Pantograph Status Report from Loc Slave Report of Type of adaptation of power (8 bits)	E	S → M	2
B_BPDJ	Ask Authorization close Main circuit breaker to Loc S	E	M → S	2
B_ZDJ	Main circuit breaker to Loc S open / close	E	M → S	2
B_VCBCLOSED	Main circuit breaker Report from Loc S open/ close	E	S → M	2 or 3?
A_VTCAT_R	Catenary Voltage (0-31) (8 bits)	E	S → M	2

→ Figure 62: Control high Voltage Power Supply.
Source: **MARATHON**

In Conclusion

The Interfaces needed to perform a correct operation of the long trains fitted with a **MARATHON** system have been defined in the present documentation. These interfaces cover all the possible types of locomotives (electric and diesel) and all the possible operational situations. Nevertheless the specific application of the system will determine whether all the different interfaces are needed or not to assure the correct operation of the system.

The Calculation of Longitudinal Dynamics (only reference to Deliverable)

One of the most used ways to assess the composition of new trains is to evaluate the longitudinal compressive forces and to compare these forces with the admissible values, that can be safely carried by the vehicles of the composition. In this report, for different compositions and different operational scenarios these forces are reported. Namely, the attention is here focused on the 10 m longitudinal compressive forces (10 m LCF) for safety reasons, since it is necessary a lasting level of LCF in order to make a vehicle derail. Here are also considered the 2m LCF in order to give information on the "maximum" level of LCF reached during a computation, and useful for maintenance purpose. For the same reason, the 2m LTF (tension forces) are computed and reported along with the 10 m LTF for completeness. Such quantities have been computed using TrainDy (owned by UIC and developed by Faiveley Transport and the University of Rome "Tor Vergata"), the internationally certified software for computation of train longitudinal dynamics.

In the following results, for each operational scenario and each composition the behavior with an Alstom loco and with a Vossloh loco is considered: usually there is not a big impact of the loco, so that the **MARATHON** train can run with both types of locos. Aiming to perform a complete investigation of the problem, the resulting report is very long, so it is useful a brief explanation of the topics considered in the different sections of the full deliverable since it is not possible to insert into this document a 265 pages report.

Section 2 overviews the different operational scenarios agreed during the meetings thanks to the contribution of the different experts. The operational scenarios are divided into nominal mode (everything works fine) and degraded mode (there is a radio link loss among the locos): this is necessary in order to prescribe operational rules (mainly regarding the allowed speed) that let the train run also when there is a radio link loss.

Section 3 and 4 reports the major data considered for the modeling.

Section 5 lists the names of the configurations and of the operations of TrainDy inputs, in order to reproduce the results here reported.

Section 6 shows the sketches of the main train compositions studied. For the first type of train-set, it is also investigated the traditional train composition, i.e. with only one loco.

Section 7 reports the stopping distances of the vehicles considered in the analysis to show the agreement with the UIC 544-1.

Section 8 the results dealing with the first type of train-set. It is worthwhile to mention that for this type of the train-set it has been performed also a statistical investigation. This type of analysis has not been considered for the bulk wagons since their behavior has been found to be less critical.

Section 9 deals with the train-set made of bulk vehicles.
The Adaptation Design and Verification

This is the configuration of the **MARATHON** system for adaptation to the Locomotive Alstom BB37000 architecture. The block diagram of the architecture is described into the next Figure.

Lead Locomotive

→ Brake system: FT brake panel already installed on locomotive.

Communication between BCU (Brake Control Unit) end DPCU lead (MRTH Distributed Power Control Unit) is based on Rs232 serial link.

→ Traction system: already installed on locomotive.

Communication between MPU e DPCU is based on Rs485 serial link with data communication managed by NFF protocol.

→ **MARATHON** Radio Communication System: LC100 device with:

450mhz radio - Interface
6 hard-wired Input & Output signals: SIL3
2 CAN networks (Valent & Anti-Valent data stream management): SIL2
2.4Ghz radio – Interface
Ethernet IP protocol used for message data communication: SIL 0 (diagnostic)

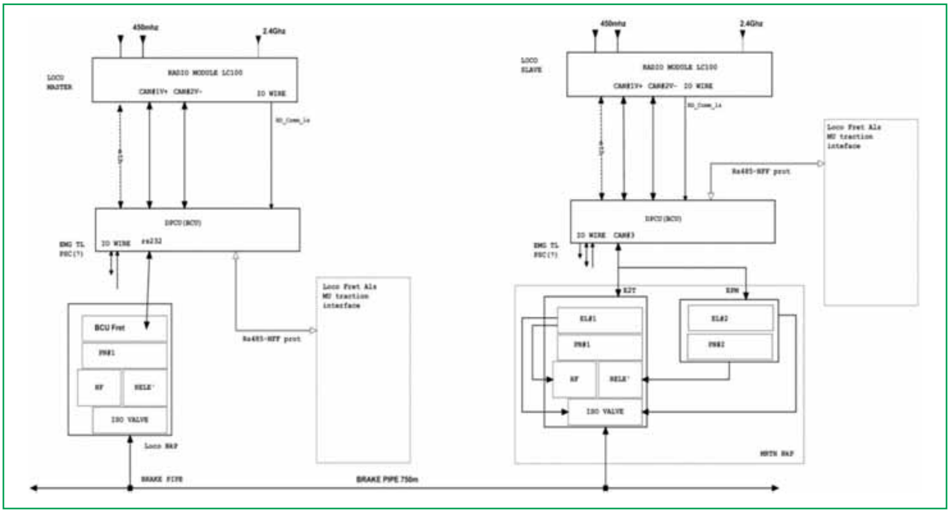
Slave Locomotive

1. **MARATHON** Radio Communication System: LC100 device with:
   450mhz radio - Interface
   6 hardwired signals Input & Output: SIL3
   2 CAN networks (Valent & Anti-Valent data stream management): SIL2
   2.4Ghz radio – Interface
   message the protocol: SIL 0 (diagnostic)

2. Traction system: already installed on locomotive. Communication between MPU e DPCU is based Rs485 serial link with data communication managed by NFF protocol.

3. Brake system: new MRTH brake panel installed on locomotive – refer to picture.2 (see below). Communication between DPCU trail and MRTH brake panel device is based on CAN network.

Architecture Alstom BB3700



→ Figure 63: Architecture Alstom BB3700.
Source: **FAIVELEY for MARATHON Project**

Safety Related Signals.

The following digital signals are managed by directly by the radio LC100R according to the SIL3 requirement association. The LC100R manage these signals in order that in case of radio link communication loss all the output signals - a part the signal Com_Loss_R - maintain the latest valid state.

→ Com_Loss_R – output in both Lead and Slave. This signal is read by both E2T and EPM (slave mode). The state of the CL_radio signal is transmitted on their PDOs.

Signal state:
off → during radio link initialization process
on → radio link OK (active high)
off → case of Radio comm. Loss (> 5 * 455ms = 2.275sec).

→ EMG_BK – input and output on both Lead and Slave. This signal is read by both E2T and EPM (slave mode). The state of the signal is transmitted on their PDOs.

Emergency brake signal is active low.

→ EMG_Pantograph – Input signal on Lead and driven output signal on Slave

Emergency pantograph signal is active high.

Traction Signals

The following data variables are exchanged between the MPU and DOCU device over the NFF serial communication link in order to manage in synchronous way the traction system of the lead and trail locomotive.

	Signals transmitted by leading loco			
	MPU	LS 485		DPCU
Description	Name	Name	size (bit)	Name
Cabine en service	B_MES	B_MES_EMISLS	1	xxxxx
Marche avant	B_AVANT	B_AVANT_EMISLS	1	xxxxx
Marche arrière	B_ARR	B_ARR_EMISLS	1	xxxxx
Pas de sens de marche sélectionné	B_0SENS	B_0SENS_EMISLS	1	xxxxx
Commande de traction / freinage	B_SMPC0 B_SMPC1 B_SMPC2	B_SMPC0_EMISLS B_SMPC1_EMISLS B_SMPC2_EMISLS	1 1 1	xxxxx xxxxx xxxxx
Commande de coupure traction	B_xxxxx	TR_Cutoff	1	xxxxx
Commande d'effort de traction / freinage (voir / note 2)	N_COEFFES	N_COEFFES_EMISLS	6	xxxxx

→ Figure 64: Traction signals - Lead Locomotive.
Source: **MARATHON**

	Signals transmitted by trailing loco			
	MPU	LS 485		DPCU
Description	Name	Name	size (bit)	Name
Tension caténaire sélectionnée	N_TTR	N_TTR_EMISLS	0..2	xxxxx
Sens de marche erroné	B_xxxxx		0	xxxxx
Traction Effort réalisé	B_xxxxx		1..6	xxxxx
Commande de coupure traction	B_xxxxx	TR_cutoff	7	xxxxx

→ Figure 65: Traction Signals - Trail Locomotive.
Source: **MARATHON**

Pantograph Management Signals

The following data variables are exchanged between the MPU and DOCU device over the NFF serial communication link in order to manage in synchronous way the pantograph and the traction inverter of both lead then trail locomotive.

	Signals transmitted by leading loco			
	MPU	LS 485		DPCU
Description	Name	Name	size (bit)	Name
Cabine en service	B_MES	B_MES_EMISLS	1	xxxxx
Tension caténaire sélectionnée	N_TTR	N_TTR_EMISLS	3	xxxxx
Panto sélectionné	N_SPT	N_SPT_EMISLS	2	xxxxx
Commande ouverture DJ	ZDJ	Ouv_DJ_EMISLS	1	xxxxx
Commande fermeture DJ	BPDJ	Ferm_DJ_EMISLS	1	xxxxx
Limitation Puissance	N_TAP	N_TAP_EMISLS	2	xxxxx
Demande de sablage manuel	B_DSAM	B_DSAM_EMISLS	1	xxxxx
Annulation du sablage automatique	B_ASA	B_ASA_EMISLS	1	xxxxx
Acquitement de détection incendie	B_ACKINC	B_ACKINC_EMISLS	1	xxxxx
Commande du baisser d'urgence du pantographe	B_xxxxx		1	xxxxx

→ Figure 66: Pantograph Management Signals - Lead Locomotive.
Source: **MARATHON**

Description	Signals transmitted by trailing loco			
	MPU	LS 485		DPCU
	Name	Name	size (bit)	Name
Tension caténaire sélectionnée	N_TTR	N_TTR_EMISLS	0..2	xxxx
Panto sélectionné	N_SPT	N_SPT_EMISLS	3, 4	xxxx
DJ ouvert	B_xxxxx		5	xxxx
Autorisation fermeture DJ	B_xxxxx		6	xxxx
DJ fermé	B_xxxxx		7	xxxx
Nb Loco en UM radio (=1)	N_LUMRAD		0..2	xxxx
Demande de sablage	B_DSAB		3	xxxx
Incendie détecté	B_INC		4	xxxx

→ Figure 67: Pantograph Management Signals - Trail Locomotive.
Source: **MARATHON**

The Case of Vossloh locomotive

This is the configuration of the **MARATHON** system for adaptation to the Locomotive Vossloh E4000 architecture. The block diagram of the architecture is described in the following Figures.

Lead Locomotive

- Brake system: FT brake panel already installed on locomotive.

Communication between BCU (Brake Control Unit) end DPCU lead (MRTH Distributed Power Control Unit) is based on Rs232 serial link.

- Traction system: already installed on locomotive. The interface of DPCU with the interface is based on the MU standard signals.

Traction demand

The Traction Demand read by DPCU is coded over 8(+2) positions that are code with the signals indicated in the following Table.

NOTCH	AV	BV	CV	DV	GFC
IDLE					
1					X
2	X				X
3			X		X
4	X		X		X
5		X	X	X	X
6	X	X	X	X	X
7		X	X		X
8	X	X	X		X
ENG STOP				X	-

→ Figure 68: Traction Demand - Lead Locomotive.
Source: **MARATHON**

Dynamic Brake

When the braking lever is moved beyond BRAKE SETUP point, a dynamic brake is activated, and tells to the trail locomotive to brake according with the below Brake Demand.

DynBrakeEnable DPCU reads the digital input signal BRST_M and sets the PDO field C_DynBrakeEnabled.

DynBrakeRequest It is the analog signal DYR_M (0-10V ↔ 500mV- 4500mV) that shall be transmitted in 5 bits to Trail as voltage value.

PDO field C_DynBrakeRequest bit[0-4]: 1bit = 310mV.

→ **MARATHON** Radio Communication System: LC100 device with
450mhz radio - Interface
6 hard-wired Input & Output signals: SIL3
2 CAN networks (Valent & Anti-Valent data stream management): SIL2
2.4Ghz radio – Interface

→ message eth protocol used for diagnostic information and system status behavior. SIL 0 (diagnostic)

Slave Locomotive

1. **MARATHON** Radio Communication System: LC100 device with
   - 450mhz radio - Interface
     - 6 hardwired signals Input & Output: SIL3
     - 2 CAN networks (Valent & Anti-Valent data stream management): SIL2

- 2.4Ghz radio – Interface
  - message eth protocol used for diagnostic information and system status behavior. SIL 0 (diagnostic)

2. Traction system: already installed on locomotive. The interface of DPCU with the interface is based on the MU signals std.

Traction demand

The traction demand driven by DPCU is coded over 8(+2) positions that are code with the signals indicated in the following table

NOTCH	AV	BV	CV	DV	GFC
IDLE					
1					X
2	X				X
3			X		X
4	X		X		X
5		X	X	X	X
6	X	X	X	X	X
7		X	X		X
8	X	X	X		X
ENG STOP				X	-

Figure 69: Traction Demand - Lead Locomotive.
Source: **MARATHON**

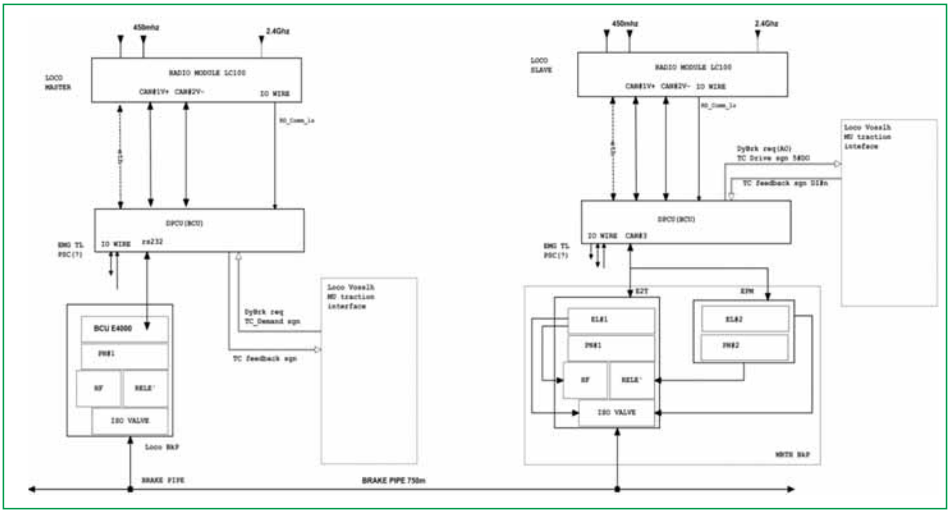
When the braking lever is moved beyond BRAKE SETUP point, a dynamic brake is activated, and tells to the trail locomotive to brake according with the below Brake Demand.

DynBrakeEnable - DPCU reads the digital input signal BRST_M and sets the PDO field C_DynBrakeEnabled.

DynBrakeRequest - It is the analog signal DYR_M that shall be transmitted to Trail as the radio PDO field C_DynBrakeRequest.

3. Brake system: new MRTH brake panel installed on locomotive – refer to picture.3 (see below). Communication between DPCU trail and MRTH brake panel device is based on CAN network.

Architecture Vossloh



→ Figure 70: Architecture Vossloh.
Source: **FAIVELEY for MARATHON Project**

Safety related Signals

The following digital signals are managed by directly by the radio LC100R according to the SIL3 requirement association. The LC100R manage these signals in order that in case of radio link communication loss all the output signals - a part the signal Com_Loss_R - maintain the latest valid state.

→ Com_Loss_R – output in both Lead and Slave. This signal is read by both E2T and EPM (slave mode). The state of the CL_radio signal is transmitted on their PDOs.

Signal state:
off → during radio link initialization process
on → radio link OK (active high)
off → case of Radio comm. Loss (> 5 * 455ms = 2.275sec).

→ EMG_Brake – input and output signals on both Lead and trail locomotive. This signal is read by both E2T and EPM equipment installed on MRTH brake panel: MRTH slave operational mode . This signal connect together the safety loop o the 2 locomotive passing through the radio link.

Emergency brake signal is active low.

→ GFC_S – input on Lead locomotive, output on Slave locomotive.
MU Governor Field Control signal: traction enabled signal for the slave loco.
GFC_S signal is active high.

→ FIRE_S – input on Slave, output on Lead.
Fire alarm from the slave loco.
GFC_S signal is active high.

Traction Signals

The following hardwired signals shall be exchanged between the 2 loco equipments:

#	Name	Type	Value	BINARY threshold	Description
1	C_ENG_START	DI_1			
2	C_ENG_STOP	DI_1	72V	> 32V=1	1 = TRCB on 0 = TRCB off
3	C_TRAC_TEST	DI_1	72V		Driver push button
5	FOR_M	DI_2			Forward direction
6	REV_M	DI_2			Reverse direction
7 8 9 10	AV_M BV_M CV_M DV_M	DI_2 DI_2 DI_2 DI_2			Traction level
11	BRST_M	DI_2			Dynamic Brake Enable
12	TCO_M/S	DI_2			Loco Traction Cut-out status
13	GFC_M	DI_2			Enable Traction Controller
14	SAND_M	DI_2			Manual Sanding
15	DYR_M	AI_1	0 - 10V		Dynamic Brake Request
16	I_TRC_LV	AI_1	0 - 10V		Traction current effort feedback

→ Figure 71: Hardwired signals - Lead locomotive.
Source: **MARATHON**

#	Name	Type	Description	Output logic
2	FOR_S	DO_1	Forward direction	
3	REV_S	DO_1	Reverse direction	
4 5 6 7	AV_S BV_S CV_S DV_S	DO_1 DO_1 DO_1 DO_1	Traction level	
8	BRST_S	DO_2	Dynamic Brake Enable	
9	TCO_S	DO_2	Traction Cut-Off command	0 = enable traction 1 = disable traction
10	SAND_S	DO_2		
11	DYR_S	AO_1	Dynamic Brake Request	0 – 10V
12	ENG_START_S	DO_2		
13	GFC_S	DI_1	Traction Controller enable Signal driven only by LC100R	
14	I_TRC_LV	AI_1	Traction effort feed-back	0 – 10V
15	WSP_S	DI_1		
16	TCO_M/S	DI_2	Loco Traction Cut-off status	

→ Figure 72: Hardwired signals - Trial locomotive.
Source: **MARATHON**

MARATHON Brake System

Lead Locomotive: The existing loco brake panel is fully operational on the Lead locomotive. The following brake information are used by MRTH brake system. This information are transmitted over rs232 serial link by the BCU that control the brake panel and read by lead DPCU.

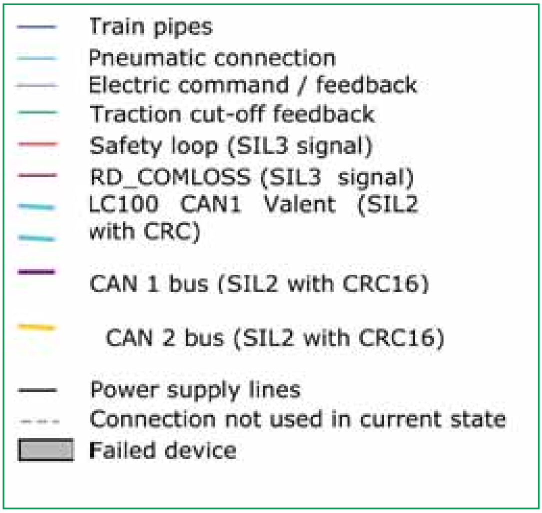
Brake Data: Brake Pipe request Set-point. The lead ER pressure set point [BCU variable] shall be coded into radio CAN PDO field.

Emergency Brake Request: The Lead emergency brake signal [BCU variable] shall be coded into radio CAN PDO field. The Lead loco emergency brake signal (high active loop) is read also in parallel by radio LC100 device on one DI channel (SIL 3) and transmitted to the trail loco. On Slave loco an equivalent DO channel (SIL3) shall drive by the LC100 device.

Quick Release Command: The lead Quick release command [BCU variable] shall be coded into radio CAN PDO field.

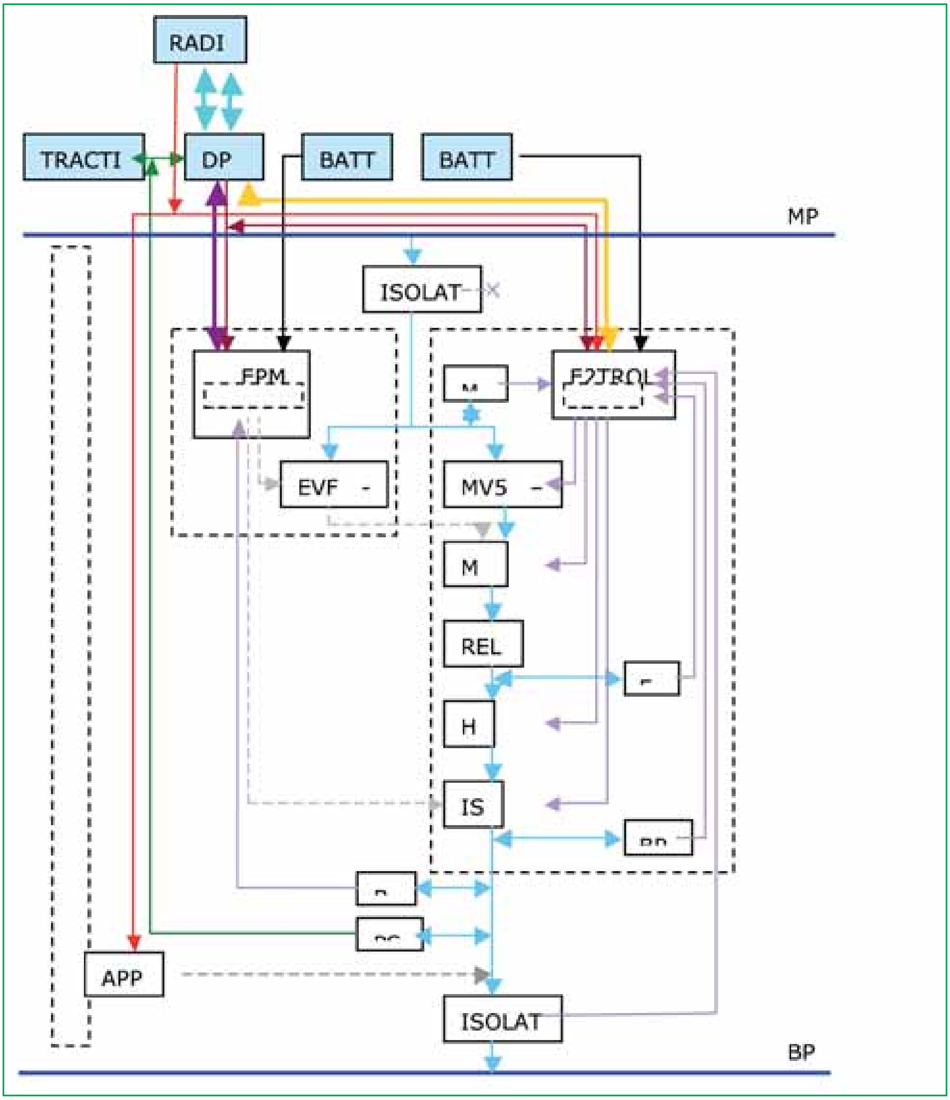
Neutral and Isolation Commands: The lead Neutral command shall be coded into radio CAN PDO field.

Slave Locomotive: The loco driver brake valve, installed on the existing brake panel, has to be disabled (ISO on). The MRTH brake panel (driver brake valve remote controlled) installed on slave locomotive – refer to the following Figure – has to be operational (power on and ISOLATION COCK switch on).



→ Figure 73: MARATHON Brake System.
Source: **MARATHON**

MARATHON Brake Panel



→ Figure 74: MARATHON Brake Panel.
Source: **MARATHON**

MARATHON - MAke RAil The HOpe for protecting Nature

Brake Pipe Management Panel: In MRTH working condition the E2TROL controls the BP according to the brake request received on CAN bus from the DPCU. When the BP is TBD bar from the target the E2TROL activates the ISO valve letting the master loco control the BP autonomously to prevent fluctuations in the pipe. High flow function is controlled by E2TROL according to the request received on CAN 2 bus from the radio.

Service Brake application and Release: For any new brake request the ISO valve has to be energized (set ON) in order to cut-in the MRTH brake panel with the Brake Pipe. Any new brake request (both for BP apply then BP release) has to be apply at the 95%[parameter] of the target pressure. When the target pressure shall be archived the MRTH brake panel disabled has to be isolated with a time delay that shall be function of Air flow information Defined timeout function of MRTH train length information: DPCU. I_Train_lenght.

Special Case: First brake step procedure: The E2TROL must store the information about the first brake step. For the whole duration of the procedure it must change into the status "first brake step" which can only be interrupted by: emergency or deactivation of the BP control. The E2TROL must de-energize MV6 to perform first brake step in UIC timing. The E2TROL has finished the procedure and follows again the handle position information. ,The intention of this procedure is to achieve a quick RE pressure decrease in order to fulfil the following requirement: the first BP pressure difference of 350 mbar must be reached in a maximum time of 0.5 s.

Quick Release: The quick release function has the following purpose: release the brake completely; quick BP filling due to the section change of the air supply.

The conditions needed to start quick release are: DPCU field C_Brake_Quick Release =1 AND before validating the quick release command, the current RE pressure and the target pressure PREG must have the condition P < PREG - 250 mbar.

Quick release command is the following: HF valve is energized.

The quick release request must be deactivated after a continuous use of 60sec., independently of all the other conditions or requests. The quick release request must be deactivated when any kind of brake request is detected. The actual BP pressure must be stored in this situation. Quick release is interrupted by the following events:

- service brake;
- full service brake (penalty);
- emergency;
- isolation (MRTH cut-out).

In these cases the E2TROL Control Unit must execute the procedure which has interrupted the quick release and store the interruption.

Brake Test: **MARATHON** system brake test is mandatory in order to put in operational mode the MRTH train.

Brake test Activation: After MRTH system power up, brake test procedure shall be activated on Lead loco by the driver. The following procedure steps has to be executed by the drive and monitored by DPCU:

0. Lead DPCU receives the brake test command from the driver.
1. Brake Pipe continuity test of the whole MRTH train
2. MRTH train Brake pipe refill
3. MRTH train Brake apply & release
4. 1° step brake test
5. MRTH train Brake pipe leak test

Safety Aspects of the **MARATHON** DPCU Architecture: The architecture described above for realizing the interface between the train logic and the radio control system is a DPCU associated to different I/O boards, which can be set-up according to the DPCU configuration. The new equipment has been designed by Faiveley considering the Technological constraints reported in the Preliminary Hazard Analysis, which need to be implemented to ensure that the new subsystem is:

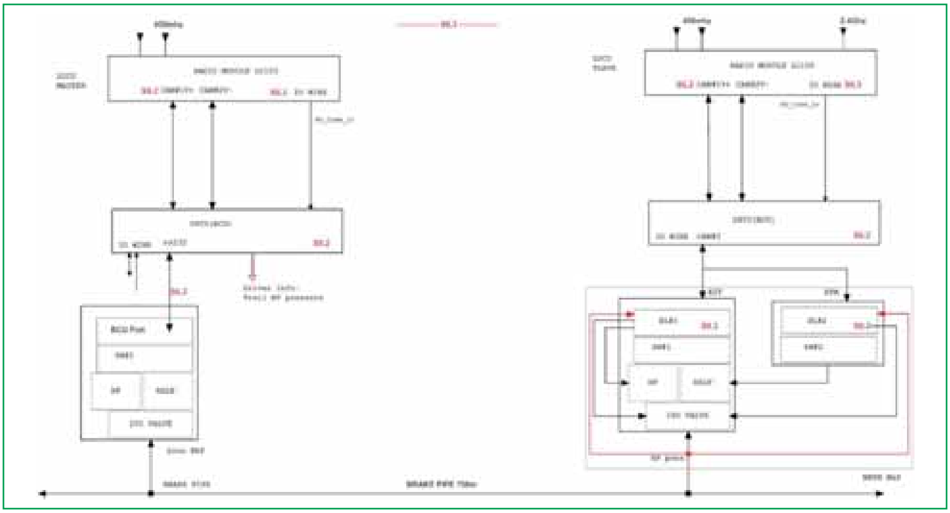
- → able to ensure the same level of functional safety of the two uncoupled trains for the new coupled train,
- → not intrusive towards the existing vehicle equipment.

In the following subsections, it has been described and analyzed the way in which FT DPCU envisage to implement these two instances at functional architecture level. According to the description above reported and to the input safety requirements produced in the Hazard Analysis, in particular with reference to the [MTH_SR_13] which is:

The new brake panel and the relevant interfaces with the brake pipe, the train and the gateway shall be realized with at least the same Safety Integrity Level than the substituted one.

This general requirement has been issued to ensure that all the modifications introduced at train level to create a new single train vehicle allow the fulfillment of the same Safety Integrity Levels of the two separate vehicles.

As regards the DPCU and the brake interface, object of FT intervention, this fact implies that the same safety integrity level can be ensured by the architecture and functionalities here allocated, or, in other words that no additional hazard has been introduced by the new architectural concept. More in details, as it can be seen by the scheme below reported, the DPCU can guarantee a SIL2/SIL3 compatible I/Os.



→ Figure 75: Compatibility I / Os to SIL2 / SI.
Source: **MARATHON**

These interfaces involve the communication with the Radio Module and the braking equipment by means of both wired and CAN supports. In particular, wired I/Os can be managed by DPCU according to SIL3 and CAN I/Os according to SIL2. The list of the signals implemented and allocated via SIL3 wired I/Os and via SIL2 CAN I/Os have been envisaged in respect of the safety recommendations issued in the Hazard Analysis. For this reason, it can be stated that the DPCU architectural implementation can be considered safe enough provided that the following assumptions are fulfilled by the product implementation:

- DPCU is able to manage internally (SW and HW) wired interfaces in respect of SIL3 requirements and CAN interfaces in respect of SIL2 requirements,
- Transmission of the signals via the Radio Module and Communication radio channels can be realized in compliance with the SIL2 and SIL3 associated to each signal,
- The train logic responsible for the functional management of each signal is designed and configured to manage safely the new coupled system operating scenario.

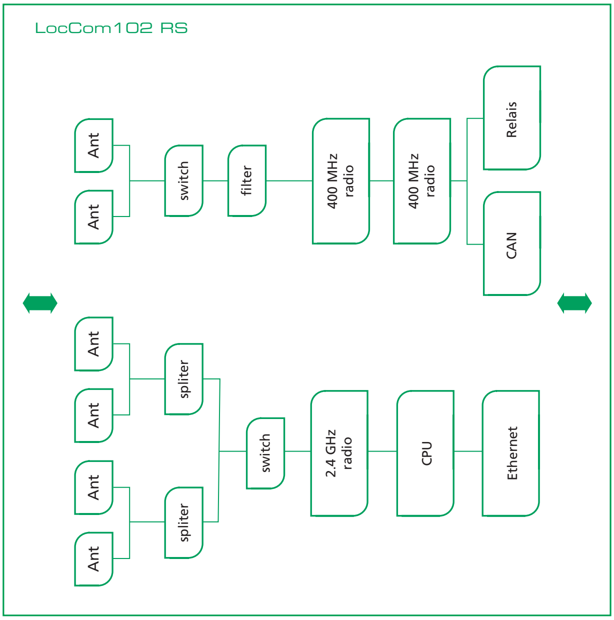
The list of SIL3 and SIL2 signals exchanged at the interface is reported in other parts of this document. The general request of non-intrusiveness has been already proposed at Hazard Analysis level, by means of the countermeasure. The two separate trains shall be safe in each part and function at the single vehicle level. This means that once the MRTH equipment installed, it shall not introduce any hazard scenario to the operations of the single vehicles. The safety concept above proposed is correctly implemented in the proposed architecture. In fact, during the single train operations, the MRTH braking equipment is safely isolated from the brake system, so that no failure of the MRTH equipment can lead to any hazardous condition. This aspect is fundamental to go ahead with the safety demonstration of the MRTH equipment, as anyhow during the normal mission of each train which can also be used for coupled operations, each train shall behave as if no modification is introduced.

The Communication Laboratory testing

This test report was created to demonstrate the proper functionality of the LocCom102 RS system as a preparation of the static and dynamic tests within the whole **MARATHON**-Kit. The tests were performed in a standalone configuration with two linked LocCom102 RS. The integration tests performed by Faiveley will demonstrate the proper functionality on a higher system level. This is not the scope of the tests. The test goal was to ensure the full functionality of the signal interface and performance of the radio links. The scope of the tests is aligned to the interface of the LocCom102 RS.

So the tests covers the

hard wired signals
CAN-interface
Ethernet interface
Antenna switching
400 MHz link
2.4GHz link



→ Figure 76: LocCom 102.
Source: **FAIVELEY for MARATHON Project**

A visual inspection was performed to ensure the proper assembling, regarding the mechanical influences on the locomotive during the tests. The next chapters describe the procedures of testing and present the specific results. For several procedures existing tests from our standard product LocControl100 RS were used. These tests are not described in detail.

Results:
Hard wired signals: All signals are transmitted as defined. The wiring is correct. Also the behavior in case of radio link interruption is as defined.

CAN-Interface: The CAN-Bus configuration is correct. The telegrams are transmitted completely. Ethernet interface: The data are transmitted correctly.

Antenna switch: The rf-signal is distributed correctly to the rf-connectors assigned to the selected direction.

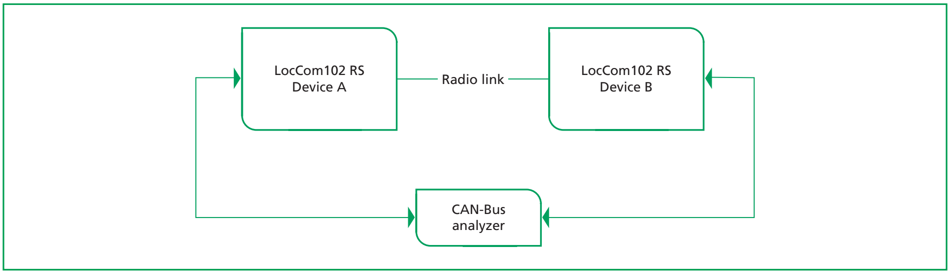
400 MHz link: The link margin is as specified.

2.4GHz link: The link margin is as specified.

→ The tested LocCom102 RS are suited for the static and dynamic tests on the locos

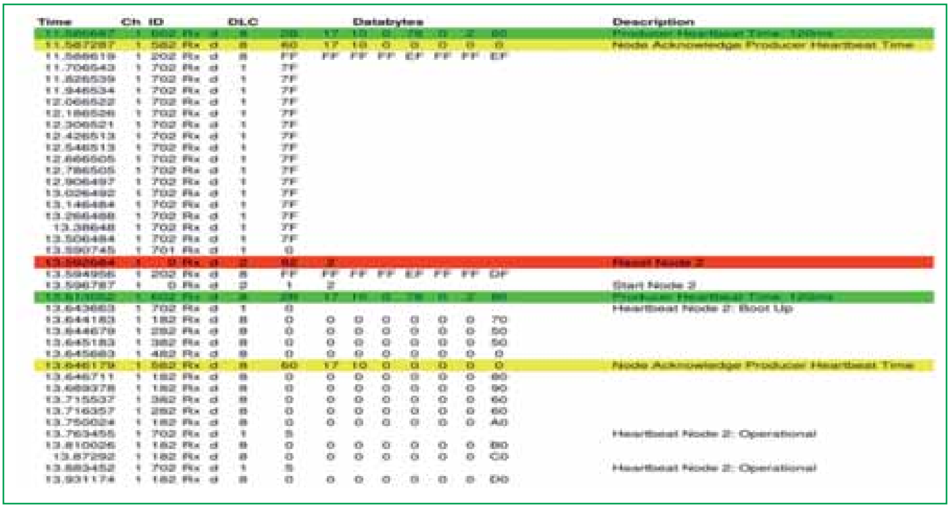
Hard Wired Signals: In order to test these signals, every input signal will be applied and the reaction on the output measured. By increasing the attenuation of the radio link up to a radio link interruption, the reaction of the radio link loss signal will be tested. The definition of the signals was tested according chapter 0 and 0. All signals are correctly transmitted and in case of a radio link interruption, the signal "COM_LS" appears after 2 seconds.

CAN Interface: By a CAN-bus analyzer the throughput of CAN-telegrams over the radio link was tested. Therefore the analyzer have to use the CAN-bus configuration of the LocCom102 RS (node address, bus speed), else no data can be transferred. The analyzer sends telegrams which contains a "counting" byte into both LocCom102 RS and receives them from both of them. If on both sides all telegrams with increasing "counting" byte correctly arrive, the link is working and the configuration is correct.



→ Figure 77: CAN interface.
Source: **MARATHON**

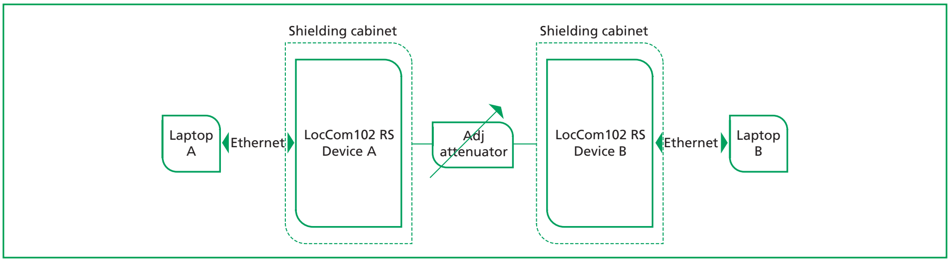
The configuration is correct and all telegrams are transmitted correctly.



Time	Ch	ID			DLC	Databytes								Description
11.586687	1	602	Rx	d	8	2B	17	10	0	78	0	2	00	Producer Heartbeat Time: 120ms
11.587287	1	582	Rx	d	8	60	17	10	0	0	0	0	0	Node Acknowledge Producer Heartbeat Time
11.588619	1	202	Rx	d	8	FF	FF	FF	FF	EF	FF	FF	EF	
11.706543	1	702	Rx	d	1	7F								
11.826539	1	702	Rx	d	1	7F								
11.946534	1	702	Rx	d	1	7F								
12.066522	1	702	Rx	d	1	7F								
12.186526	1	702	Rx	d	1	7F								
12.306521	1	702	Rx	d	1	7F								
12.426513	1	702	Rx	d	1	7F								
12.546513	1	702	Rx	d	1	7F								
12.666505	1	702	Rx	d	1	7F								
12.786505	1	702	Rx	d	1	7F								
12.906497	1	702	Rx	d	1	7F								
13.026492	1	702	Rx	d	1	7F								
13.146484	1	702	Rx	d	1	7F								
13.266488	1	702	Rx	d	1	7F								
13.38648	1	702	Rx	d	1	7F								
13.506484	1	702	Rx	d	1	7F								
13.590745	1	701	Rx	d	1	0								
13.592084	1	0	Rx	d	2	82	2							Reset Node 2
13.594956	1	202	Rx	d	8	FF	FF	FF	FF	EF	FF	FF	DF	
13.596787	1	0	Rx	d	2	1	2							Start Node 2
13.613062	1	602	Rx	d	8	2B	17	10	0	78	0	2	00	Producer Heartbeat Time: 120ms
13.643663	1	702	Rx	d	1	0								Heartbeat Node 2: Boot Up
13.644183	1	182	Rx	d	8	0	0	0	0	0	0	0	70	
13.644679	1	282	Rx	d	8	0	0	0	0	0	0	0	50	
13.645183	1	382	Rx	d	8	0	0	0	0	0	0	0	50	
13.645683	1	482	Rx	d	8	0	0	0	0	0	0	0	0	
13.646179	1	582	Rx	d	8	60	17	10	0	0	0	0	0	Node Acknowledge Producer Heartbeat Time
13.646711	1	182	Rx	d	8	0	0	0	0	0	0	0	80	
13.689378	1	182	Rx	d	8	0	0	0	0	0	0	0	90	
13.715537	1	382	Rx	d	8	0	0	0	0	0	0	0	60	
13.716357	1	282	Rx	d	8	0	0	0	0	0	0	0	60	
13.750024	1	182	Rx	d	8	0	0	0	0	0	0	0	A0	
13.763455	1	702	Rx	d	1	5								Heartbeat Node 2: Operational
13.810026	1	182	Rx	d	8	0	0	0	0	0	0	0	B0	
13.87292	1	182	Rx	d	8	0	0	0	0	0	0	0	C0	
13.883452	1	702	Rx	d	1	5								Heartbeat Node 2: Operational
13.931174	1	182	Rx	d	8	0	0	0	0	0	0	0	D0	

→ Figure 78: Configuration and Telegrams transmission.
Source: **MARATHON**

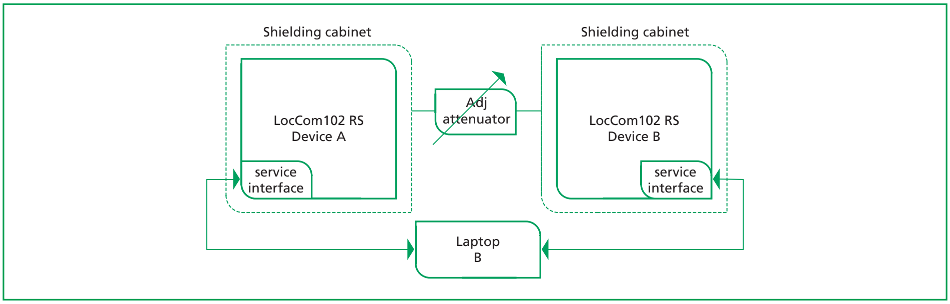
Ethernet Interface / 2.4 GHz Link / Antenna Switch: The Ethernet connection is tested by a simple computer to computer (laptop) Ethernet data transmission. In this case we established a network connection between the two laptops. By increasing the attenuation until the transmission stops, the link margin of the 2.4GHz is measured. By changing the antenna "direction" the functionality of the antenna switch for the 2.4GHz is tested. If close to the maximum of attenuation the wrong direction is selected on one LocCom102 RS, the radio link will be interrupted. Therefore the two LocCom102 RS are placed in two shielded cabinets, to have no other radio connections than through the adjustable attenuator.



→ Figure 79: DCPU network.
Source: **MARATHON**

The network is working properly and stable on both antenna "directions". The link margin is for both antenna "directions" 90dB.

400 MHz Link / Antenna Switch: The LocCom102 RS is always transmitting telegrams on the 400 MHz link. So there is no generation of data needed. By the service interface all telegrams can be recorded and analyzed with a specific tool. With this tool we can check how many telegrams will be lost related to the applied attenuation. This standard test for LocControl100 RS gives a very clear result about the link performance and the link margin.



→ Figure 80: DCPU Interfaces.
Source: **MARATHON**

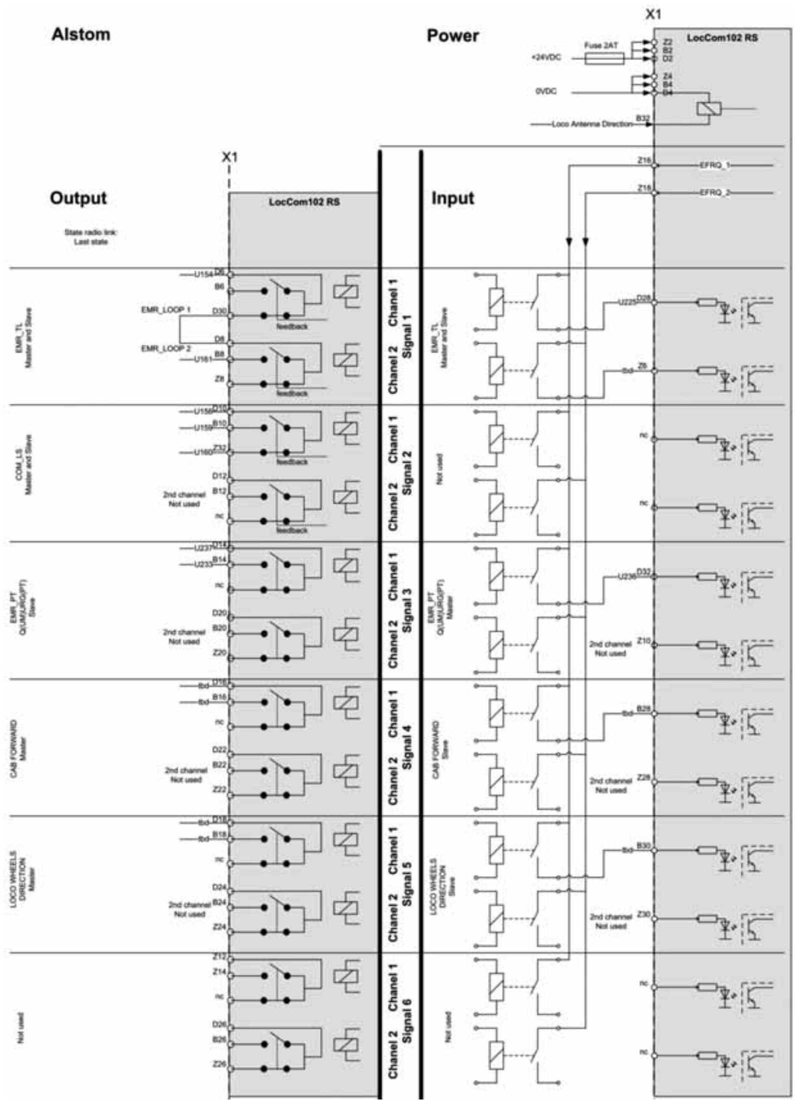
Measurement results:

Attenuation		131dB (min 95%)	136dB (min 80%)	139dB (min 30%)	Radio link interruption
Direction		Transmission			Attenuation
Antenna	Data	[%]			[dB]
1	AB	100	94	54	143
2	AB	99	95	49	142
1	BA	100	92	42	141
2	BA	100	95	46	141

→ Figure 81: Measured Results.
Source: **MARATHON**

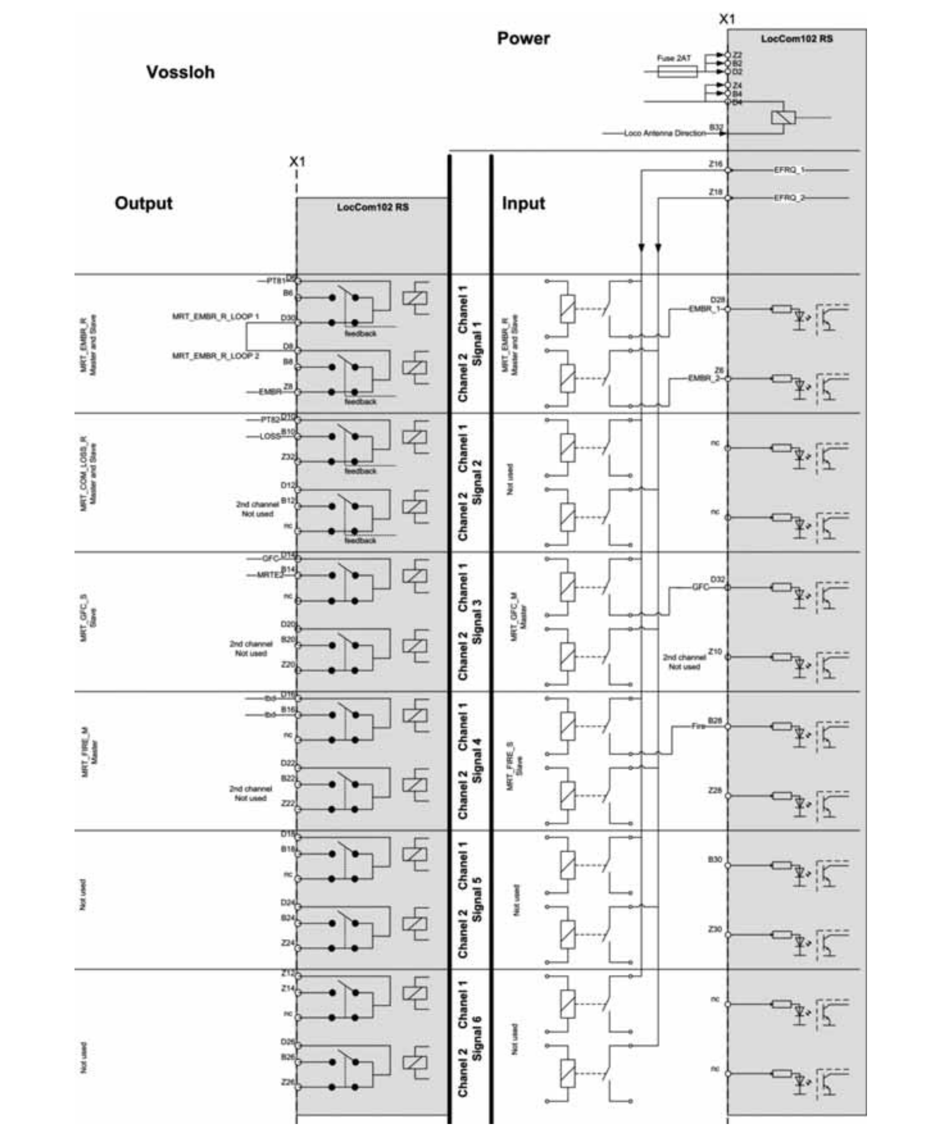
The radio link characteristic has passed in all conditions.

Definitions: Pin out - hard wired signals Alstom.



→ Figure 82: Alstom Signals.
Source: **MARATHON**

Pin out - hard wired signals Vossloh



→ Figure 83: Vossloh Signals.
Source: **MARATHON**

The Adaptation Design and Verification: The architecture of the MRTH system has been full defined and specified when the unit Distributed Power Control Unit (DPCU) has been introduced. The advantage of used one DPCU for each locomotive in the design of the MRTH system is evident passing from the conceptual phase to the engineering phase of the system both to adapt it to diverse types of locomotives today existing both in case of installation of new systems. This approach is already winning during in the implementation phase on the locomotives class:

Alstom BB3700; Vossloh E4000:

Adding the DPCU device as a standard object of the MRTH system the following improvement has been achieved:

- Standardization of the hardware interface signals used to control the LC100 radio;
- Standardization of the communication data-base adopted for the Radio Remote control system;
- Flexible and modular hardware interface necessary to connect to the on board system already existing or further developed that can include:
- Tractions
- Brake
- Power management & locomotive control

The Case of Alstom locomotive: This is the configuration of the **MARATHON** system for adaptation to the Locomotive Alstom BB37000 architecture. The block diagram of the architecture is described below.

Lead Locomotive

- Brake system: FT brake panel already installed on locomotive.

Communication between BCU (Brake Control Unit) end DPCU lead (MRTH Distributed Power Control Unit) is based on Rs232 serial link.

- Traction system: already installed on locomotive.

Communication between MPU e DPCU is based on Rs485 serial link with data communication managed by NFF protocol.

- **MARATHON** Radio Communication System: LC100 device with:
  450mhz radio - Interface
  6 hard-wired Input & Output signals: SIL3
  2 CAN networks (Valent & Anti-Valent data stream management): SIL2
  2.4Ghz radio – Interface
  Ethernet IP protocol used for message data communication: SIL 0 (diagnostic)

Slave Locomotive

1. **MARATHON** Radio Communication System: LC100 device with:
   - 450mhz radio - Interface
     - 6 hardwired signals Input & Output: SIL3
     - 2 CAN networks (Valent & Anti-Valent data stream management): SIL2
     - 2.4Ghz radio – Interface
     - message the protocol: SIL 0 (diagnostic)

2. Traction system: already installed on locomotive. Communication between MPU e DPCU is based Rs485 serial link with data communication managed by NFF protocol.

Brake system: new MRTH brake panel installed on locomotive – refer to picture.2 (see below). Communication between DPCU trail and MRTH brake panel device is based on CAN network.

The Train Mock Up Test

Scope of this document is to resume and report the results of the test performer on the pneumatic simulator of the Faiveley Transport. The train simulator has been used to develop, test and verify the brake functions and theirs related performance, specifically thought and developed to control and manage the MRTH train.

The **MARATHON** Brake System: The brake system developed for the MRTH train is a vital component necessary to control and manage a modular train longer up to 1500m.

The system manages the function related to:

- Brake in nominal condition
- Safety Brake back-up in system degraded mode

The nominal brake system is operational when the MRTH system is in nominal operational mode: in detail the radio safety channel is fully operational. The brake back-up system is operational when the MRTH operational condition enters in degraded mode: in detail when the radio safety channel is down for a window time > 2.2sec.

Brake Function Lead Locomotive: The existing locomotive brake panel is fully operational on the Lead locomotive. The following brake information are used by MRTH brake system. This information are transmitted over rs232 serial link by the BCU that controls the lead brake panel and read by lead DPCU.

Brake Data- Brake Pipe Request Set-point: The lead ER pressure set-point [BCU variable] shall be coded into radio CAN PDO field.

Emergency Brake request: The Lead emergency brake signal [BCU variable] shall be coded into radio CAN PDO field. The Lead loco emergency brake signal (high active loop) is read also in parallel by radio LC100 device on one DI channel (SIL 3) and transmitted to the trail loco.

Quick Release Command: The lead Quick release command [BCU variable] shall be coded into radio CAN PDO field.

Neutral-Isolation Command: The lead Neutral command shall be coded into radio CAN PDO field. Trail Locomotive: The loco driver brake valve, installed on the existing brake panel, has to be disabled (ISO on). The MRTH brake panel (driver brake valve remote controlled) installed on slave locomotive has to be operational (power on and ISOLATION COCK switch on).

Brake Pipe Management: In MRTH working condition the E2TROL controls the BP according to the brake request received on CAN bus from the DPCU. When the BP is TBD bar from the target the E2TROL activates the ISO valve letting the master loco control the BP autonomously to prevent fluctuations in the pipe. High flow function is controlled by E2TROL according to the request received on CAN 2 bus from the radio.

Service Brake Application and Release: For any new brake request the BKSLU ISO valve has to be energized (set ON) in order to cut-in the MRTH brake panel with the Brake Pipe. Any new brake request (both for BP apply then BP release) has to be apply at the 95%[parameter] of the target pressure. When the target pressure shall be archived the MRTH brake panel disabled has to be isolated (ISO valve off) with a time delay that shall be function of:

- Air flow information
- Defined timeout function of MRTH train length information: DPCU. I train length.

First Brake Step

First brake step procedure: The E2TROL must store the information about the first brake step. For the whole duration of the procedure it must change into the status “first brake step” which can only be interrupted by: emergency or deactivation of the BP control. The E2TROL must de-energize the vent valve to perform first brake step in UIC timing. The E2TROL has finished the procedure and follows again the handle position information. The intention of this procedure is to achieve a quick RE pressure decrease in order to fulfil the following requirement: the first BP pressure difference of 350 mbar must be reached in a maximum time of 0.5 s.

Quick Release: The quick release function has the following purpose:

- release the brake completely
- quick BP filling due to the section change of the air supply.

The conditions needed to start quick release shall be: -DPCU field C_Brake_Quick Release =1 AND before validating the quick release command, the current RE pressure and the target pressure PREG must have the condition P < PREG - 250 mbar.

Quick release command is the following: -Q Release Valve is energized. The quick release request must be deactivated after a continuous use of 60sec., independently of all the other conditions or requests. The quick release request must be deactivated when any kind of brake request is detected. The actual BP pressure must be stored in this situation. Quick release is interrupted by the following events:

- service brake, -full service brake (penalty) -emergency, -isolation (MRTH cut-out)

In these cases the E2TROL Control Unit must execute the procedure which has interrupted the quick release and store the interruption.

Overcharge and Assimilation:

It must be possible into the slave brake to control the BP pressure in order to reach higher pressure values (= overcharge) than the normal release pressure which is defined at 5 bar. This helps the driver to align the pressure reference in all distributor valves of the MRTH train.

Normal Operation:

The procedure is divided in three phases:

1. overcharge phase i.e. BP pressure increase
2. holding of the reached pressure level for a specific time
3. assimilation phase i.e. slow BP pressure decrease

Overcharge is activated by a driver's command on the lead loco.

Command is received by the E2TROL unit via CAN network (DPCU PDO. Overcharge cmd =1).

Emergency Brake By Driver Handle:

On Slave loco an equivalent DO channel (SIL3) shall drive by the LC100 device.
This mode is forced by the signal EM_Brk (DI2) = 0
E2T sets

- PDO field E2T.I_Bkt_status. Emergency on =1.
- target ER pressure = 0 immediately.
- MV3 ISO valve has to be energized (=1) until emergency brake is active: EM_Brk (DI2) = 0.

This modality has to be confirmed by DPCU: PDO field Status state = emergency.

Brake Back-Up: It was evident from field testing and laboratory simulation that condition of radio link communication loss could happen and that it has to be managed by the MRTH system in order to increase the safety and reli-ability of the overall MRTH train. In order to manage and mitigate the condition of radio communication loss, 2 communication timeout has been introduce at system level:

- Tloss = 2.275s
- Tmax = 20s

The MRTH brake system specified for the slave locomotive is the key actor that has to take care of the train brake also in degraded operational mode (Radio Com Loss). In Back-up mode this function has to be implemented.

First Brake Step: With BP in nominal condition (BP = 5bar),
In case a brake action was requested by the driver after t > tloss
- if a delta BP pressure is detected by the slave MRTH brake panel
- Full service brake has to be applied.

Brake Increase: Trail brake has applied the latest valid target and then it is isolated by the BP. Lead increases the braking effort: the pipe is discharged first from the lead (uncontrolled gradient).
Trail brake system monitors the BP pressure:
- If BP pressure < (BP last valid target -200mbar[])
- trail brake starts to discharge following the BP pressure.

Brake Back-Up: It was evident from field testing and laboratory simulation that condition of radio link communication loss could happen and that it has to be managed by the MRTH system in order to increase the safety and reliability of the overall MRTH train. In order to manage and mitigate the condition of radio communication loss, 2 communication timeout has been introduce at system level:
- Tloss = 2.275s
- Tmax = 20s

The MRTH brake system specified for the slave locomotive is the key actor that has to take care of the train brake also in degraded operational mode (Radio Com Loss).In Back-up mode this function has to be implemented.

First Brake Step: With BP in nominal condition (BP = 5bar), in case a brake action was requested by the driver after t > tloss
- if a delta BP pressure is detected by the slave MRTH brake panel
- Full service brake has to be applied.

Brake Increase: Trail brake has applied the latest valid target and then it is isolated by the BP Lead increases the braking effort: the pipe is discharged first from the lead (uncontrolled gradient). The Trail brake system monitors the BP pressure:
- If BP pressure < (BP last valid target -200mbar[])
- trail brake starts to discharge following the BP pressure.

MARATHON Train Configuration: The Brake Pipe train simulator is configured according to The MRTH train. The MRTH train configuration defined is listed in this table:

N	Name	T [t]	W [t]	Cumul. W (V) [t]	L [m]	Cumul. L. (V) [m]
01	Loco	90 (A)/ 123 (V)	0	123	19.54 (A)/ 23.02 (V)	23.02
02	Sgns681	19	0	142	19.74	42.76
03	Sgns681	19	20	181	19.74	62.5
04	Sgns681	19	20	220	19.74	82.24
05	Sgns691	20	30	270	19.74	101.98
06	Sgns691	20	50	340	19.74	121.72
07	Sgns691	20	50	410	19.74	141.46
08	Sgns692	20	25	455	19.64	161.1
09	Sgns692	20	50	525	19.64	180.74
10	Sgns692	20	50	595	19.64	200.38
11	Sgns705	20	25	640	19.74	220.12
12	Sgns705	20	50	710	19.74	239.86
13	Sgns705	20	50	780	19.74	259.6
14	Sgns735	20	0	800	19.64	279.24
15	Sgns735	20	50	870	19.64	298.88
16	Sgns735	20	50	940	19.64	318.52
17	Sggmrs715	30	40	1010	33.94	352.46
18	Sggmrs715	30	80	1120	33.94	386.4
19	Sggmrs715	30	80	1230	33.94	420.34
20	Sgns681	19	0	1249	19.74	440.08
21	Sgns681	19	20	1288	19.74	459.82
22	Sgns681	19	20	1327	19.74	479.56
23	Sgns691	20	30	1377	19.74	499.3
24	Sgns691	20	50	1447	19.74	519.04
25	Sgns691	20	50	1517	19.74	538.78
26	Sgns692	20	25	1562	19.64	558.42
27	Sgns692	20	50	1632	19.64	578.06
28	Sgns692	20	50	1702	19.64	597.7
29	Sgns705	20	25	1747	19.74	617.44
30	Sgns705	20	50	1817	19.74	637.18
31	Sgns705	20	50	1887	19.74	656.92
32	Sgns735	20	0	1907	19.64	676.56
33	Sgns735	20	50	1977	19.64	696.2
34	Sgns735	20	50	2047	19.64	715.84
35	Sggmrs715	30	40	2117	33.94	749.78
36	Sggmrs715	30	80	2227	33.94	783.72
37	Sggmrs715	30	80	2337	33.94	817.66
38	Sggmrs715	30	0	2367	33.94	851.6

N	Name	T [t]	W [t]	Cumul. W (V) [t]	L [m]	Cumul. L. (V) [m]
39	Loco	90 (A)/ 123 (V)	0	2490	19.54 (A)/ 23.02 (V)	874.62
40	Sgns681	19	0	2509	19.74	894.36
41	Sgns681	19	20	2548	19.74	914.1
42	Sgns681	19	20	2587	19.74	933.84
43	Sgns681	19	20	2626	19.74	953.58
44	Sgns691	20	30	2676	19.74	973.32
45	Sgns691	20	50	2746	19.74	993.06
46	Sgns691	20	50	2816	19.74	1012.8
47	Sgns691	20	50	2886	19.74	1032.54
48	Sgns692	20	0	2906	19.64	1052.18
49	Sgns692	20	50	2976	19.64	1071.82
50	Sgns692	20	50	3046	19.64	1091.46
51	Sgns692	20	50	3116	19.64	1111.1
52	Sgns705	20	0	3136	19.74	1130.84
53	Sgns705	20	50	3206	19.74	1150.58
54	Sgns705	20	50	3276	19.74	1170.32
55	Sgns705	20	50	3346	19.74	1190.06
56	Sgns735	20	0	3366	19.64	1209.7
57	Sgns735	20	50	3436	19.64	1229.34
58	Sgns735	20	50	3506	19.64	1248.98
59	Sgns735	20	50	3576	19.64	1268.62
60	Sgns735	20	50	3646	19.64	1288.26
61	Sggmrs715	30	40	3716	33.94	1322.2
62	Sggmrs715	30	80	3826	33.94	1356.14
63	Sggmrs715	30	80	3936	33.94	1390.08
64	Sggmrs715	30	80	4046	33.94	1424.02
65	Sggmrs715	30	80	4156	33.94	1457.96
66	Sggmrs715	30	0	4186	33.94	1491.9

→ Figure 84: Composition.
Source: **MARATHON**

The Brake Pipe train simulator is configured as per MRTH train listed in this table

N	Name	T [t]	W [t]	Cumul. W (V) [t]	L [m]	Cumul. L. (V) [m]
01	Loco	90 (A)/ 123 (V)	0	123	19.54 (A)/ 23.02 (V)	23.02
02	Sgns681	19	0	142	19.74	42.76
03	Sgns681	19	20	181	19.74	62.5
04	Sgns681	19	20	220	19.74	82.24
05	Sgns691	20	30	270	19.74	101.98
06	Sgns691	20	50	340	19.74	121.72
07	Sgns691	20	50	410	19.74	141.46
08	Sgns692	20	25	455	19.64	161.1
09	Sgns692	20	50	525	19.64	180.74
10	Sgns692	20	50	595	19.64	200.38
11	Sgns705	20	25	640	19.74	220.12
12	Sgns705	20	50	710	19.74	239.86
13	Sgns705	20	50	780	19.74	259.6
14	Sgns735	20	0	800	19.64	279.24
15	Sgns735	20	50	870	19.64	298.88
16	Sgns735	20	50	940	19.64	318.52
17	Sggmrs715	30	40	1010	33.94	352.46
18	Sggmrs715	30	80	1120	33.94	386.4
19	Sggmrs715	30	80	1230	33.94	420.34
20	Sgns681	19	0	1249	19.74	440.08
21	Sgns681	19	20	1288	19.74	459.82
22	Sgns681	19	20	1327	19.74	479.56
23	Sgns691	20	30	1377	19.74	499.3
24	Sgns691	20	50	1447	19.74	519.04
25	Sgns691	20	50	1517	19.74	538.78
26	Sgns692	20	25	1562	19.64	558.42
27	Sgns692	20	50	1632	19.64	578.06
28	Sgns692	20	50	1702	19.64	597.7
29	Sgns705	20	25	1747	19.74	617.44
30	Sgns705	20	50	1817	19.74	637.18
31	Sgns705	20	50	1887	19.74	656.92
32	Sgns735	20	0	1907	19.64	676.56
33	Sgns735	20	50	1977	19.64	696.2
34	Sgns735	20	50	2047	19.64	715.84
35	Sggmrs715	30	40	2117	33.94	749.78
36	Sggmrs715	30	80	2227	33.94	783.72
37	Sggmrs715	30	80	2337	33.94	817.66
38	Sggmrs715	30	0	2367	33.94	851.6

N	Name	T [t]	W [t]	Cumul. W (V) [t]	L [m]	Cumul. L. (V) [m]
39	Loco	90 (A)/ 123 (V)	0	2490	19.54 (A)/ 23.02 (V)	874.62
40	Sgns681	19	0	2509	19.74	894.36
41	Sgns681	19	20	2548	19.74	914.1
42	Sgns681	19	20	2587	19.74	933.84
43	Sgns681	19	20	2626	19.74	953.58
44	Sgns691	20	30	2676	19.74	973.32
45	Sgns691	20	50	2746	19.74	993.06
46	Sgns691	20	50	2816	19.74	1012.8
47	Sgns691	20	50	2886	19.74	1032.54
48	Sgns692	20	0	2906	19.64	1052.18
49	Sgns692	20	50	2976	19.64	1071.82
50	Sgns692	20	50	3046	19.64	1091.46
51	Sgns692	20	50	3116	19.64	1111.1
52	Sgns705	20	0	3136	19.74	1130.84
53	Sgns705	20	50	3206	19.74	1150.58
54	Sgns705	20	50	3276	19.74	1170.32
55	Sgns705	20	50	3346	19.74	1190.06
56	Sgns735	20	0	3366	19.64	1209.7
57	Sgns735	20	50	3436	19.64	1229.34
58	Sgns735	20	50	3506	19.64	1248.98
59	Sgns735	20	50	3576	19.64	1268.62
60	Sgns735	20	50	3646	19.64	1288.26
61	Sggmrs715	30	40	3716	33.94	1322.2
62	Sggmrs715	30	80	3826	33.94	1356.14
63	Sggmrs715	30	80	3936	33.94	1390.08
64	Sggmrs715	30	80	4046	33.94	1424.02
65	Sggmrs715	30	80	4156	33.94	1457.96
66	Sggmrs715	30	0	4186	33.94	1491.9

→ Figure 85: Composition.
Source: **MARATHON**

Train Simulation Lay-out

→ Figure 86: Train Simulation lay-out.
Source: **MARATHON**

Distributor Valve: The position of the DV along the brake pipe train simulator is listed into this table

A			B			C			D			E		
54	1	75	16	1	120	53	1	75	42	1	120	7	1	75
75	1	75	6	1	120	28	1	75	39	1	120	44	1	120
95	1	75	11	1	120	21	1	75	37	1	120	128	1	120
65/MRT1	1	75	13	1	120	103	1	75	71	1	120	47	1	120
	0		4	1	120	109	1	75	58	1	120	10	1	75
	0		17	1	75		0		114	1	120	15	1	75
	0		22	1	75		0		74	1	75	82	1	75
	0		27	1	75		0		122	1	75	113	1	75
	0			0			0		126	1	75		0	
	0			0			0			0			0	

A			F			G			H			L		
54	1	75	36	1	120	31	1	120		1	120	101	1	120
75	1	75	45	1	120	34	1	120	8	1	120	130	1	75
95	1	75	79	1	75	123	1	75	98	1	120	51	1	75
65/MRT1	1	75	38	1	120	9	1	120	94	1	120	100	1	75
	0		43	1	120	56	1	120	111	1	120	MRT2	0	0
	0		86	1	120	77	1	75		0		96	1	75
	0		108	1	120	25	1	120		0		117	1	75
	0		119	1	120	52	1	120		0		124	1	120
	0		91	1	120	97	1	120		0			0	
	0			0		92	1	120		0			0	

→ Figure 87: Distributor Valve.
Source: **MARATHON**

Number Total Distributor 65
MRT1 - loco slave: MRTH brake panel testing position
MRT2 - loco slave: MRTH brake panel final position

Leak Test Procedure: The pneumatic train configuration has been validated in front of pneumatic leak. Procedure results are listed is listed into tables below:

Test of leak [10min.]				
TP [m]	Δp CG	dm³	Δp CG+DIS	dm³
255,5	0,042	371	0,091	371
522,5	0,070	244	0,171	244
700,5	0,136	175	0,359	175
878,5	0,025	314	0,181	314
1146	0,087	435	0,275	435

Total leak: 1466m brake pipe + 63 Distributor at 5bar for 10min	0,43 bar

Acceptance Criteria:

Leak Acceptability: 0,35bar in 1minute

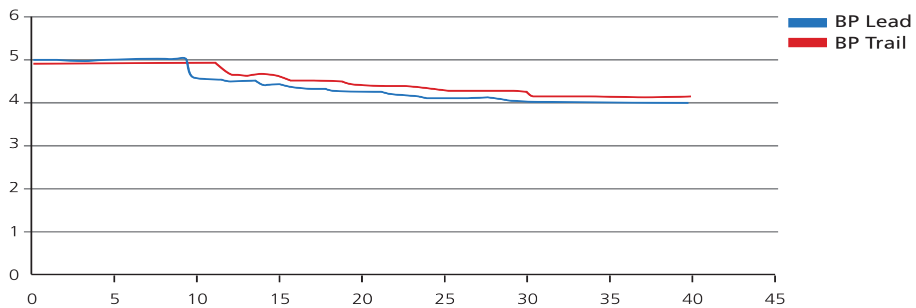
→ Figure 88: Leak test procedure.
Source: **MARATHON**

The following digital signals are managed by directly by the radio LC100R according to the SIL3 requirement association. The LC100R manage these signals in order that in case of radio link communication loss all the output signals - a part the signal Com_Loss_R - maintain the latest valid state.

Brake Function: All the MRTH brake functionality specified into Chap 2 and implemented into the MRTH brake panel (BKSLU) has been tested and validated on the pneumatic train simulator. The test results report are listed into the next paragraphs.

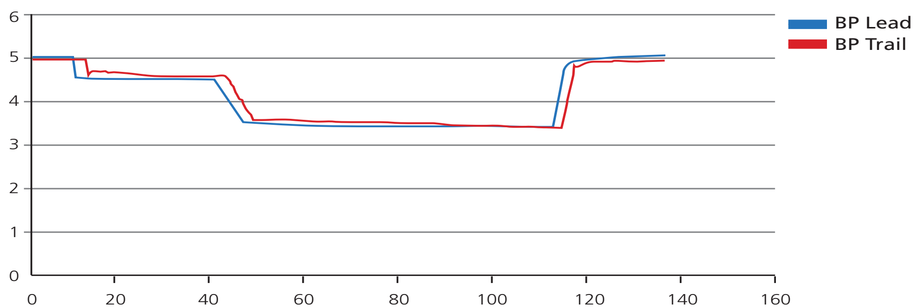
Brake Application

Operational Mode: Radio Channel is ON -Lead and Trail Brake panels applied brake in parallel with target BP pressure set-point 4bar.



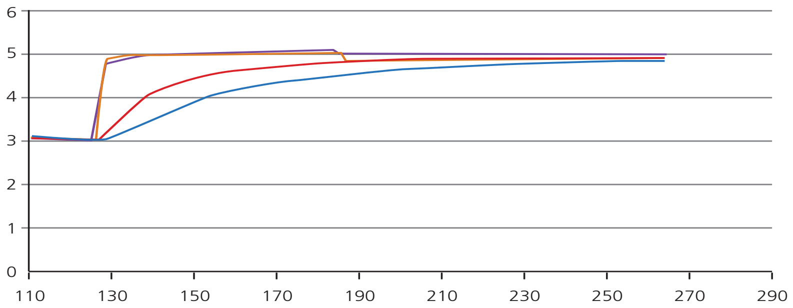
→ Figure 89: Brake Application.
Source: **MARATHON**

Brake Applied & Release Operational Mode: Radio Channel is ON Lead and Trail Brake panels applied brake and release commands in parallel.



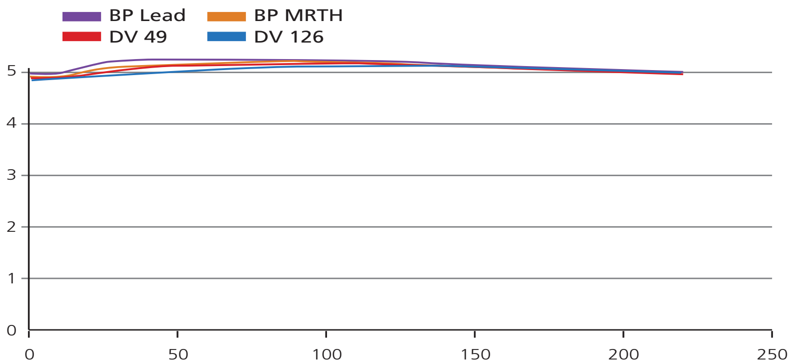
→ Figure 90: Brake Application.
Source: **MARATHON**

Brake Quick Release: Operational Mode: Radio Channel is ON
Lead and Trail Brake panels applied Quick release command in parallel.



→ Figure 91: Brake Application.
Source: **MARATHON**

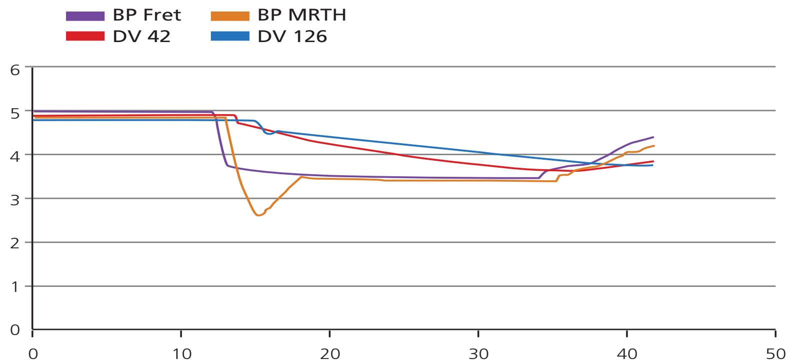
Brake Overcharge & Assimilation: Operational Mode: Radio Channel is ON.
Lead and Trail Brake panels perform in parallel the Overcharge and Assimilation procedure according to UIC e540.



→ Figure 92: Brake Application.
Source: **MARATHON**

MARATHON - MAke RAil The HOpe for protecting Nature

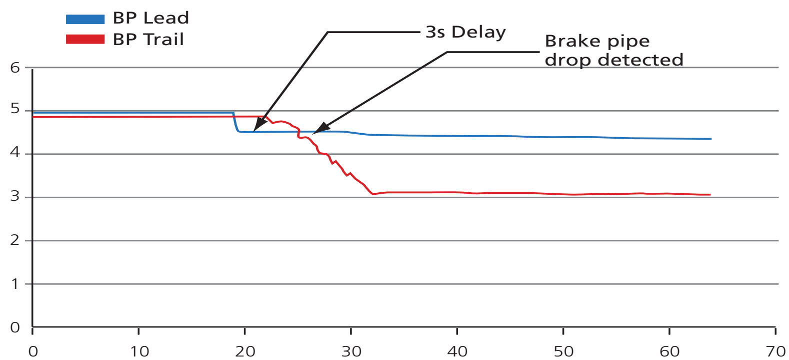
Brake Emergency by Driver Handle: Operational Mode: Radio Channel is ON.
Lead and Trail Brake panels applied a maximum service brake requested by setting the driver handle in Emergency position.



→ Figure 93: Brake Application.
Source: **MARATHON**

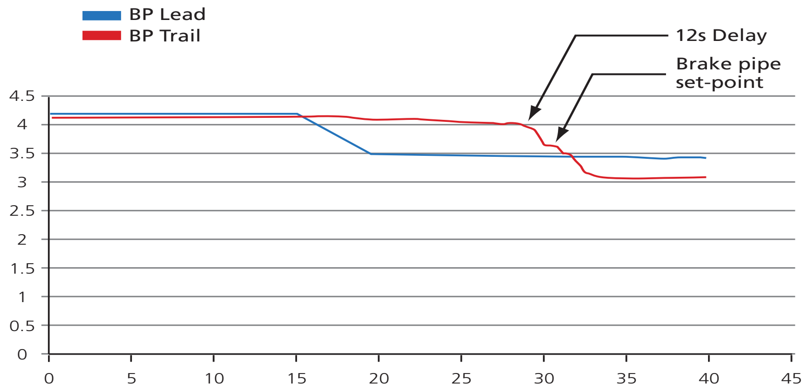
Brake Back Up Mode: No Brake applied – Brake Pipe = 5 Bar.

- → Radio Channel is OFF: Com Loss > 2.25s
- → Lead increases the brake application
- → Trail brake detects that the BP set-point is decreased and applies a Full service brake (set-point 3bar)



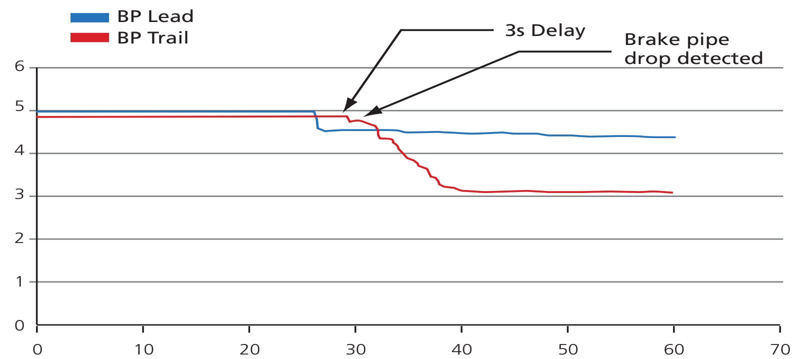
→ Figure 94: Brake Application.
Source: **MARATHON**

Brake Applied – Brake pipe <4.5barRadio:Channel is OFF: Com Loss > 2.25s.
Lead applies a 1step brake Trail Brake detects the brake pressure drop and applies a Full service brake (se No Brake Applied – DV Isolated.



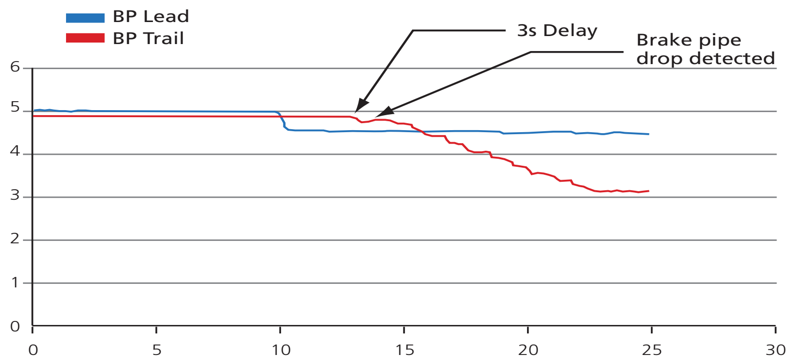
→ Figure 95: Brake Application.
Source: **MARATHON**

#1 DV isolated (25m) between Lead and Trail Locomotive: Radio Channel is OFF: Com Loss > 2.25s
Lead applies a 1step brake; Trail Brake detects the brake pressure drop and applies a Full service brake (set point 3bar) set pin 3bar.



→ Figure 96: Brake Application.
Source: **MARATHON**

No Brake Applied – DV Isolated up to 90m according to UIC e 540.
#4 consecutive DVs isolated (90m) between Lead and Trail Locomotive: Radio Channel is OFF: ComLoss > 2.25s Lead applies a 1step brake; Trail Brake detects the brake pressure drop and applies a Full service brake (set-pint 3bar).



→ Figure 97: Brake Application.
Source: **MARATHON**

Mock up Test conclusion

The result of the test performer on the pneumatic brake simulator have got evidence of the right behavior of the MRTH brake system, for all its functionality defined. These tests produce the real pneumatic behavior of the braking systems along the train and the data collected has been used to validated and eventually correct or tuning the MRTH train mathematical model calculated with TrainDy. The feedback of the real pneumatic data gathered in the TrainDy mode is real import for further development study.

3.3 BUSINESS CASE SIMULATION & EVALUATION (WP 4)

The Business Case

According to MARATHON "Description of Work", the project aims at extracting the maximum productivity from the existing rail infrastructure for producing efficiency, reducing operating costs and attracting new traffic to rail. The aim of the Business Case presented in this document is to demonstrate the effectiveness of the introduction up to market uptake of longer and heavier trains on a selected high-volume Trans European freight corridor. This report is structured as described here below:

- → Business Needs and Desired Outcomes: this paragraph identifies the need (problem or opportunity) facing the sponsoring organization and the desired business outcomes;

- **MARATHON** Business Model: this paragraph identifies the scope of work of the project;
- **MARATHON** Assumptions, Constraints and relevant variables: it resumes the main characteristics of the business case and relevant variables of the project;
- **MARATHON** Business Case: it identifies the **MARATHON** Business Case.

Business Needs

Rail transport is based on single trains running along the European Corridors conveying freight at costs not very attractive. The Rail Freight in Europe is not satisfactory for the following main reasons:

- Rail network is not sufficient;
- Rail freight is not attractive;
- Service cost are not competitive;
- Marketing and commercial penetration is inadequate.

Drivers of Change

The following drivers for change have been identified):

- the Rail freight capacity generation;
- the increase of frequency set he traffic bundling for economies of scale;
- operating cost reduction.

Business Outcomes

At the end of change, the following business outcomes are expected:

- reduction of operating cost and environmental impact;
- increasing the traffic volume on rail freight service;
- improve the efficiency of rail freight.

Market Constraints

The possible ways to improve the efficiency of rail freight and reduce the operating cost have been considered. As results, the following solutions have been identified:

- infrastructure improvements;
- new control command system (ERTMS), which allows the improvement of train management and network capacity;
- increased wagon efficiency;
- new marketing of railway services;
- better drivers management for the incumbents;
- double stack transportation system;
- use of longer, heavier and commercially faster trains.

Most of these solutions are either impossible to apply in Europe or require many infrastructure investment, e.g., double stack on long corridors due to tunnels, or need a long time and massive investments.

The MARATHON Business Model

This section describes the bordering market in which **MARATHON** Project has been developed, highlighting the business need, drivers for change, business outcomes and the possible options to satisfy the business need.

The MARATHON Mission

MARATHON is driven by market requirements, by the need of increasing the European Rail Network capacity, hence of reducing the operating costs and improving the service performance.

Dealing with commercially faster, longer and heavier trains, means to tackle a number of issues, that could be technical, operational, systemic (safety related), and sometimes cultural or psychological.

The main drivers for change cover the following aspects:

- Competitiveness: increase service timetable and reduce transport costs while preserving a high level of reliability;
- Economics: increase the volume of goods to transport by train (shifting from road to rail) and decrease the freight rail transport costs;
- Technology: technological solutions for coupling two different trains;
- Environment: reduction of the freight mobility carbon footprint improving the use of the rail transport mode that is the most environmentally friendly mode.

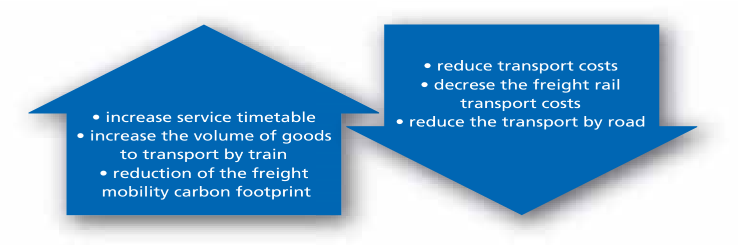


Figure 98: Main Drivers for Change.
Source: **MARATHON**

Further drivers for change are the needs of securing sustainability for long-term economic development, the fast implementation of existing technologies developed in previous research work, the creation of the basis leading to harmonization and standardization for operating longer, heavier and commercially faster trains on main European Rail connections. In **MARATHON** Project the costs reduction is achieved by doubling the length of trains up to 1500 m in coupling two trains and by improving the carrying capacity using the same "train path slot" on a "Point to Point" of the rail corridor (minimizing impact on the service availability). In order to attract more volumes to rail freight, some corridors should be dedicated to rail freight, providing good conditions in terms of service and an easy passage from one national network to another.

MAIN ADVANTAGES AND DISADVANTAGES OF THE MARATHON SOLUTION

An intermodal service provider is operating two or more daily trains between two terminals (a single origin/destination). In this case, the bundling of two train departures into one train would enable to produce the rail traction more efficiently. This benefit, however, has to be traded against the potential disadvantage of the customers facing a reduced service flexibility (no differentiation of departure and arrival times).

Strategic Vision, SWOT Analysis

The **MARATHON** original idea is to couple rapidly two existing trains with the second locomotive in the middle of the convoy connected by radio communication technology to the front one. The STRENGTHS of **MARATHON** Project individuated in the SWOT Analysis developed in the D 1.1 are:

- Transport industrialization;
- Production cycles on 24 h-365 days;
- Cost curve reducing progressively with distance increase;
- Time tabling ability;
- Environment friendliness;
- Energy efficiency;
- Accident safety;
- Easier risk management.

The opportunities of **MARATHON** Project individuated in the SWOT Analysis:

- Societal readiness for cleaner, safer, sustainable transport;
- driving hours regulations & Eurovignette implementation;
- road traffic congestion & truck drivers shortage;
- accessible market enlargement & new accessing Countries;
- preserving frequency of departure and thus the filling coefficient by coupling rapidly two trains from two different catchment areas to create a **MARATHON** train;
- maritime economy of scale & overland traffic combination possibilities;
- longer, commercially faster and heavier trains deployment;
- new rolling stock, radio technologies evolution & ITC communications availability;
- traffic attraction zones knowledge & future traffic projections awareness;
- cooperation/partnership approach opportunity;
- customer supply chain innovative market requirements;
- Mega Hubs and freight villages availability as traffic & Logistics opportunities multipliers;
- multichannel distribution approach exploitation with OSS or SPC strategy adoption;

- marketing, branding, time tabling as market penetration tools.

The WEAKNESSES of the project are:

- Rigidity of Rail freight being a closed system;
- Inferior accessibility;
- Elements of complexity;
- Inability to provide equipment at a required time.

The THREATS of the project are:

- Psychological barriers;
- Labour blocking forces;
- Political decisions threatening investments.

MARATHON Business Outcomes

At the end of change, the following business outcomes are expected:

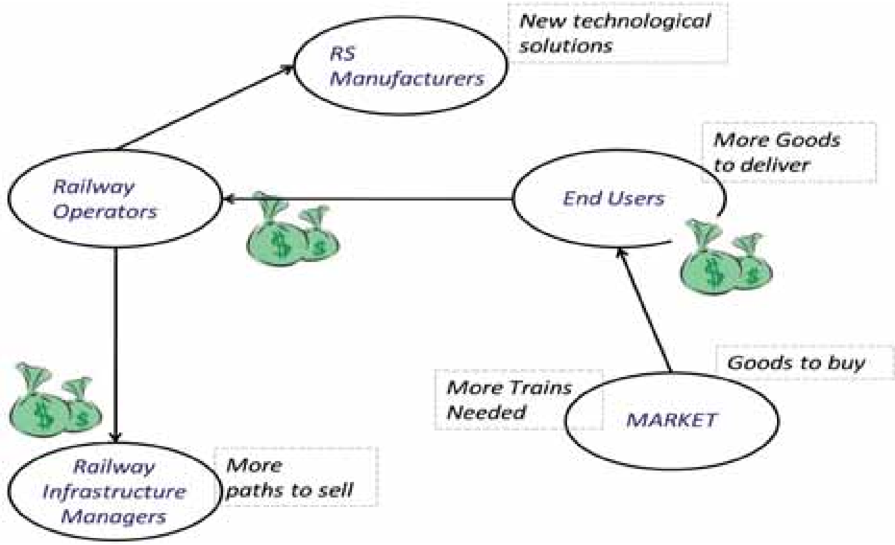
- due to train coupling increasing of paths availability in the time-table to be filled with new trains;
- lowering of rail transport costs for the end users;
- shifting freight from road transport to rail transport;
- increasing of EU standardization and harmonization process encouraging greater rail freight productivity and facilitating the adoption of recognized Safety rules;
- decreasing the number of drivers (one instead of two), because the second coupled train (slave train) is remotely controlled by the first one (master train).

Stakeholders Analysis

Stakeholders involved in the business case realization are:

- Railway Infrastructure Managers;
- Railway Operators;
- Rolling Stock & Train Owners;
- Users of the Service.

In this analysis, for the sake of simplicity, is it supposed that new trains are not necessary, for this reason, the “Rolling Stock & Train Owners” are not included in Figure 99: Stakeholders Benefits and Advantages



→ Figure 99: Stakeholders Benefits and Advantages.
Source: **MARATHON**

All the Stakeholders involved in the project gain benefit and advantages:
Railway Operators can rely on longer trains with enhanced capability of carrying the goods:

- more offer of goods to transport (longer trains);
- more competitive costs for railway transportation (shift to rail);
- less energy to be used for traction (train coupled).

Railway Infrastructure Manager can offer more services to the railway traffic:
- more and wider tracks to be sold;
- more energy to be sold for traction to the trains.

Rolling Stock Manufacturers can offer new technological solutions for the coupling/decoupling of trains:
- more income for selling trains including new technological solutions.

Users of the Service can rely on a more capable and competitive railway service:
- can deliver more goods to the market by means of rail transportation (shift to railway) at lower prices (with respect to road transportation);
- having a wider availability of goods at more competitive prices.

Basic Steps to **MARATHON** Asset Based Business Model

As explained in "Market requirement", the **MARATHON** Business Model is built around the rotation of assets in order to guarantee high service availability (365 days/24 hours) with competitive costs. The service cost reduction is becoming effective by filling up the full train capacity. To fill up the full train capacity the migration from a "Demand Driven" approach to "Offer Driven" approach of the market for Rail is necessary, increasing the quantity of goods carried by trains and shifting goods transportation from road to rail. At the same time, it is necessary to increase the network capacity through a better utilization of the network slots.

The basic steps to achieve the **MARATHON** Business model are detailed in D 1.1 "Market requirement" and summarize in the following Figure 100.

→ Figure 100: Basic Steps to MARATHON Asset Based Business Model.
Source: **NEWOPERA Aisbl**

MARATHON Assumptions, Constraints and Variables:

In the following section, the hypotheses to be considered for the development of a Business Case for **MARATHON** Project and the relevant variables have been identified.

The Business Case has been carried out under the following additional hypotheses:

→ no modifications to TAF-TSIs will be required; the provision of longer trains would not need specific new TAF TSI but a simple adaptation of relevant specifications that enables to regroup

- in the coupled (longer) train – the information on the two single trains which were coupled, without merging them;

- no major modification to railway infrastructure can be required (this will lead to negative effects on business);
- no suppression of train runs can be taken into account as credible to let room to **MARATHON** Trains;
- to optimize the track occupancy, only length of train inferior or equal to mean track sections are efficient (constraint to be considered for train configuration);
- as a reference time, a coupling time of 10-15 minutes will be considered (additional hypothesis: trains have to be healthy and on time);
- both master and slave trains contribute to the traction and the breaking phases. For this reason, the slave train remains active when it is coupled to the master one, in order to avoid unacceptable longitudinal efforts in the train (D 2.1 "Operational scenario for the MARATHON cases).

The Train Composition – Technical Feasibility

The **MARATHON** train composition is described in this paragraph, providing also explanations about the technical feasibility of the proposed solution. The **MARATHON** train is composed by doubling the length of trains up to 1500 m, using two locomotors. The 1500 m length of the trains will be acceptable due to the progressive infrastructure adaptation (or by specific operational methodology); the maximum load of the train will be limited by the electric power availability in the catenary or by the maximal tension efforts in the couplers. In the coupling of two standard trains, each of them will have a maximum length of 750 m including the locomotive, thus creating a long train of a maximum 1500 m length.

Figure 101: The MARATHON Train Composition.
Source: **MARATHON**

Each of the two locomotives contributes to the traction, and to the electric and pneumatic braking specifically in accelerating the braking and releasing of the pneumatic braking. The radio remote control is utilized for each of these actions. In case of a failure of the radio connection, a redundant solution is based on the main brake pipe: the slave locomotive measures permanently the pressure and the variations of pressure and according to each pre-analyzed situation a set of actions is automatically executed (opening the circuit breaker, lowering the pantograph, reducing and cutting traction, service braking, emergency braking, etc.). The choice of having the slave locomotive active while it is placed in the middle of the train, is to accelerate the venting of the brake pipe from two points of the train (front and middle) in order to master the stopping distance within the authorized limits and to try to reduce the longitudinal compression forces created by the braking system of the first part of the train. The choice of using the slave locomotive compressor is made to increase the pressure in the brake pipe and the auxiliary reservoirs more rapidly in order to release the brakes more rapidly.

The relevant variables to be considered in the Business Case are:
- Transportation costs and benefits (refer to § 4.2);
- Time required for implementation.

Transportation Costs and revenues: In the following tables, the main costs that are supposed to change in the **MARATHON** solution with respect to the "standard" train configuration are listed; moreover, the revenues for the different stakeholders due to the coupling of two trains have been identified. Each cost and revenue is then explained more in details in the paragraphs after the tables.

Railway Operators		
Cost Category	Cost Sub-category	Increase/Reduction
PERSONNEL	Terminal Staff	Increase
	Refresher course for drivers/staff	Increase
ACTIVITIES	Coupling/Decoupling	Increase
Benefit Category	Benefit Sub-category	Increase/Reduction
PERSONNEL	Drivers number	Reduction
ENERGY	Energy supply	Reduction
INFRASTRUCTURE	Track access charge	Reduction
ACTIVITIES	Time Freight storage	Reduction

→ Figure 102: Railways Operators Cost Category.
Source: **MARATHON**

Railway Infrastructure Managers		
Cost Category	Cost Sub-category	Increase/Reduction
INFRASTRUCTURE	Income from track access charge	Reduction
ACTIVITIES	Income from freight storage	Reduction
	Income from loading/unloading phase	Reduction
Benefit Category	Benefit Sub-category	Increase/Reduction
INSURANCE	Accident fee	Reduction
ACTIVITIES	Shunting required	Increase
	Income from time slots	Increase

→ Figure 103: Infrastructure Managers Costs Category.
Source: **MARATHON**

Rolling Stock and Equipment Manufacturers		
Cost Category	Cost Sub-category	Increase/Reduction
VEHICLE UPDATE	Software development/technical assistance/	Increase
Benefit Category	Benefit Sub-category	Increase/Reduction
VEHICLE UPDATE	Systems application and development	Increase

→ Figure 104: Rolling Stock & Equipment Manufact. Cost Category.
Source: **MARATHON**

Users of the Service		
Cost Category	Cost Sub-category	Increase/Reduction
COMPETITIVE COSTS	Goods offer	Increase
Benefit Category	Benefit Sub-category	Increase/Reduction
TRANSPORT TIME	Indirect income from the reduction of transport time	Increase

→ Figure 105: Users Cost category.
Source: **MARATHON**

Railways Operators

Costs

PERSONNEL

Terminal Staff: increase of staff in the railway stations dedicated to coupling/decoupling maneuvering and to staff dedicated to loading and unloading goods (only in case of non-automatic coupling);
Refresher courses for drivers/staff; drivers will need training courses dedicated to the use of the ICT solutions/radio adopted for the MARATHON solution; staff operating along the line and dedicated to maneuvering will also need training courses;

ACTIVITIES

Coupling/decoupling; coupling/decoupling activities will increase while adopting the MARATHON solution; these activities are not necessary in the case of using two separate trains.

The Benefits

PERSONNEL: Drivers number: the number of drivers will decrease after coupling because the second locomotive will be a "slave" and therefore only one driver is needed in the MARATHON solution;
ENERGY: Energy supply; the total energy required with the adoption of a coupled train is less (about 5%) than using two separate trains;
INFRASTRUCTURE: Track access charge: fee for track access is reduced for the Railway Operator because less trains are running, but it increases in case new available slots are sold;
ACTIVITIES: Time Freight storage: time for storage is reduced because more goods are transported

at the same time (on longer trains); therefore all related costs(such as surveillance of depots) is reduced.

Railways Infrastructure Managers

Costs

INFRASTRUCTURE: Income from track access charge: the income generated through the track access charge will be reduced by using the MARATHON solution, as less trains will circulate on the network (considering that the traffic will not increase and the new available slots are not sold).
ACTIVITIES: Income from freight storage: goods are kept in storage depots for a lower time, because train capacity is higher, therefore incomes from storage is reduces (unless no additional good are to be transported);
Income from loading/unloading phase: loading/unloading phases can be done by optimizing staff shifts

Benefits

INSURANCE: Accident fee: this fee is reduced because usually accidents are paid on the basis of train-km and by having a single train this number is lower;
ACTIVITIES: Shunting required: the shunting and maneuvering activities are increased with the MARATHON solution because of the additional coupling/decoupling;
Income from time slots: revenues can be foreseen due to the increase of free time slots that can be sold for other transport services.

Rolling Stock and Equipment Manufacturers

Costs

VEHICLE UPDATE
Technical assistance/software development: costs will increase for the implementation of new technological solutions to couple the trains (radio communication and ICT solutions); in order to keep those solutions working properly, technical assistance/maintenance is also needed;

Benefits

VEHICLE UPDATE
Systems application and development; the design and implementation of new technological solutions to allow the two coupled trains communicating will bring revenues to the rolling stock manufacturers as a new system is being sold to customers.

Service Users

Costs

COMPETITIVE COSTS
Goods offer: An increase of the goods offer will be introduced with the MARATHON solution, providing more free time slots for transport;

Benefits

TRANSPORT TIME

Indirect income from the reduction of transport time: the users of goods transport services will benefit from the **MARATHON** solution, on single track lines, because of the reduction of transport time.

> TRAIN TIMETABLE
>
> The use of coupling train rather than two, generates free track, exploitable by another train for the other freight transport or passenger transport.
> Furthermore, an intermodal service provider is operating two or more daily trains between two terminals (a single origin/destination). In this case, the bundling of two train departures into one train would enable to produce the rail traction more efficiently.
> This benefit, however, has to be traded against the potential disadvantage of the customers facing reduced service flexibility (no differentiation of departure and arrival times).

Time required for Implementation

In order to implement a corridor, an implementation plan shall be available at the latest 6 months before making the freight corridor operational. This plan shall:

- describe the characteristics of the corridor as well as the measures necessary for its creation (efficient radio frequency, points where signaling must be moved to avoid risk of blocking switches or level crossings, sidings to be lengthened, power availability...);
- the essential elements of a transport market study on the possible impact of the corridor on the traffic (both for passengers and for freight);
- the objectives for the freight corridor, with particular regard to the quality of the service and the capacity of the freight corridor;
- the investment plan referred;
- the measures concerning: coordination, a one-stop shop for application for infrastructure capacity, capacity allocated to freight trains, authorized applicants, traffic management, information on the conditions of use of the freight corridor, quality of service on the freight corridor.

MARATHON Business Cases, The Theoretical MARATHON scenario application

The reference scenario of a **MARATHON** train derives from the needs of different operators that have to deliver freights along the same origin-destination path, or along the same rail section.
The theoretical reference scenario involving a **MARATHON** train is shown in Figure 106, and is organized as follow:

- a first train (train 1) arrives “at first” from station A to station C, with destination B;
- a second train (train 2) arrives “at second” from station F to station C, with destination E;

the two trains can run together along the corridor between stations C and D.

- in C station trains wait each other to couple;
- in D station trains shall decouple.

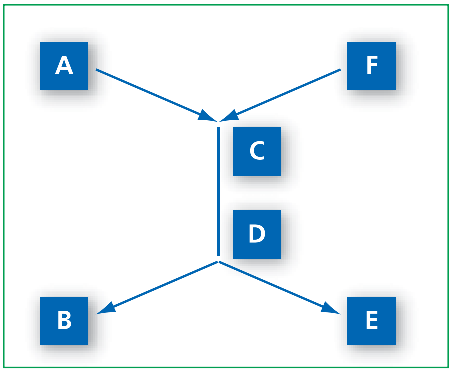


Figure 106: Theoretic MARATHON Scenario.
Source: **MARATHON**

The stations A, B, C, D, E, F will be defined for the specific business case.

A practical example of what is shown in Figure 106 may be represented in the French section of the Lisbon/Madrid/Barcelona/Berlin corridor. This corridor is one of the longest in Europe, and it branches out near Metz across Belgium reaching the Port of Antwerp (§ B 1.1.2 of Annex I).

This Business Case regards the French section of the Lisbon/Madrid/Barcelona/Berlin corridor. Referring to Figure 107, stations A, B, C, D, E, F are identified by:

- Station A is Rotterdam;
- Station B is Perpignan;
- Station C is the coupling station located in Woippy;
- Station D is the decoupling station located in Lyon;
- Station E is Genoa;
- Station F is Hamburg.

As consequence, the possible railway lines are:

- ACDB: From Rotterdam to Perpignan (station A - station B);
- ACDE: From Rotterdam to Genoa (station A - station E);
- FCDB: From Hamburg to Perpignan (station F - station B);
- FCDE: From Hamburg to Genoa (station F - station E).

→ Figure 107: Business Case scenario.
Source: **MARATHON**

INFLUENCE OF WAGON CHARACTERISTICS ON MARATHON TRAIN COUPLING

As explained in D 2.1 "Operational scenario for the MARATHON cases", some scenarios have been analyzed according the following criteria:

- corridors have been selected according with the market demand;
- the trains considered are currently available on the market.

As results, in D 2.1 "Operational scenario for the **MARATHON** cases" the following scenario has been considered:

"Baseline scenario": combined trains with SGNSS wagons (or similar)
19 m length
Coupling 85T
Capacity assumptions (loading units/wagon):
3 TEU
2 Class C (7.45 m.) swap bodies
1 Class A (13.60 m.) swap body
"104' scenario": combined trains with SGGMRSS (104') wagons (or similar)
33,5 m. length
Coupling 135T

Capacity assumptions (loading units/wagon):

- 5 TEU;
- 4 Class C (7.45 m.) swap bodies;
- 2 Class A (13.60 m.) swap body

The results of capacity assessment of the previous scenario, calculated in D 2.1 “Operational scenario for the **MARATHON** cases”, are summarized in Table 1.

Train length	Wagons Baseline scenario	Capacity (loading units) Baseline scenario	Wagons 104' scenario	Capacity (loading units) 104' scenario
1260	64	192 TEU 128 Class C SB 64 Class A SB	36	180 TEU 144 Class C SB 72 Class A SB
1100	52	156 TEU 104 Class C SB 52 Class A SB	30	150 TEU 120 Class C SB 60 Class A SB
860	40	120 TEU 80 Class C SB 40 Class A SB	23	115 TEU 92 Class C SB 46 Class A SB

The results of capacity assessment made on intermodal train cases led to significant results: in the baseline scenario, coupled trains show a capacity of up to 192 TEU per train, i.e. almost 1000 TEU per week per direction on daily connections. The capacity offered is almost triple than the available capacity on intermodal trains in other European power corridors, e.g. Gotthard17.

In the “104'” scenario, coupled trains show a capacity of up to 144 swap bodies (Class C) per train, i.e. more than 600 per week per direction on daily connections. As expected, the “104'” scenario is more suitable for swap body transport, since this kind of loading units exploits the capacity offered by longer wagons better than containers. Moreover, almost all types of 104' flat wagons allow the transport of high profile swap bodies and semitrailers.

Figure 108: Wagons Charact. on MARATHON Train Coupling.
Source: **MARATHON**

In order to ensure continuity with the analysis already carried out by the previously issued deliverables and in order to use a strong Business Case application, the following railways lines have been identified:

- Dourges (Lille)-Marseille
- Dourges (Lille)-Vénissieux (Lyon)
- Valenton (Paris)-Miramas (Marseille)

The idea is to coupling two trains from Lille to Lyon or from Paris from Marseille. The following figure shows the railways lines individuated.

Figure 109: The MARATHON Train Exemplary Corridor.
Source: **MARATHON**

The trains should have the following characteristic	
Trains	2
Type of Transport	Combined
Length	1400 – 1500 m
Number of wagons	60-64
Wagon tare	22 t
Wagons length	19 m

Figure 110: MARATHON Train Characteristics.
Source: **MARATHON**

The Simulation of Train Circulation

The theoretical reference scenario developed in the business case is shown in xx, and it is organized as described in the following:

- a first train (train 1) arrives "at first" from station A to station C, with destination B;
- a second train (train 2) arrives "at second" from station F to station C, with destination E;

the two trains can run together along the corridor between stations C and D.

- in C station trains wait each other to couple;
- in D station trains shall decouple.

Figure 111: Theoretical MARATHON Scenario.
Source: **MARATHON**

Station C and D has to be chosen as "suitable" for train coupling/decoupling, i.e.:

- enough space shall be available for the trains to couple/decouple on the same track (to save time – it is not feasible to operate such trains in depots or in deadlines);
- a second line shall exist so "quicker" trains can over-pass the trains to be coupled/decoupled.

The Line between C and D shall be chosen in such a way that there are frequent places in which the **MARATHON** train can be over-passed by other trains (and vice versa).Starting from the **MARATHON** Business Case described in § 0, a scenario for simulation has been defined, in order to demonstrate the consequences of the application of the **MARATHON** solution in operation. The simulations are described in details in the following paragraphs.

Impacts of the **MARATHON** solution on traffic and operations

Signaling: when adopting the **MARATHON** solution, it is possible that the coupled train (1500 m) is longer than the traction section; if it is the case, according to signaling constraints, a train running right after the **MARATHON** train could have a delay or shall reduce its speed, if the timetable is not properly scheduled, because the **MARATHON** train will occupy more than one track section; in a traffic flowing normally the delay is equal to the length of the extra block occupied divided by the speed which for a block of 1km would mean 36 seconds.

Time required for coupling uncoupling: maneuvering times are higher by adopting the **MARATHON** solution, because of the coupling and decoupling needed; those activities are not necessary in case of running separate trains. Coupling (and decoupling) of trains has been calculated in 10-15 minutes. The first train arriving in the station where coupling is performed will have to wait for a maximum time for the other train to be coupled. Timetables shall be created in order to take into account also this constraint.

Second line for Train Overtaking: Another important constraint related to the **MARATHON** solution is that no major modification to the railway infrastructure shall be required. Therefore the track should be structured in such a way that there are frequent recovery spaces. This is necessary in order to let faster trains to over-pass the lower ones (i.e. the **MARATHON** trains). However, as soon as long trains (MARATHON solution) will have a high priority (because of their efficiency compared to two separate trains in term of capacity saving per ton), frequent recovery spaces should not necessarily be present.

Open Track Simulations

Open Track began in the mid-1990s as a research project at the Swiss Federal Institute of Technology. The aim of the project, Object-Oriented Modelling in Railways, was to develop a user-friendly tool to answer questions about railway operations by simulation. Today, the railway simulation tool Open Track is used by railways, subways, the railway supply industry, consultancies and universities in different countries.

Open Track supports the following kinds of tasks:

- Determining the requirements for a railway network's infrastructure;
- Analyzing the capacity of lines and stations;
- Rolling-stock studies (for example future requirements);
- Timetable construction, analyzing the robustness of timetables (single or multiple simulation runs, Monte-Carlo simulation);
- Analyzing various signaling systems, such as discrete block systems, short blocks, moving blocks, LZB, CBTC (communication-based train control), ETCS Level 1, ETCS Level 2, ETCS Level 3;
- Analyzing the effects of system failures (such as infrastructure or train failures) and delays;
- Calculation of power and energy consumption of train services;
- Simulation of Tram/Streetcar and Light Rail systems;
- Simulation of Metro/Subway/Underground systems;
- Simulation of Maglev systems.

Open Track administers input data in three modules: network (infrastructure), rolling stock and timetable. Users enter input information in these modules and then run the simulation.

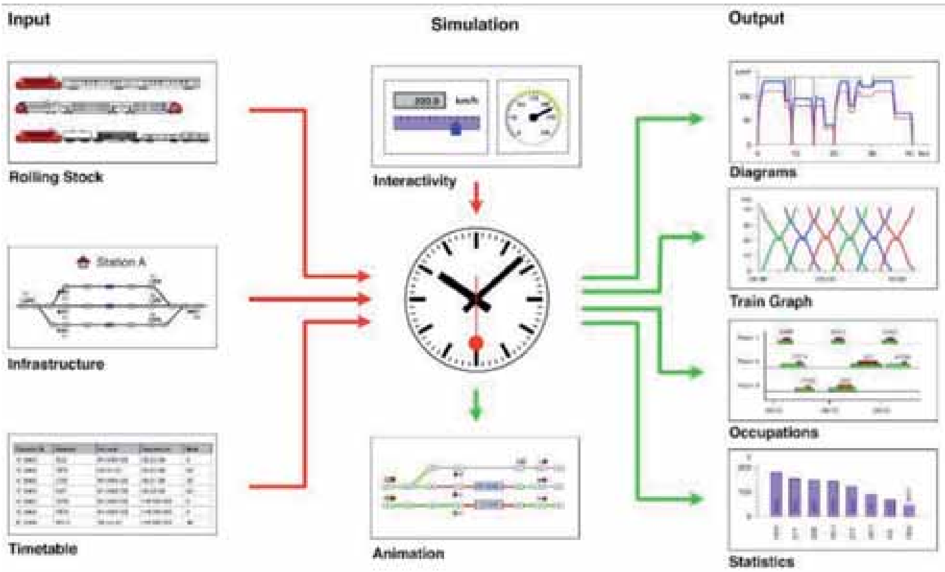


Figure 112: Open Track Process: Input – Simulation – Output.
Source: **MARATHON**

The simulation is carried out with the user defined input data: predefined trains move on predefined track layout on the conditions of the timetable data.Open Track uses a mixed discrete/continuous simulation process that calculates both the continuous numerical solution of differential motion equations for the vehicles, and the discrete processes of signal box states and delay distributions.

Open Track Input Data

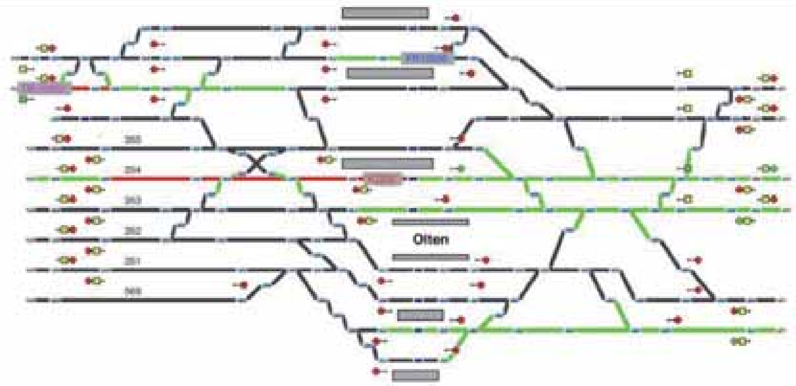


Figure 113: Example of a Station Network.
Source: **MARATHON**

Network Data: the track layout consists of a description of the physical infrastructure that is being simulated. This includes actual infrastructure such as track segments (edges), signals, stations, etc., as well as virtual elements such as vertices and routes.

Rolling Stock Data: Open Track stores each locomotive's technical characteristics, including tractive effort/speed diagrams, load, length, adhesion factor, and power systems in a database. A simulated train uses one or more locomotives from the database together with a number of passengers' or freight cars (carriages or wagons). Train sets are also organized in a database.

Timetable data: they consists of information on the movement of trains. This information includes desired arrival and departure times, minimal stop time, and connections to other trains.

Open Track Simulation Process

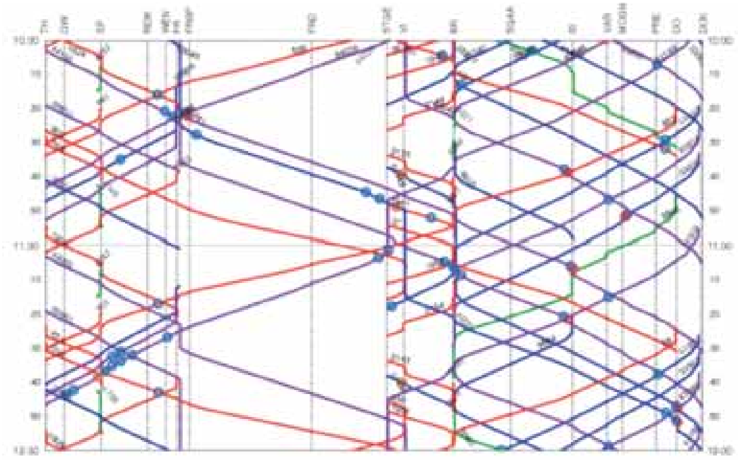
The objective of the Open Track simulation process is for the user-defined trains to fulfil the user-defined timetable on the user-defined track layout: predefined trains run according to the timetable on a railway network.

During the simulation, Open Track calculates train movements under the constraints of the signaling system and timetable (occupied tracks and restrictive signal aspects may impede a train's progress).

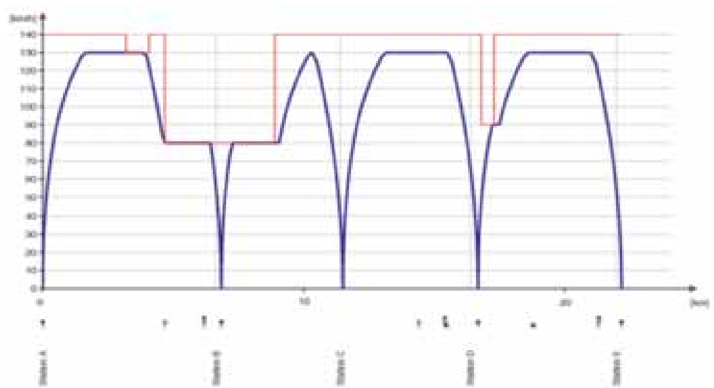
The user can watch the simulation in an animation mode, which shows the trains running and let the user analyze occupied tracks, reserved tracks and signal aspects. Moreover, Open Track handles single simulation runs as well as multiple simulation runs where random generators produce different initial delays and station delays. The motion of trains is modelled by the solution of the (continuous) differential equation of motion combined with signal information (discrete). The differential motion equation calculates the train's forward motion based on the maximum possible acceleration per time step (the acceleration rate is determined using train performance and track layout data such as maximum tractive effort, train resistance, track gradient, track radius, segment maximum speed…). The train speed is obtained using integration and the distance covered using reintegration.

Open Track Output Data

After a simulation run, Open Track can analyze and display the resulting data in the form of diagrams, train graphs, occupation diagrams and statistics. For a train, the software offers diagrams such as acceleration vs. distance, speed vs. distance, and obstructions. For a line, there are evaluations in the form of diagrams of train movements, route occupation and line profiles. Every station produces output about all the trains that used it, including arrival, stopping and departure times. In the following figures, some examples of typical Open Track output are presented.



➔ Figure 114: Train Diagram.
Source: **MARATHON**



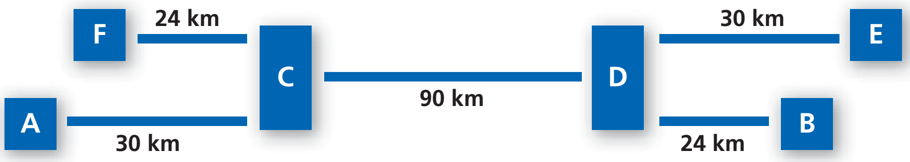
➔ Figure 115: Speed-distance profile.
Source: **MARATHON**

MATRATHON Simulation Scenario

Simulations have been performed on the basis of the theoretical MARATHON scenario and in order to be close to real applications. The composition of the MARATHON coupled vehicle is described previous paragraphs. With reference to Theoretical MARATHON Scenario the following distances have been set for simulation:

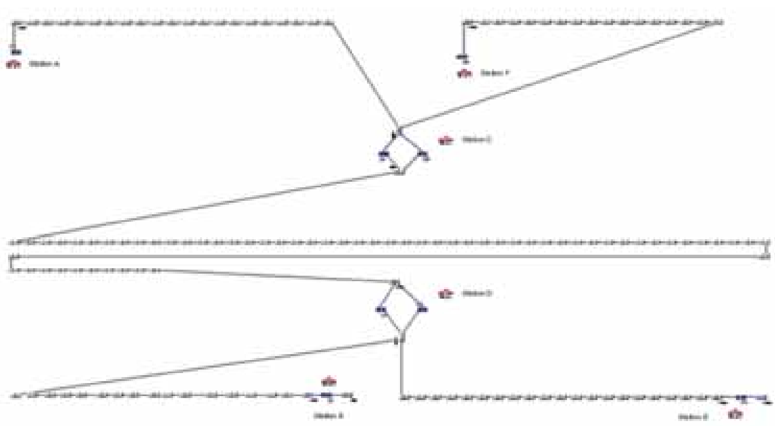
→ Figure 116: Theoretical MARATHON Scenario.
Source: **MARATHON**

A – C: 30 km
F – C: 24 km
C – D: 90 km
D – B: 24 km
D – E: 30 km



→ Figure 117: Theoretical MARATHON Scenario.
Source: **MARATHON**

The following figure shows the simulation scenario implemented in Open Track.



→ Figure 118: Open Track MARATHON Simulation Scenario.
Source: **MARATHON**

Simulations have been performed by running both freight and Intercity trains, in order to analyse the impact of the **MARATHON** solution on operations. Stations C and D are supposed to have appropriate infrastructure characteristics to allow coupling and decoupling of freight trains (i.e. a marshalling track of at least 1500 m).

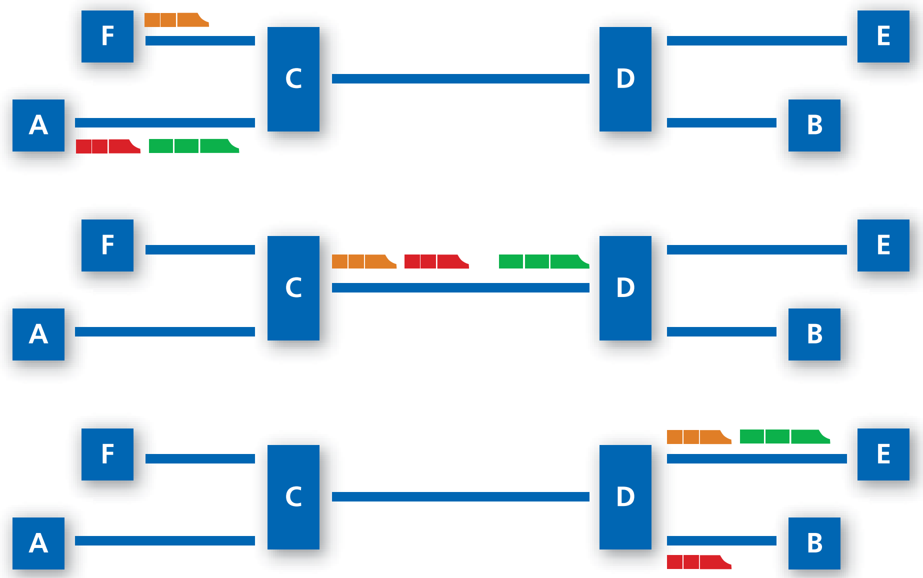
MARATHON Input Data

The following data have been used for simulations:

Length of track section: 1500 m
Time for coupling/decoupling trains: 15 minutes
"Standard" Freight train parameters: Total length of the train: 750 m
Total weight of train: 2000 tons
Upper speed limit: 100 km/h
MARATHON Freight train parameters:
Total length of the train: 1500 m
Total weight of train: 4000 tons
Upper speed limit: 100 km/h
Intercity train parameters:
Total length of the train: 350 m
Total weight of train: 750 tons
Speed limit: 160 km/h

MARATHON Simulation Results: Different operational scenarios have been simulated and results have been analyzed, in order to underline possible critical situations. In the "normal" operation, without train coupling, each freight train runs alone on the network. With the **MARATHON** solution a freight train arriving in station C has to wait for the other freight train for coupling, before starting the trip from C to D. Moreover, as already mentioned above, stations C and D infrastructure has to allow the coupling and decoupling, thus having a marshalling track for maneuvering. Coupling can also be done directly, so probably less than 15 minutes are required for the maneuvering.

Scenario 1 The first and "easiest" solution simulated is when an Intercity (IC) train leaves first from station A (green train in Figure 119:), followed by a freight train (F1 - red) on the same line section (A to C); the other freight train (F2 - orange), to be coupled with F1, comes from the other station (F). Simulations of this scenario demonstrated that no additional delays are caused by the **MARATHON** solution (except from the time for coupling and decoupling times), because IC runs faster than F1 and therefore it reaches station C early. When F1 arrives in C, it is coupled with F2, and continues its trip until D. In D the two freight trains are decoupled, thus allowing each one to reach its final destination (B and E).



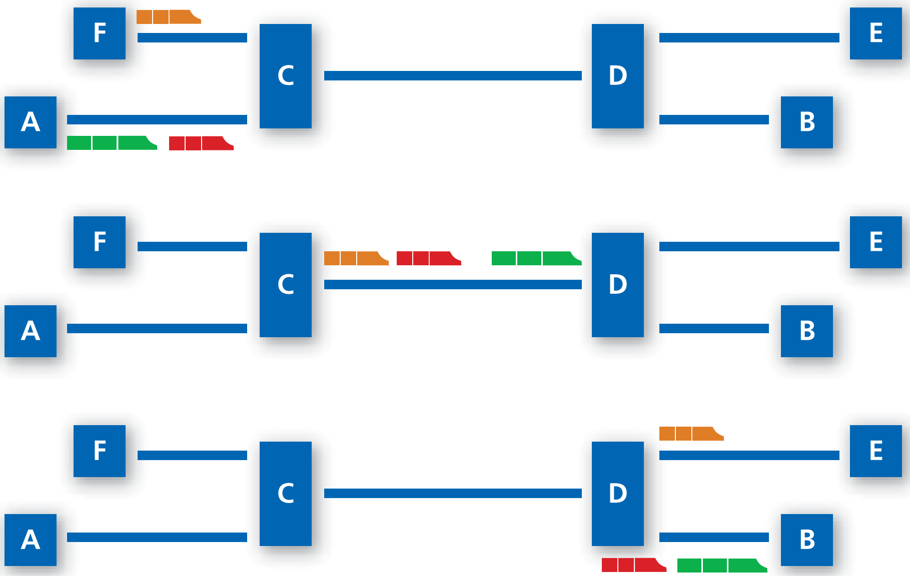
→ Figure 119: Simulation Scenario 1.
Source: **MARATHON**

A possible timetable for the solution above described in show in the following Table.

Station	Train	Time	Action
A	IC	08:00:00	departure from station
A	F1	08:05:00	departure from station
F	F2	08:00:00	departure from station
C	IC	08:13:26	arrival at station
C	IC	08:16:26	departure from station
C	F2	08:17:54	arrival at station
C	F1	08:25:48	arrival at station
C	F1+F2	08:32:54	departure from station (after coupling)
D	IC	08:47:57	arrival at station
D	IC	08:50:57	departure from station
D	F1+F2	09:22:24	arrival at station
D	F1	09:37:24	departure from station
D	F2	09:42:24	departure from station
B	F1	09:54:58	arrival at station
E	IC	09:04:00	arrival at station
E	F2	10:02:51	arrival at station

→ Figure 120: Possible Timetable Scenario 1.
Source: **MARATHON**

Scenario 2: A more critical situation is when a Intercity (IC) train leaves from station A after the freight train (F1); on the other track section, another freight train (F2) departs. The two freight trains that shall be coupled in C, each one coming from a different station (A and F).



→ Figure 121: Simulation Scenario 2.
Source: **MARATHON**

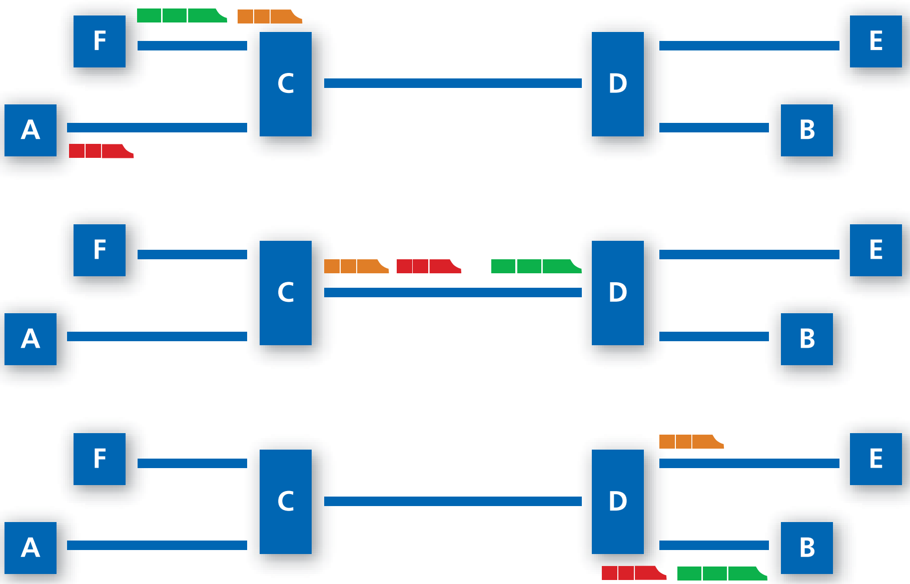
The IC shall be scheduled in such a way that it shall not reduce its speed because of the freight train which started first from station A. Different simulations have been performed to find the best solution, i.e. when IC train shall not reduce its speed because of the freight train leaving first from station A. With the selected conditions (track length 30 km, freight train maximum speed 80 km/h, intercity maximum speed 200 km/h) and with the rolling stock characteristics described the time interval between F and IC shall be minimum 9 minutes. A possible schedule of the scenario configuration is presented here below:

Station	Train	Time	Action
A	F1	08:00:00	departure
A	IC	08:09:00	departure
F	F2	08:00:00	departure
C	F2	08:17:54	arrival
C	F1	08:20:48	arrival
C	IC	08:22:26	arrival
C	IC	08:25:26	departure

C	F1+F2	08:35:48	departure
D	IC	08:56:57	arrival
D	IC	08:59:57	departure
D	F1+F2	09:25:18	arrival
D	F1	09:40:18	departure
D	F2	09:45:18	departure
B	IC	09:11:21	arrival
B	F1	09:57:52	arrival
E	F2	10:05:45	arrival

→ Figure 122: Possible Timetable Scenario 2.
Source: **MARATHON**

Scenario 3: Another scenario has been analysed, running a freight train followed by an Intercity on the section F-C, and the other train to be coupled running from A to C.



→ Figure 123: Simulation Scenario 3.
Source: **MARATHON**

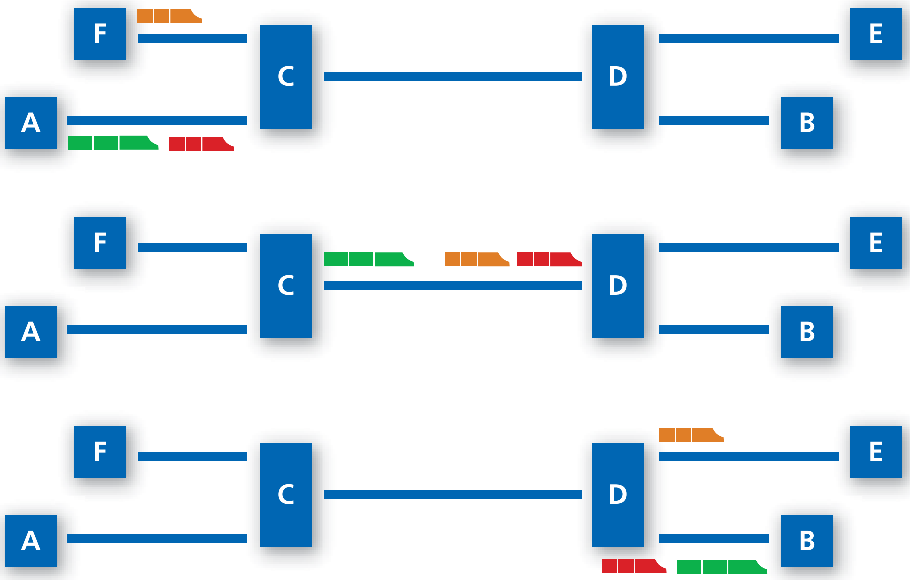
This simulation provided results quite similar to scenario 2, i.e. at least 9 minutes shall be considered between the departure of F2 from station F before IC can depart, in order not to delay this one.

A possible timetable has been prepared as shown in the following Table.

Station	Train	Time	Action
A	F1	08:05:00	departure
F	F2	08:00:00	departure
F	IC	08:09:00	departure
C	F2	08:17:54	arrival
C	IC	08:20:26	arrival
C	IC	08:23:36	departure
C	F1	08:25:48	arrival
C	F1+F2	08:40:48	departure
D	IC	08:55:07	arrival
D	IC	08:58:07	departure
D	F1+F2	09:30:18	arrival
D	F1	09:45:18	departure
D	F2	09:50:18	departure
B	IC	09:09:31	arrival
B	F1	10:02:52	arrival
E	F2	10:10:45	arrival

→ Figure 124: Possible Timetable Scenario 3.
Source: **MARATHON**

Scenario 4: This scenario has been created to analyze the impact of the **MARATHON** train on the section from C to D; it is done through the departure of IC train after the **MARATHON** train. Simulations have demonstrated that the IC train shall leave station C at least 21 minutes after the **MARATHON** train, in order to avoid speed decreases during the trip.



→ Figure 125: Simulation Scenario 4.
Source: **MARATHON**

The proposed scheduled in presented in the following table:

Station	Train	Time	Action
A	F1	08:00:00	departure
A	IC	08:25:00	departure
F	F2	08:00:00	departure
C	F2	08:17:54	arrival
C	F1	08:20:48	arrival
C	IC	08:38:26	arrival
C	F1+F2	08:35:48	departure
C	IC	08:56:48	departure
D	F1+F2	09:25:18	arrival
D	IC	09:28:19	arrival
D	IC	09:31:19	departure
D	F1	09:40:18	departure
D	F2	09:45:18	departure
B	IC	09:42:43	arrival
B	F1	09:57:52	arrival
E	F1	10:18:19	arrival

→ Figure 126: Possible Timetable Scenario 4.
Source: **MARATHON**

In conclusion the simulations of the train circulation analyzing the impacts of the MARATHON solution on normal operation have been performed. The MARATHON business model has been taken into account, in order to consider in the simulations the different stakeholder perspectives and analyze the main advantages and disadvantages of the train coupling. The theoretical reference scenario developed in the business case, shown in the following picture, has been used as reference.

→ Figure 127: Theoretical MARATHON Scenario.
Source: **MARATHON**

Different scenarios have been set, each one considering a different aspect and therefore the impact of the **MARATHON** solution on standard train operations. Specifically, Scenario 1 describes the "easiest" solution, i.e. the freight trains to be coupled run after other trains (e.g. Intercity); in this case no impacts on the train circulation are caused by the coupling of trains. Scenarios 2 and 3 analyze the impact on delays and possible timetables when one of the freight trains to be coupled is followed by an Intercity. Finally, Scenario 4 has been created to analyze the impact of the coupled train when it is followed by another train; in this case proper schedule shall be take into account in order to avoid speed decreases during the trip and possible delays. The different simulations performed have highlighted no particular issues when running the **MARATHON** train on the same line used by other trains; therefore no impacts on the normal operation are caused by running a train long 1500 m, instead of having two separate trains. The two track sections coming to C (station where coupling is performed), from A and F, have been set with different length in order to best fit to reality, where usually a freight train shall wait for another one to be coupled with; distances and timetables shall be set properly in order to set maximum waiting times for a train waiting for the other to be coupled.

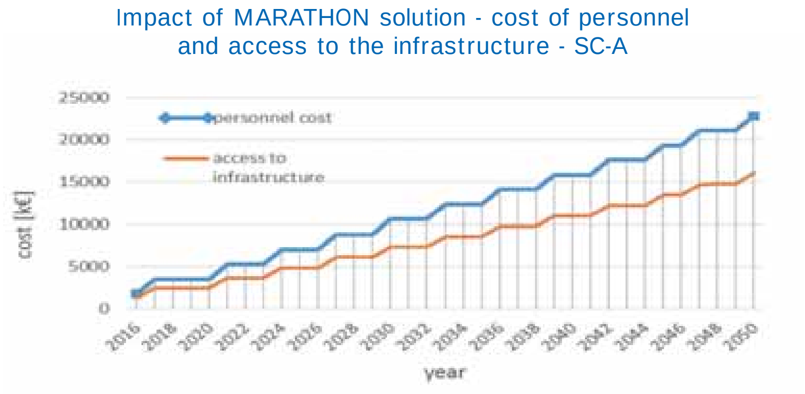
Timetables of course shall be adjusted to work properly, as the **MARATHON** train will occupy, depending on the track section length, one or more sections at the same time; this depends on the signaling set up, which varies from country to country and in different sections of the line. Simulations help to set up timetables according to the freight and other train needs. No major modifications are required to the track infrastructure; stations and marshalling yards shall be long enough to let two trains coupling, therefore a side track of at least 1500 m long shall be present, otherwise coupling cannot be performed without blocking the traffic on the line. In conclusion, the simulations and the analysis carried out on results have demonstrated that no specific issues are caused by the **MARATHON** train on the normal train operation; no major infrastructure modifications are required, if adequate space for coupling/decoupling is present (at least 1500 m of side track), and timetables can be set properly in order not to delay other trains running on same network. Coupling must be done in a station where a **MARATHON** train can be overpassed by other faster trains. If a **MARATHON** train has priority on other trains (e.g. regional), it shall be placed first on this corridor. By analyzing the frequency of recovery points (where a **MARATHON** train can be overpassed) and the traffic on a line, it can be highlighted if there are many "easy" or "critical" situations on the specific line.

The Sustainability Assessment

According to the chapter 4.3 for the financial analysis three categories of scenario have been considered. The scenario "A" represents the "no project" option; the scenario "B" represents the "baseline" **MARATHON** solution and the scenario C represents the "104" marathon solution. In the following points are reported the financial results of each of theme. It's clear that the main difference between the "no project" option and **MARATHON** solutions is represented by the cost of personnel and those to access the infrastructure and the cost of investment. The main differences of the "baseline" scenario and "104" scenario is represented by the train capacity and thus in the number of train needed to satisfy the demand.

→ Scenario SC-A

Scenario "A" considers tradtional train with a maximum length of 750m. In the current state the demand between paris-Marseille corridor is estimated in 50 kTEU per year per direction. In the time horizon of 2050 the forecast demand is estimated in more than 350 kTEU per year per durection with a linear growth rate (section 4.3). In order to satisfy the demand the supply increases from 1 daily connection per direction to 13. Thes menas that also the variable cost increases too. In the following figure are reported the personnel cost and the cost for the access to the infrastructure wich can play an important role in the difference between the "No project" option and the **MARATHON** solutions.



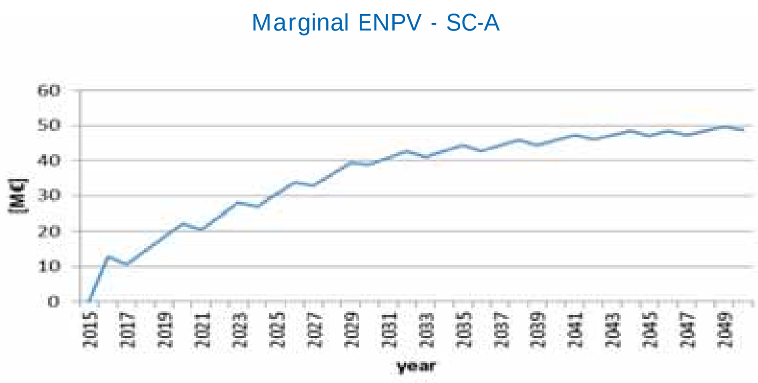
➔ Figure 128: MARATHON Case Personnel & Infrastructure Costs.
Source: **MARATHON**

It seems that every three years these cost increse according to the increse of the number of trains. In the following figure are reported the total cost which includes of course the personnel one and the cost to access to the infrastrcucture and the same cost referred to the base year (2015). In this scenario any investment cost is considered.

➔ Figure 129: MARATHON Case Total Costs.
Source: **MARATHON**

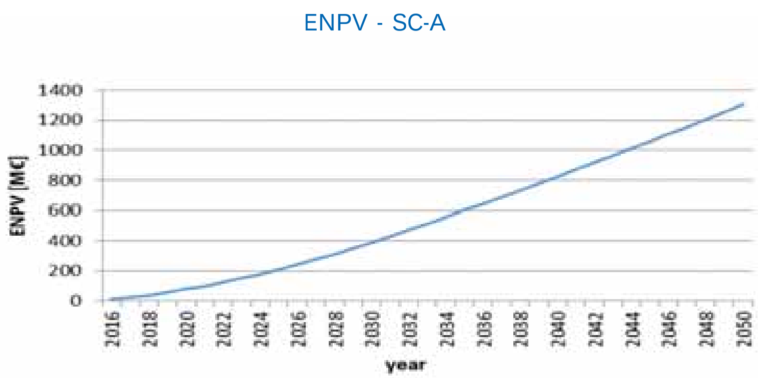
In the current state total cost is about 7M€. In the time horizon total cost rises 88M€ but if we consider the net present cost this value decreases to 25M€. According to the discont rate of section 6.1 the marginal Economic net present value rises 40M€ in the year 2030 and almost 50M€ in the year 2050.

In the following is reported the marginal ENPV:



→ Figure 130: Marginal ENPV - SC-A.
Source: **MARATHON**

According to the marginal ENPV the cumulative curve of the marginal ENPV provides the ENPV. In the year 2030 the ENPV is estimated in 389M€ and 1303M€ for the 2050. In the following figure is reported the ENPV for all years in the time horizon.

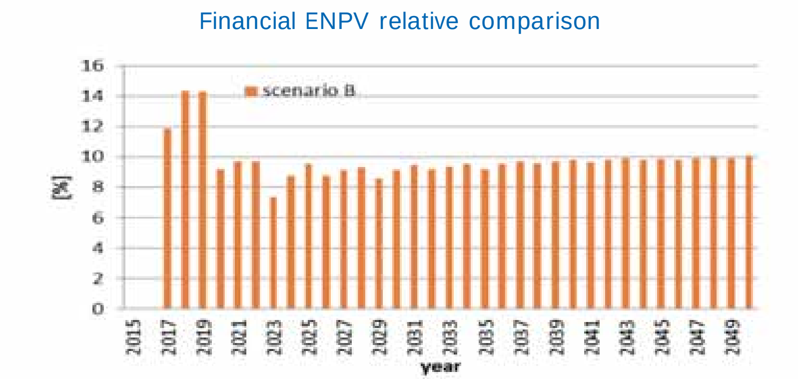


→ Figure 131: ENPV - SC-A.
Source: **MARATHON**

→ Scanerio SC-B

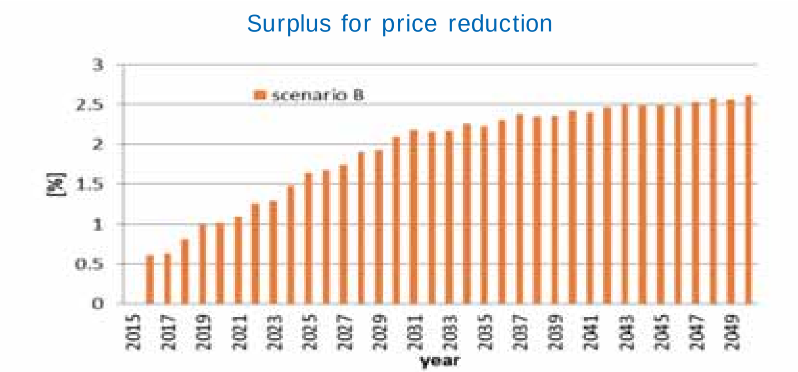
In this scenario the marathon solution is adopted. Particularly the standard wagons are used to exploit the service. According to section 4.3 before to calculate the ENPV of this scenario is necessary to estimate the generated demand. **MARATHON** solution (usign standard wagons SGNSS) provides extra profit compare to the scenario “A”.

In the following fiugure are reported the relative extra profit.



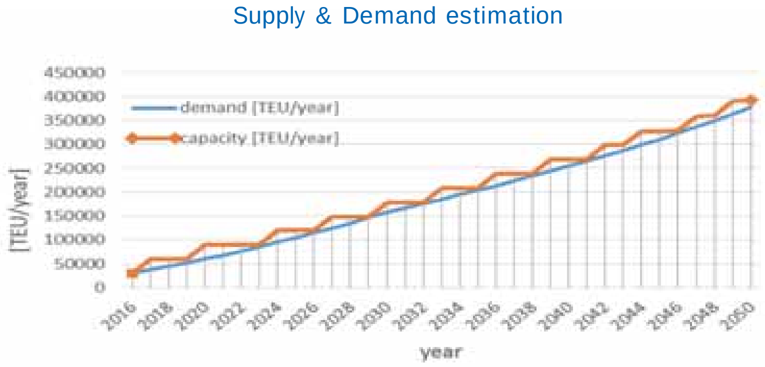
→ Figure 132: ENPV SC-B.
Source: **MARATHON**

The average potential extra profit is equal to 10%. Assuming that the half of this extra profit can be re-used to reduce the selling price (5%), it is possible to estimate the surplus year by year and its incidence on the fare system. In the following figure is reported the surplus (for the reduction of selling price).



→ Figure 133: Surplus generated by MARATHON.
Source: **MARATHON**

The average surplus incidence on fare system is equal to 3.3%. In "Understanding Transport Demands and Elasticities –Litman 2013" the demand elasticity for rail freight is equal to -0.47. Thus when the selling price decreases of 3.3% demand increases of 1.6%. This value represents the average generated demand that has been considered in addiction to the demand of scenario "A". In the following figure is reported the demand for the scenario "B"



→ Figure 134: MARATHON Supply & Demand Estimation.
Source: **MARATHON**

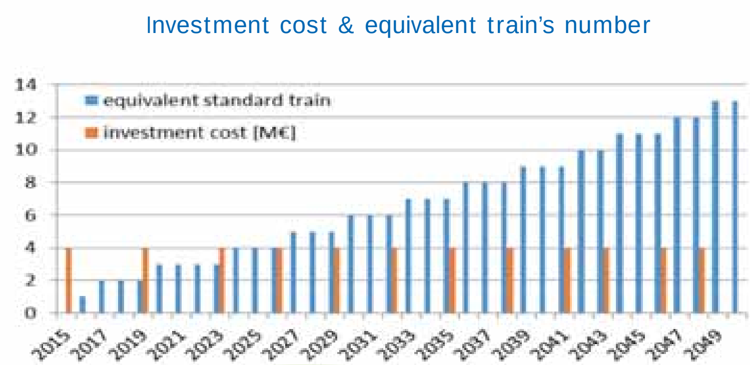
According to the demand growth a marathon train can be performed. Particularly in same case the demand can be satified using only marathon train while in other case it can be covered running marathon trains plus a standard train. Thus the cost must be computed according. So for example in case of a marathon train plus a standard train the personnel cost is equal to the case of two marathon train. In the following figure are reported the cost of personnel and the cost to access to the infrastructure.

→ Figure 135: MARATHON Solution, Personnel & Infrast. Costs.
Source: **MARATHON**

As expected in this scenario these cost are lower compare to the scenario “A”. Of course in the current state the cost is eqaul but in the year 2030 the cost of personnel can be halved and even more than halved in the year 2050. Moreover every 5-6 years the cost increases according to the growth of the number of train (instead of the three years of the scenario “A”). As expected also the total cost are lower than the scenario “A”. Specifically in the year 2030 the total cost is about 30M€ and almost 70M€ in the year 2050; but if we consider these value in the base year they decrease to 20M€. In the following figure are reported the total cost and the same cost respect to the base year.

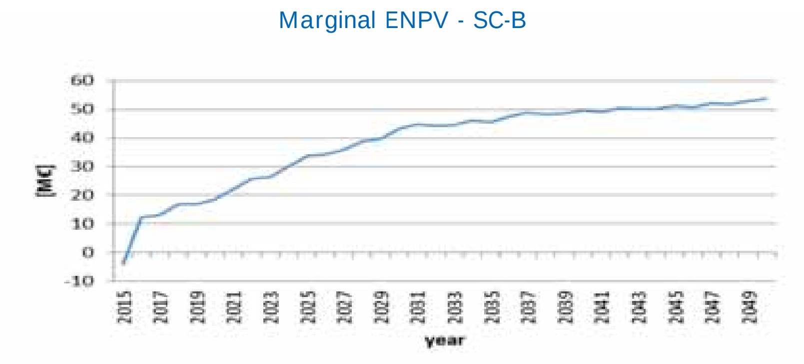
→ Figure 136: MARATHON Solution, Total Costs.
Source: **MARATHON**

In this scenario it has been considered also the investment cost. Particularly this cost have been added for each marathon train. Total cost of year 2050 is estimated in almost 60M€ which is 20M€ less than the same total cost of scenario “A”. In the following figure are reported the number of equivalent standard trains and the investment cost. In case of three standard trains actually there are one marathon train and one standard train.



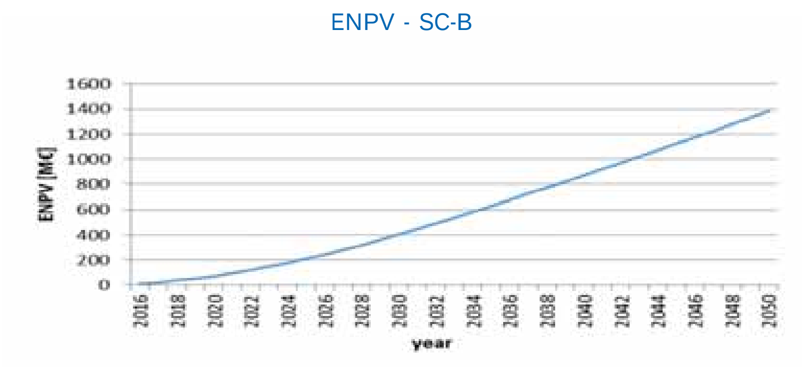
→ Figure 137: MARATHON Case, Invest: Costs & Train Numbers.
Source: **MARATHON**

Thus in the current state the marginal ENPV is negative and equal to -4M€ which represents the investment cost. In the following figure is reported the marginal ENPV for the scenario “B”.



→ Figure 138: Marginal ENPV - SC-B.
Source: **MARATHON**

Marginal ENPV can growth up to 45M€ in the year 2030 and more than 50M€ in the year 2050. The total ENPV is equal to 403M€ in 2030 and 1380M€ in 2050 (80M€ more than scneario “A”). In the following figure is reported the ENPV for the scenario “B”.

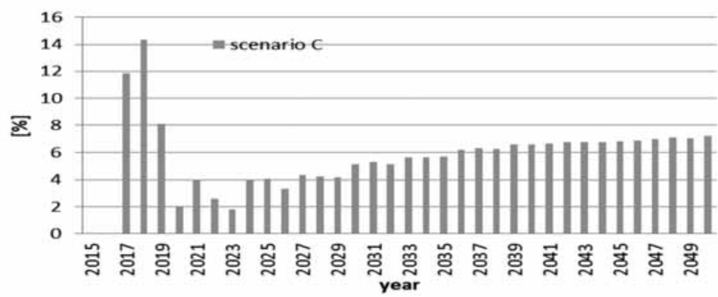


→ Figure 139: ENPV - SC-B.
Source: **MARATHON**

→ Scenario SC-C

In this section are reported the results of the scenario "C" in which the wagons SGGMRSS (104') have been considered. This scenario is very close to the baseline scenario (scenario "B") thus it has been expected a similar results of the scenario "B". According to section 4.3 before to calculate the ENPV of this scenario is necessary to estimate the generated demand. **MARATHON** solution (usign standard wagons SGGMRSS) provides extra profit compare to the scenario "A". In the following fiugure are reported the relative extra profit.

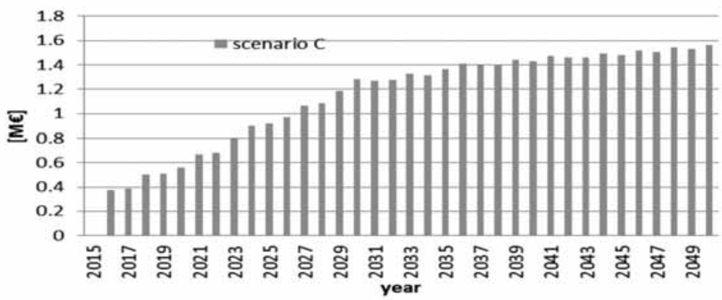
Financial ENPV relative comparison



→ Figure 140: Financial ENPV Comparison.
Source: **MARATHON**

The average potential extra profit is equal to 6%. Assuming that the half of this extra profit can be re-used to reduce the selling price (6%), it is possible to estimate the surplus year by year and its incidence on the fare system. In the following figure is reported the surplus (for the reduction of selling price).

Surplus for price reduction

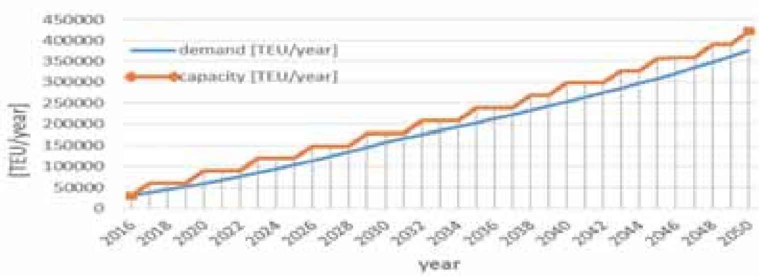


→ Figure 141: MARATHON Surplus for Price Reduction.
Source: **MARATHON**

MARATHON - MAke RAil The HOpe for protecting Nature

The average surplus incidence on fare system is equal to 2%. In "Understanding Transport Demands and Elasticities –Litman 2013" the demand elasticity for rail freight is equal to -0.47. Thus when the selling price decreases of 2% demand increases of 0.9%. This value represents the average generated demand that has been considered in addiction to the demand of scenario "A". In the following figure is reported the demand for the scenario "B".

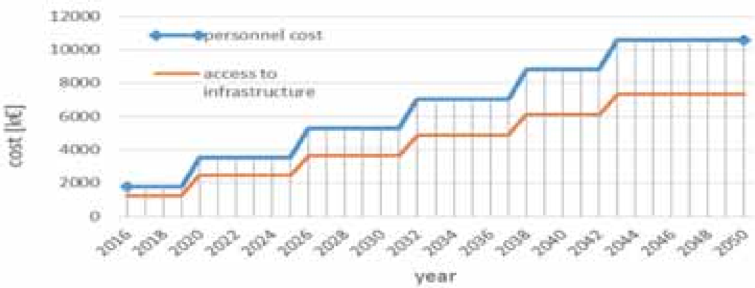
Supply & demand estimation



→ Figure 142: MARATHON Case Supply & Demand.
Source: **MARATHON**

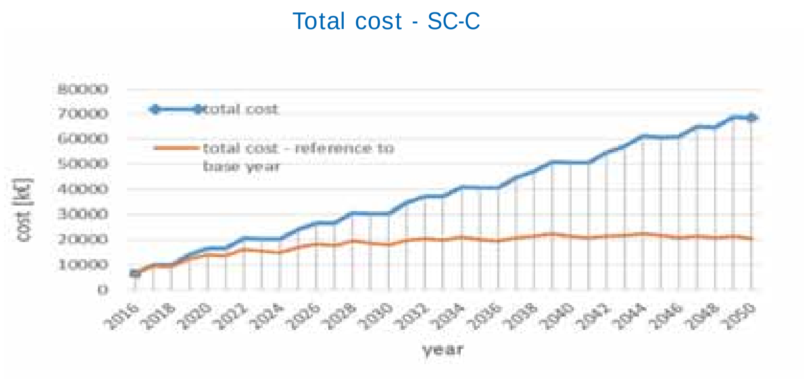
In the following figure are reported the cost of personnel and those to access to the infrastructure.

Impact of MARATHON solution - cost personnel and access to the infrastructure - SC-C



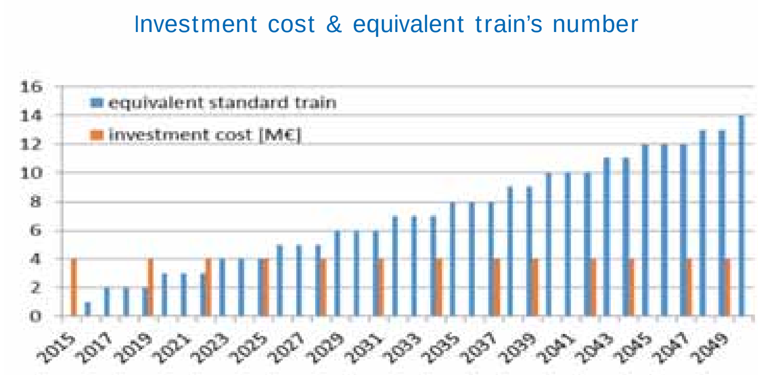
→ Figure 143: MARATHON SC-C, Personnel & Infrastructure Costs.
Source: **MARATHON**

Even it is required one train more of those of scenario “B”, these cost of are the same of scenario “B” thanks to MARATHON solution (coupling train adopting a slave locomotor). In the other hand the other cost quite increse because of the one more train. In following figure is reported the total cost.



→ Figure 144: MARATHON SC-C, Total Costs.
Source: **MARATHON**

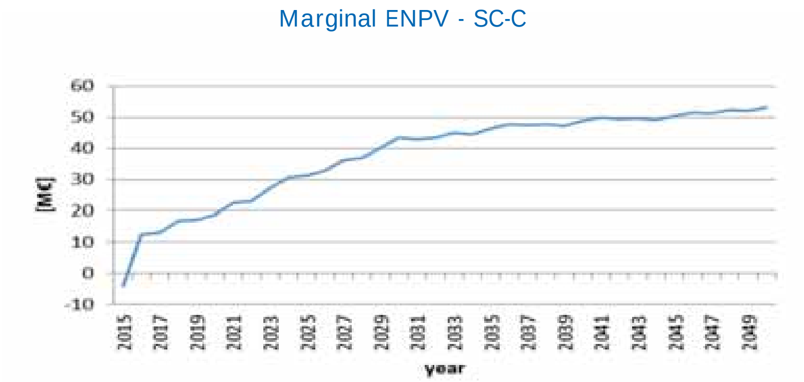
In year 2050 total cost is estimated in almost 70M€ but considering the present cost it is almost 21M€. In the following figure are reported the equivalent trains and the investment cost.



→ Figure 145: MARATHON SC-C Invest. Costs & Train Numbers.
Source: **MARATHON**

In year 2050 are required 14 trains instead of 13 of scenario “B”. This leeds to the small increase of the total cost.

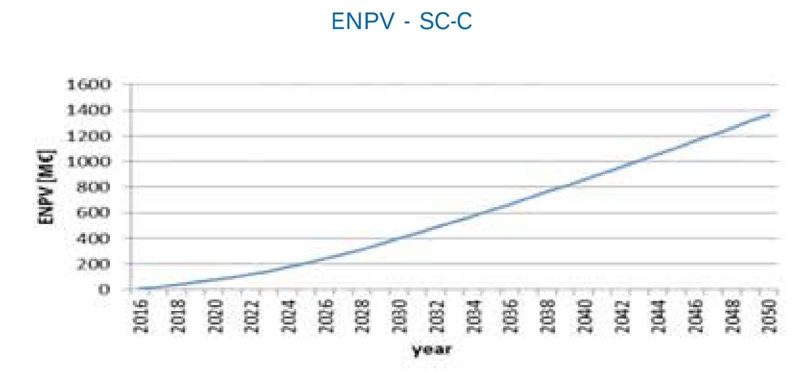
In the following figure is reported the marginal ENPV.



→ Figure 146: Marginal ENPV - SC-C.
Source: **MARATHON**

Even in thsi scenario marginal ENPV is negative for the first year because of the investment in marathon trains. In year 2030 it becomes equal to 43M€ and more than 50M€ in 2050.

In the following figure is reported the ENPV.



→ Figure 147: Financial ENPV SC-C.
Source: **MARATHON**

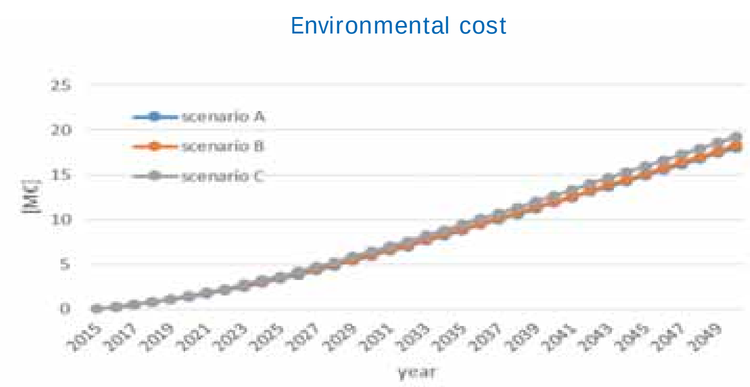
In year 2050 ENPV rises 1368M€ and about 398M€ in 2030.

Results of the Environmental analysis

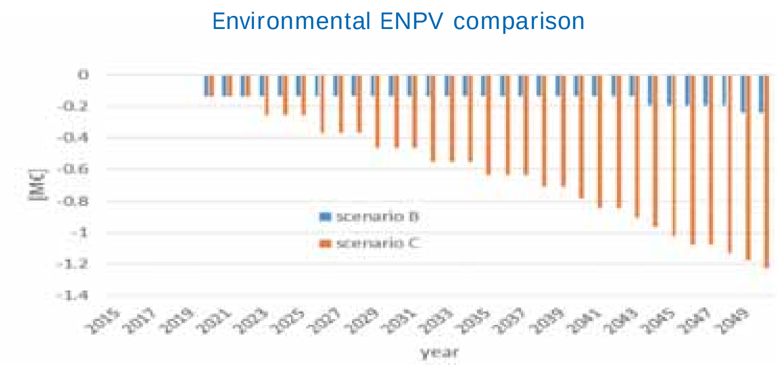
In this section are reported the results of the environmental analysis which included both the estimation of the CO2 and other pollutants and the calculation of the external cost of these pollutants. According to the section 5.2 three main categories have been taken into account. For each category the analysis has been performed comparing:

A. Scenario “B” and “C” with scenario “A”
B. The road transport system to the rail one.

A) In the following figure are reported the environmental ENPV for the scenario “A”, “B” and “C”. In the following figure are reported the relative comparison between scenarios “B” and “A” and scenarios “C” and “A”.



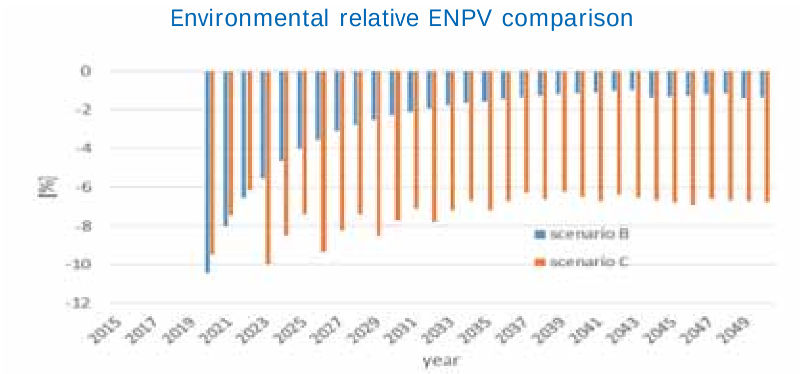
→ Figure 148: Environment Costs per Scenario.
Source: **MARATHON**



→ Figure 149: Environmental ENPV Comparison.
Source: **MARATHON**

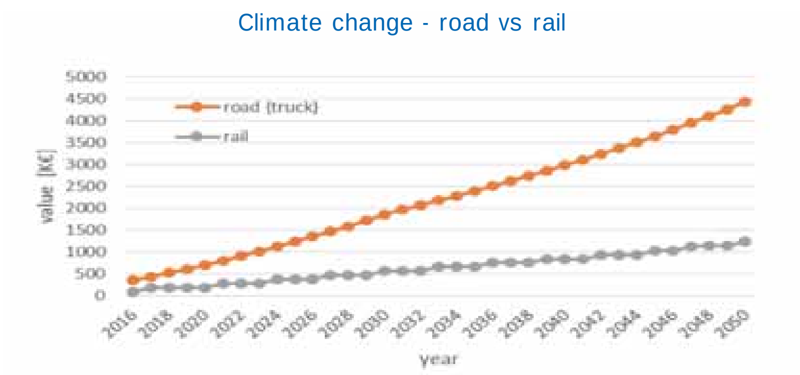
MARATHON - MAke RAil The HOpe for protecting Nature

As expected adopting **MARATHON** solution environmental values increase; in fact due to **MARATHON** solution demand and consequentially train numbers increase too; thus comparison year by year provides worst results for marathon solution. In terms of absolute values the previous incidences become the following cost.



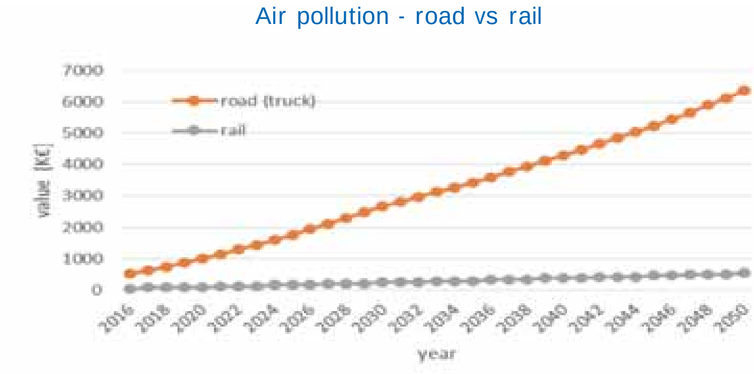
→ Figure 150: Environmental Relative ENPV Comparison.
Source: **MARATHON**

B) One of the main deliverable at European level is to increase the modal shift from road to rail. So for each year in the time horizon it has been compared the road and rail system. For road system it has been assumed that the average truck capacity is equal to 1 TEU. Thus according to demand it has been calculated the number of truck for each year able to satisfy the demand. According to the section 5.2 in the following figure it is reported the comparison between road and rail in term of climate change.



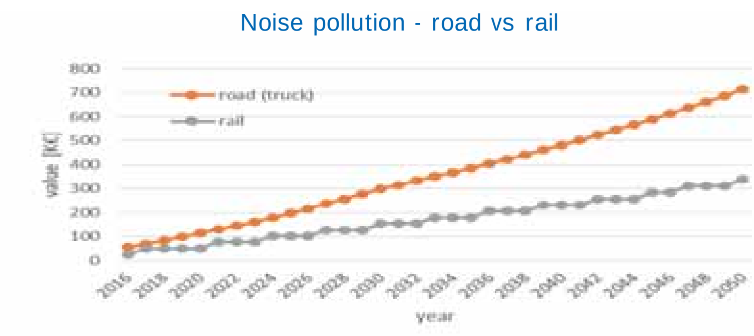
→ Figure 151: Climate Change Road Versus Rail.
Source: **MARATHON**

In year 2030 the externality of rail system is equal to 0.5M€ while the road one is almost 2M€. In year 2050 the road rises almost 4.5M€ and rail growths up to 1.3 M€. In terms of air pollution as expected, the rail system is even more competitive compare to the road one. In fact in year 2050 the road externality is more than 6M€ while the rail one is less than 1M€. In the following figure is reported the the comparison between truck and rail.



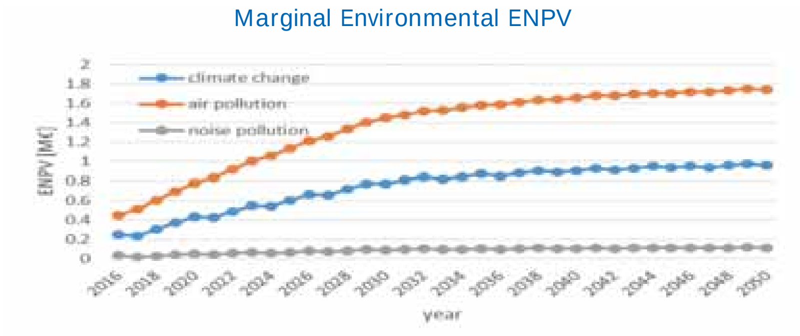
→ Figure 152: Air Pollution Road Versus Rail.
Source: **MARATHON**

Concerning the noise pollution the difference is lower than those of air pollution. This seems raisonable if we consider the high impact of a train in term of noise pollution; but in any case the rail is still better than road. A main role is played by the high capacity of a train. In the following figure is reported the comparison between the road and rail systems.



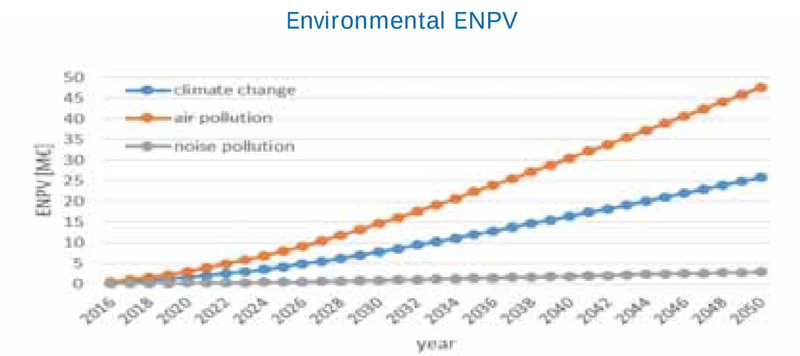
→ Figure 153: Noise Pollution Road Versus Rail.
Source: **MARATHON**

In year 2050 noise pollution can rise 0.3M€ for rail and more than 0.7M€ for road. According to the previous results it is possible to estimate the difference between road and rail system. This difference represents the benefit of rail solution (Environmental ENPV). In the following figure are reported the marginal Environmental ENPV for climate change, air pollution and noise pollution.



→ Figure 154: Marginal Environment ENPV.
Source: **MARATHON**

The main role is played by the air pollution which can bring to a difference of 1.6M€ in year 2050. Climate change has also an important impacts while the noise one actually doen't play a significant role. In the following figure is are reported the Envirnmental ENPV for the three categories of parameters.



→ Figure 155: Environment ENPV.
Source: **MARATHON**

According to the marginal Environmental ENPV the cumulative curve increases the difference between the impacts of each categories; in year 2050 the value of the reduction in air pollution is estimated equal to about 45M€, the climate change one in more than 25M€ and the noise one in 3M€.

Results if the Social Analysis.

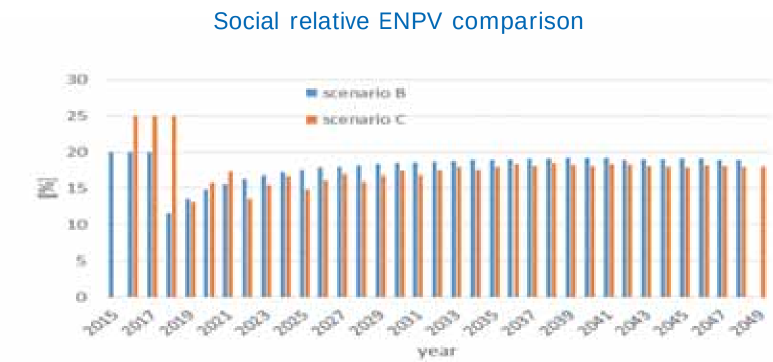
In this section are reported the results of the social analysis which include the accident reduction when goods are shifted from road truck to rail system. According to section 5.2 it has been analysed:

A. Scenario “B” and “C” with scenario “A”
B. The road transport system to the rail one.

A) In the following figure are reported the accident cost for scenario “A”, “B” and “C”.

→ Figure 156: Accident Costs.
Source: **MARATHON**

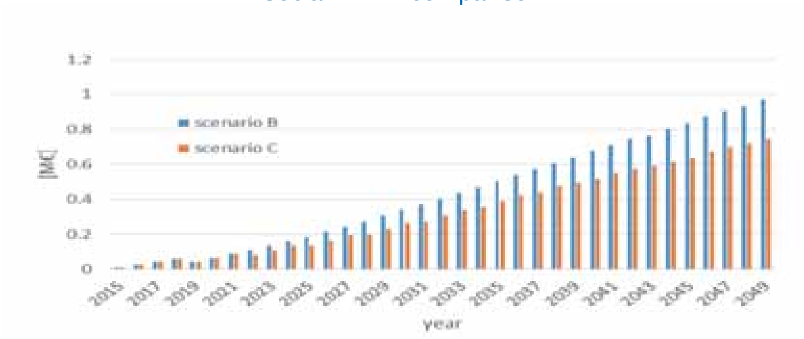
In the following figure are reported the comparison between scenario “A” and scenario “B” and “C”.



→ Figure 157: Social Relative ENPV Comparison B) & C).
Source: **MARATHON**

In term of absolute value the incidence in previous figure leads to a significant profit (0.4M€ in the year 2030 and almost 1M€ in 2050). In the following figure are reported the social ENPV year by year.

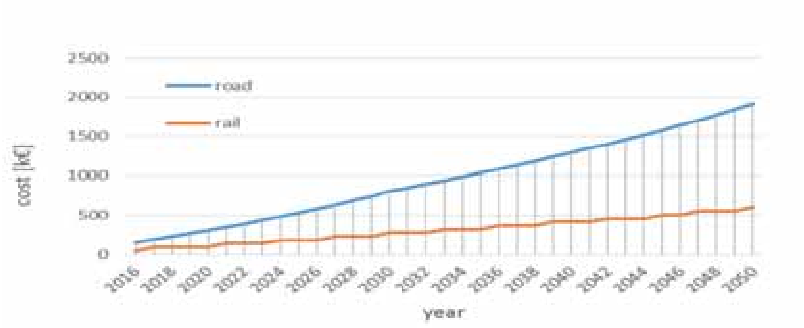
Social ENPV comparison



→ Figure 158: Social ENPV Comparison B) & C).
Source: **MARATHON**

In the other hand it has been compare also the road truck system with the scenario “A” in order to underline the profitability of rail system itself. Average load capacity of truck has been assumed equal to 1TEU. Considering the unit cost (marginal cost) reported in section 5.3 and taking into account the demand growth of section 4.3 it have been estimated the accident cost for road and rail system. In the following figure is reported the comparison for all year in the time horizon.

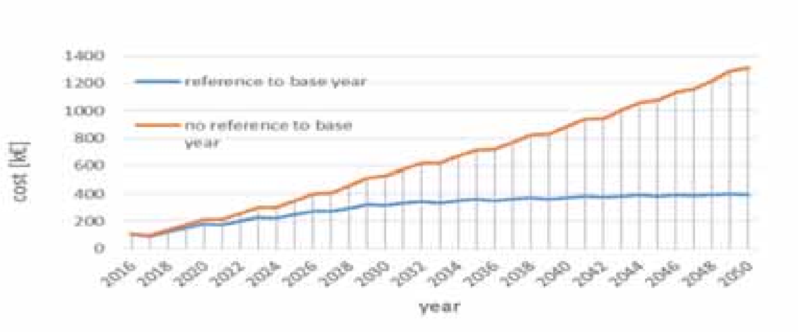
Accident cost



→ Figure 159: Accident Costs.
Source: **MARATHON**

In the current state accident cost is equal to 0.15M€ for road and 0.05M€ for rail; but looking at year 2030 and 2050 these cost increase respectively up to 0.8M€ and 1.9M€ for road and 0.27M€ and 0.6M€ for rail. In order to quantify the real benefit of rail it has been calculated the difference between road and rail. In the following figure is reported the marginal accident cost saving.

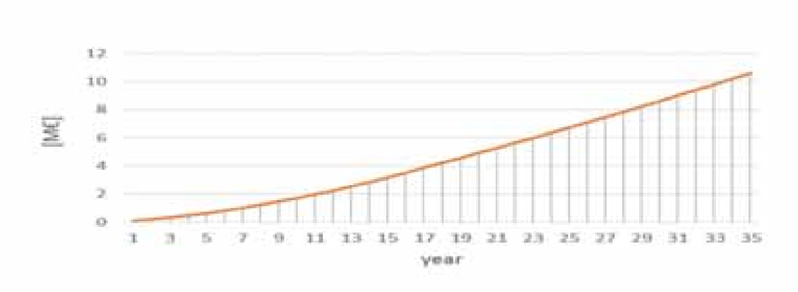
Marginal accident cost saving



→ Figure 160: Marginal Accident Costs Savings.
Source: **MARATHON**

In year 2030 the present marginal cost saving is estimated in 0.35M€ and 0.4M€ in the year 2050. In terms of cumulative results this means that in 2030 it is possible to save about 3M€ and more than 10M€ in 2050.

ENPV



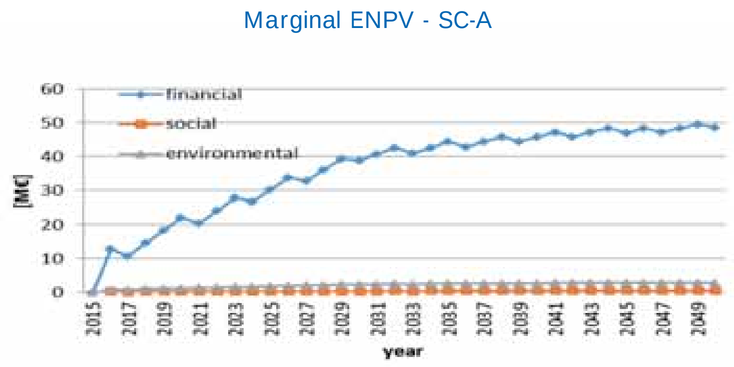
→ Figure 161: ENPV.
Source: **MARATHON**

Results of the overall CBA Analysis

In the following sub-sections is reported the overall CBA analysis for each scenario.

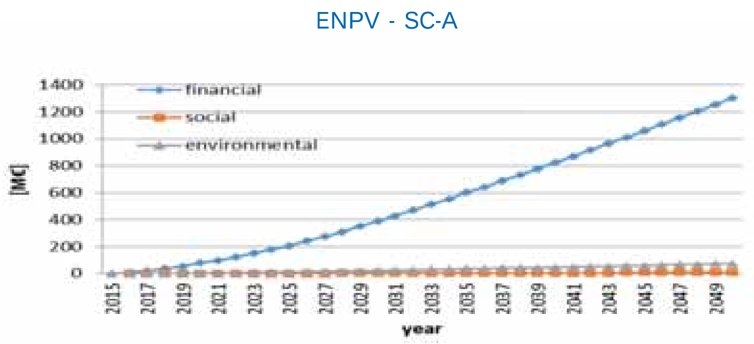
→ Scenario SC-A

In the following figure are reported the marginal ENPV related to the financial, social and environmental aspects.



→ Figure 162: Marginal ENPV SC-A.
Source: **MARATHON**

Financial marginal ENPV plays the main role and his order of magnitude is greater than those of social and environmental ones. Thus in terms of ENPV (cumulative) financial aspects has again the main magnitude. In the following figure are reported the ENPV for the three categories.

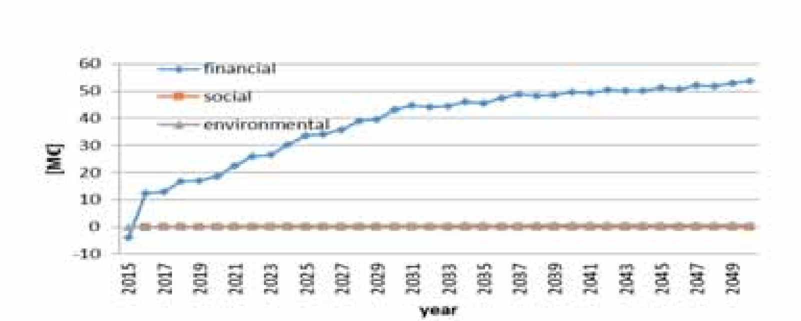


→ Figure 163: ENPV SCV-A.
Source: **MARATHON**

→ Scenario SC-B

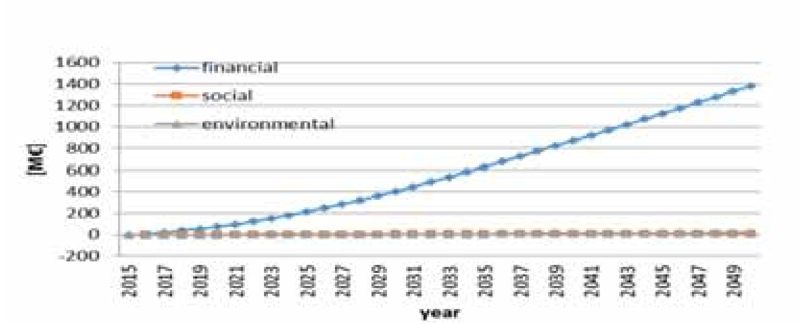
As for the previous sub-section in the following figure are reported the marginal ENPV of each category (financial, social and environmental).

Marginal ENPV - SC-B



→ Figure 164: Marginal ENPV SC-B.
Source: **MARATHON**

ENPV - SC-B



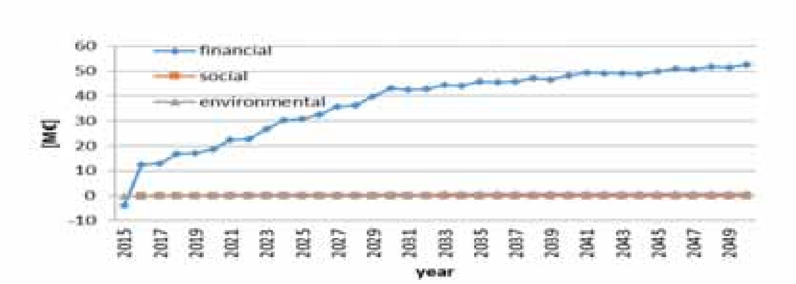
→ Figure 165: ENPV SC-B.
Source: **MARATHON**

Even for the scenario “B” financial has the main magnitude.

→ Scenario SC-C

In the following figure are reported the marginal ENPV of each category (financial, social and environmental).

Marginal ENPV - SC-C



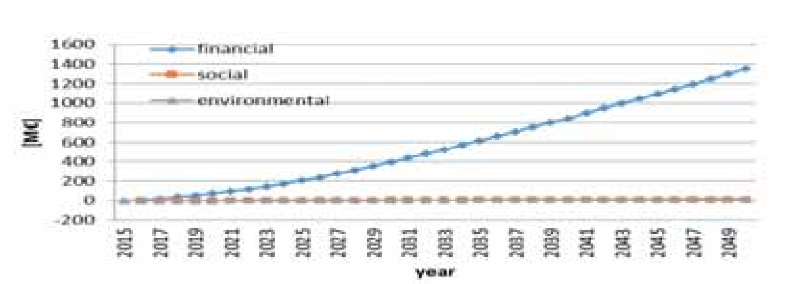
→ Figure 166: Marginal ENPV - SC-C .
Source: **MARATHON**

As expected even for the scenario "C" financial has the main magnitude

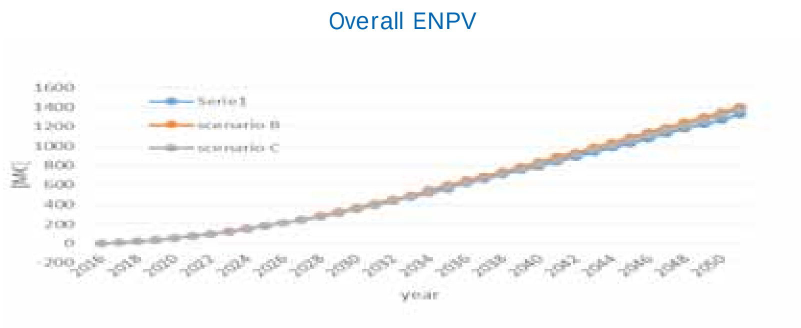
→ Scenario comparison

In this section is reported the comparison between the scenario "A"-"B"-"C".

ENPV - SC-C

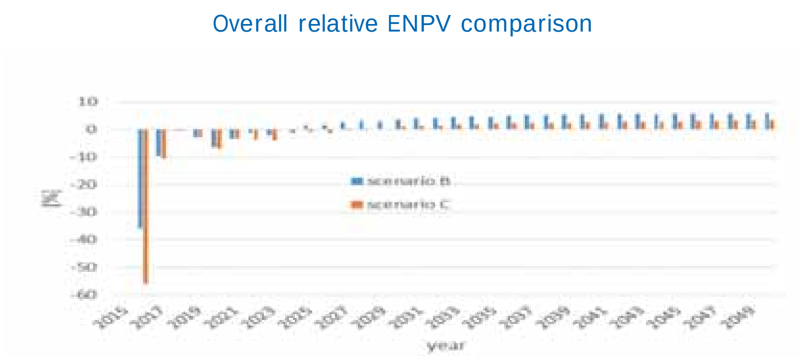


→ Figure 167: ENPV - SC-C .
Source: **MARATHON**



→ Figure 168: Overall ENPV.
Source: **MARATHON**

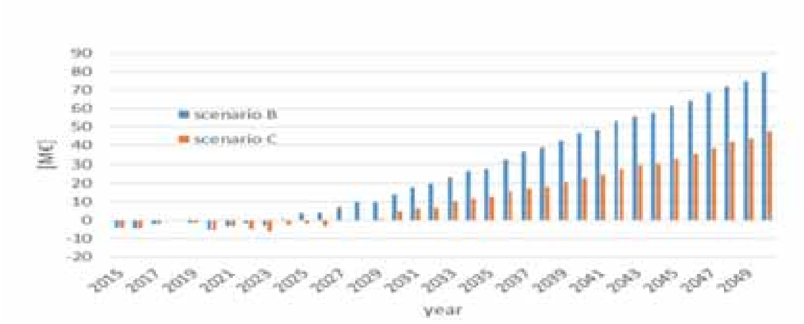
The differences are quite hidden because of the high value for the fixed cost that are equal for every scenario. In the following figure is reported the comparison in terms of overall ENPV. Scenario "B" seems to be the best one; in fact in scenario "B" the capacity of each train is higher than the others bringing to a visible cost reduction. Scenario "A" represents the "no project "scenario. In the following figure is reported the impact of both marathon solutions (scenario "B" and "C") respect to the scenario "A". Scenario "A" represents the base scenario. Thus it's important to analyse the relative impacts of scenario "B" and "C" over the scenario "A" (following figure).



→ Figure 169: Overall Relative ENPV Comparison.
Source: **MARATHON**

MARATHON - MAke RAil The HOpe for protecting Nature

Overall ENPV comparison



→ Figure 170: Overall ENPV Comparison.
Source: **MARATHON**

In terms of relative incidence the base year plays a significant role because in scenario “A” there isn’t any investment. But in absolute term both scenario “B” and “C”, e.g. MARATHON solution, seem profitable. Scenario “B” provides 80M€ of extra profit compare to scenario “A”. Scenario “C” provides 50M€.

In Conclusion in this report a cost benefit analysis of **MARATHON** solution in the rail corridor Paris-Lyon-Marseille has been performed. A macroscopic approach has been used considering the large scale dimension of the area. The time horizon for the analysis is the year 2050. Forecast demand has been estimated according to the EU freight growth rate and taking into account the EU target for rail freight modal split in the year 2030 (equal to 30%) and year 2050 (equal to 50%). **MARATHON** solutions consist in two alternative options: using SGNSS wagons or using SGGMRSS wagons (104’). Thus three scenarios have been developed also considering the scenario of “no project” (scenario “A”). Scenario “B” and “C” respectively represent the **MARATHON** solution with SGNSS wagons and SGGMRSS wagons. For the cost benefit analysis three categories of indicators have been analyzed: financial; environmental and social. Scenario “A” represents the base scenario; scenarios “B” and “C” are compared with scenario “A” in order to quantify the benefit of **MARATHON** solution. For the environmental and social analysis it has been performed a comparison between road transport and rail one in order to quantify the profitability of rail itself. The economic net present value has been considered as CBA indicator. A discount rate of 3.5% has been chosen before to start all simulation. In absolute value financial impact plays the main role. The ENPV for financial is around 1300M€ while the same values for the environmental and social one is 17M€ and 4M€ in the year 2050.

Most interesting results are provided by the relative compare to the scenario “A” (no project). In this case results show how **MARATHON** solutions can increase the operative margin up to 10%

for scenario “B” and up to 6% in scenario “C”. This potential surplus can be re-used to decrease selling price. Assuming an actual surplus equal to 50% of this potential surplus marathon solution can leads to an average reduction of selling price equal to 3.3% for scenario “B” and 2% for scenario “C”. According to the demand elasticity **MARATHON** solution can generate a new demand estimated in 1.6% for scenario “B” and around 1% for scenario “C”. These results underline how **MARATHON** solution allows in the same time the price reduction and the extra increase of freight transport demand. Social analysis shows a significant reduction in accidents cost. The average relative reduction to the scenario “A” is almost 20%. The comparison to road transport puts in evidence the effectiveness of rail system; accidents cost of rail is equal to 25% of those of road transport system (truck).

Environmental analysis provides less significant results according to the difficulty of a macroscopic model use. The average relative impact of scenario “B” and “C” on scenario “A” is equal to 2% and 6%; the **MARATHON** solution generates new demand and thus the number of trains can increase before the natural growth of the standard trains number. The environmental indicators in a macroscopic approach should not change significantly for the three scenarios; in a macroscopic and aggregate view a **MARATHON** train or two standard train should have the same power consumption, same noise level (even if the frequency of disturbances is reducing for the **MARATHON** solution but this detailed analysis cannot be developed with a macroscopic approach) and same CO2 production. Results are expected to be almost the same. In conclusion considering the results of the overall analysis, scenario “B” seems the most profitable providing a benefit of 80M€ in the year 2050. Scenario “C” is also profitable providing a benefit of 48M€.

3.4 PILOT TEST (WP5)

The Pilot Test chapter is rather short when compared to the previous sections of this handbook. This in itself is a proof of the **MARATHON** Project success. The ample preparatory work had been thorough and exhaustive lasting full three years of research and applied work allowing the **MARATHON** Project partners to approach the Test Phase with the confidence that the tests would have been successful having left nothing to chance.

The **MARATHON** Train Consists Simulation

The **MARATHON** Products Integration on Locomotives

The **MARATHON** Products developed during the project lifetime researched, developed and tested in the partners laboratories and on the operating field have been defined as the “**MARATHON** Kit”. This kit whose technological components are the property of the producing partners is constituted by:

- The Radio Communication System between the two locomotives
- The Computerized Interface DCPU for categorizing and managing the radio messages from the from to the slave locomotive

➔ The **MARATHON** Tran Braking System

These components researched and developed by the interested partners constitute the **MARATHON** Project "Foreground" and each producing partner will protect its discoveries as per their company policy in accordance with the project rules. These components prior to the Pilot Test runs have been integrated first on the AKIEM ALSTOM locomotives in Belfort for the Test Run effected on Saturday January 18th for the electric trial and second on the VOSSLOH locomotives in Valencia for the Test Run effected on Saturday April 12th for the diesel trial.

The MARATHON Train Pilot Test Run on the Network

SNCF took responsibility of the two test Runs execution. The testing theatre was a stretch of about 300 km of RFF network between Sibeling (Lyon) and Nymes. The first test took place on January 18th with two ALSTOM electric locomotives supplied by AKIEM. The second Test took place on April 12th with two VOSSLOH diesel locomotives moved specifically from their Valencia factory.

Both "on the field" operating trials were very successful. The trains travelled for long stretches at 100 km/h and over with braking sessions in between for testing the trains stability behavior in various braking conditions. As it happened the train was very stable and the longitudinal dynamic forces appeared to be inferior than the ones expected from the laboratory testing. The operating trials in both cases were effected in true market conditions. The three commercial trains assembled in the **MARATHON** train, were supplied by KOMBIVERKEHR originating from Germany destined to Spain. They were assembled in the rail marshalling yard of Sibeling. Some empty flat wagons were added in order to reach the full planned train length of 1500 m. In Nymes the **MARATHON** train was disassembled and the three original trains continued their journey to their final destination in Spain. Ample video documentation was provided as documentary evidence supported by extended press release information which reached every part of Europe and beyond. It is necessary to mention the partners involved directly in the physical Pilot Test Work Package. Rff, Sncf, Alstom, Trafikverket , Vossloh, Akiem, Faiveley Transport ,Schweizer Electronics, Kombiverkehr, Createch as well as all the other **MARATHON** partners who had a vital role in the planning and preparatory work conducive to the Test trial success. Such preparatory research, technological, laboratory testing work lasted full three years.

3.5 DISSEMINATION AND KNOWLEDGE TRANSFER (WP6)

The **MARATHON** Tools for Dissemination

As integral part of the **MARATHON** Project it was agreed with the European Commission that the solutions discovered and applied during the project lifetime which conduced to the two tested trials with Electric and Diesel locomotives were to be disseminated at international level. The classic tools for dissemination were adopted such as:

- Website organization operational from day one of the project startup phase
- Meetings and conference presentations
- Brochures and newsletters
- Press releases
- Stencils

International events such as Munich Transport and Logistics in June 2013, FERRMED at European Parliament in Brussels in March 2014, TRA 2014 in Paris in April 2014, The European Freight and Logistics Leaders Forum(F&L) in Istanbul in May 2013, in Rotterdam on November 2013 and Prague on June 2014, UNIFE massive Rail Award event in Brussels in January 2014, Multimodal Birmingham April 2014 UIC Global Rail Freight Conference in Vienna in June 2014. , Innotrans in September 2014 have been used as ideal vehicles for accessing European and World wide targeted audiences.

ERRAC Plenary in Brussels and Paris both in 2013 and 2014.

In all these events dedicated **MARATHON** Project presentations were made including when available the projection of the **MARATHON** videos after the trains tested trails. At the European Freight and Logistics Leaders Forum in Prague in addition to the **MARATHON** Project presentation a dedicated workshop was organized specifically for the **MARATHON** Project for discussing, elaborating disseminating the **MARATHON** trains concept together with its future commercial development. This workshops was chaired by the F&L President to mark the strategic importance of the **MARATHON** achievement. The F&L is constituted by the Leading European Logisticians representing the most important European Leading corporations cross modes. The F&L membership is the ideal target for bringing about the needed changes in the market place since the leading Companies having massive traffic flows are those capable of leading the modal shift towards more competitive sustainable and environment friendly mobility systems.

Final Conference at project conclusion took place at the Innotrans Trade Fair for Transport Technology in Berlin on September 24th. This event was organized jointly by UNIFE and NEWOPERA with the European Commission support. This event appeared to be the ideal venue for the Final Event coinciding with the project conclusion set to be September 30th 2014. The earlier presentation made at the Munich Transport and Logistics in June 2013 where the **MARATHON** locomotive was on show was an outstanding success. Similarly at Innotrans many **MARATHON** partners have their own stand with their products' technology exhibition. The **MARATHON** Project final event together with the delivery of the **MARATHON** handbook provides an additional element of innovation for each partner giving the opportunity of describing a technological achievement capable of changing the rail freight competitive game in Europe.

The **MARATHON** Project handbook titled " The **MARATHON** 1500m train opening up new horizons in Rail Freight Transport in Europe", containing the Tec Rec proposal, the Deployment Plan and the Handbook was produced printed and distributed at the **MARATHON** Final Event which took place at Innotrans in Berlin on September 24th 2014.

Unofficial amateur Videos and pictures produced by the **MARATHON** team technicians and engineers during the **MARATHON** two tested trials trains both on electric and diesel traction between Sibeling and Nimes were posted on YouTube. They attracted hundreds of accesses. These videos concentrated on the physical demonstration while the train was running at slow and high speed giving an impressive perspective of length compared to ordinary freight trains of about 500 m length.

The official videos produced both by SNCF and VOSSLOH to be used in official events and for training purposes concentrated more on the technological achievements, on the radio communication between the front and the slave locomotive, on the longitudinal dynamic forces, on the braking technology system, on the computerized DCPU interface and last but not least on the coupling and decoupling of the trains during the assembly and disassembling operations. These videos moreover insisted on the economic advantages of the **MARATHON** trains such as the substantial operating costs savings up to 30% and the capacity generation on the rail tracks due to a much lower rail track occupancy emerging for transporting more cargo with a much lesser number of trains.

The Training Workshop

The Training Workshop session took place at Innotrans immediately after the **MARATHON** Final Event in direct continuation. The speakers changed according to the circularized agenda leaving the floor to the technicians, the rail engineers, the technology partners, the Radio Communication, the operators. The targeted audience was selected according to the indications provided by the Rail Operating companies in order to have an adequate number of attendees. At the same time the operating personnel in charge of the two tested trials the technicians and the trains pilots were in attendance to describe their experiences. The idea of the Training Workshop is to train a number of key strategic personnel capable of driving these trains. Such trained personnel during the **MARATHON** trains operations will be capable in turn to fulfill “training on the pulpit” to new operational staff representing this the most productive and effective way to operate the training on the job. Each member attending the Training Workshop received the marathon Handbook containing both the proposal for the Tec Rec and the handbook for the operating guidelines. So in addition to the theoretical and operative explanations the delegates was delivered the proper documentation giving substance to the training lesson.

04. CONCLUSIONS and RECOMMENDATIONS

European Commission

SEVENTH FRAMEWORK PROGRAMME

This Report has the objective of summing up the **MARATHON** Project process development up to full market uptake. **MARATHON** since the project beginning had to face a difficult market situation due to the economic recession. One has to say that MARATHON satisfied perfectly the European Commission requirements for co-funded projects being capable of developing full market uptake possibilities into the market place. The **MARATHON** demonstrated solutions are based on rail traffic industrialization. The solutions adopted by **MARATHON** Project have been largely internationalized and disseminated throughout Europe with a series of dedicated conferences and workshops which took place in specialized worldwide events in order to give the dissemination effort the maximum impact both by physical presence and the press. Videos were shown and the **MARATHON** trains were explained and elaborated. Questions were answered.

Conclusions with Market relevance

The basic paradigm to be addressed by **MARATHON** Project was represented by the economies of scale generated at Sea by the giant CT vessels that did not find the same compatibility when the containers had been discharged on the Ports quay Terminals. Therefore the immediate challenge to be overcome is the generation on land, be the modality Road, Rail or Inland Waterways, of the economies of scale compatible with those generated at Sea. Hence the transport industrialization, to/from Sea Ports to hinterland destinations via Dry Ports by rail. To this effect **MARATHON** Project has proven to be a forward looking one since road modality which is prevailing in Europe does not seem to be suitable for transport industrialization. Additionally the need of energy and environment conservation are progressively driving towards modal shift to rail and sustainable mobility.

MARATHON Project has proven the validity of the Sea Ports, Dry Ports, Mega Hubs and Freight Villages as freight bundling centers for economies of scale generation. In particular these infrastructures located on major European freight corridors (TEN-T Network or European rail Network for Competitive Freight) constitute the vital nodes where freight multiplication, freight optimization and transport industrialization can become effective. It is obvious that these infrastructures must have capacity characteristics compatible with economies of scale and transport industrialization requirements.

The presence and availability of such Dry Ports/Mega Hubs/ Freight Villages on major European corridors constitute integral part of the Rail Network for Competitive Freight. In fact it is through them that it is possible to connect the peripheral terminals into the whole rail intermodal network creating a capillary distribution system where co-modality can be exploited at its best with long hauls operated by trains or inland waterways and last mile distribution from peripheral terminals operated by road.

The strategic relevance of these nodes is capable of delivering an additional value to the European Network. In fact for decades the traffic development in Europe was concentrated on the axis North-South and vice versa. The expansion of the European Union towards the East and the development of the new accessing Countries having above average growth rate, materialized a greater need of freight exchanges in the West-East direction and vice versa. It is through the intersection of the nodes that the North-South corridors integrate with the West-East ones giving substance to the full integration of the various corridors into the European Network.

The **MARATHON** Research has evidenced that the Shipping Lines Business Model is driven by reduction of their production costs achieved through the deployment of giant CT vessels. Most of them, in order not to be pre-emptied in the competition game by the more aggressive ones, have embarked in a colossal renewal of their fleets. At the time of writing this report about 150 new constructions have been delivered with capacity varying between 10 to 14000 TEU. A leading Shipping Line ordered to a Korean Shipyard four new CT ships of 18000 TEU capacity and ships designs are already available for vessels having capacity of up to 23000 TEU. These giant vessels produce their competitive advantage while at Sea which entails that they are calling at a fewer number of Ports where they will be performing a higher number of movements. This race towards giant tonnage is bound to bring about further changes in Ports CT handling as well as additional hinterland industrial distribution requirements to/from these Ports.

It appears obvious that in these high capacity nodal points the production tools such as gantry cranes, reach stackers, lifting equipment, maneuvering locos, etc., must allow state of the art loading/unloading and train to train operations compatible to the economies of scale of a totally industrialized production process. To this effect also the rolling stock deployed on the shuttle trains must be of the latest technology allowing **MARATHON** longer, heavier and faster trains to be operated between the serviced Sea Ports, Dry Ports or Mega Hubs. Needless to say that repair workshops for both rolling stocks and containers are available facilities at the nodal point in order to secure a continuous operation during the 24 hours production cycle.

Last but not least the **MARATHON** Project highlighted the existence of a series of bureaucratic and psychological barriers needed to be overcome. Those encountered within the **MARATHON** Project lifetime have been faced and resolved. However outside the Project boundaries both the operators and the competent Authorities have to make renewed efforts for improving the traffic fluidity. Reference is made to self-generated impediments, the "it cannot be done" syndrome. Manual, visual and physical interventions are still required in various phases of the transportation process also when new technologies, radio communications, satellite communications, video cameras remote controls, RFID bar code technologies, X-rays, E-seals, transponders, pods and similar tools make them absolutely redundant, unnecessary, costly and therefore inefficient.

The **MARATHON** market relevance elements indispensable for the Market Uptake are represented by:

- the effective costs reduction when operating the **MARATHON** trains. The costs reduction is calculated up to 30% compared to a traditional train.
- the generation of capacity on the rail tracks by assembling conventional trains into longer trains which means the liberation of trains paths on the existing rail infrastructure which in several

places in Europe is congested. The capacity generation is very substantial since the saving on capacity on the rail tracks is exceeding 50%. It is possible to run 5 **MARATHON** trains in the slot allocated to 6 conventional short trains, equating to carry more than double capacity of freight with an inferior number of trains paths.

- the capacity generation on the existing rail infrastructures is avoiding expensive new investments in new infrastructures which are not possible in the foreseeable future due to Government constraints. At best the **MARATHON** trains implementation postpones for some decades the need of any new rail infrastructure. This is a very relevant feature resolving a Budget problem at European level. The **MARATHON** trains allow the continuous efficient and effective use of the existing infrastructure for the foreseeable future.
- the timing for the commercial exploitation of the **MARATHON** trains has been indicated by SNCF as early as 2016 making the **MARATHON** longer commercially faster and heavier trains the biggest step change in rail freight development in modern time. This development is as big as the step change in air transportation when the small class jets have been replaced by the "wide bodied or jumbo jets" or in sea transportation when the 3/4000TEU vessels have been replaced on the longest sea lanes by the 14/18000 TEU vessels. It is a completely different ball game bringing about structural changes in rail freight competitiveness. Some adjustments to the rail infrastructures are however necessary although in rail terms of relatively modest nature such as lengthening the overtaking rail sidings on the corridors, modification of rail tracks length at the departing and arrival terminals and for assembly and disassembly maneuvers. The short time to market indicated by SNCF is a material proof that the used technologies are adequate for starting operations and that any further improvements on technology development from the pilot tested trials will constitute a marked improvement both in terms of service performances and safety /security.
- the **MARATHON** tested pilot trains have moreover evidenced a further benefit not planned or considered at the project conception. A saving of 10% of energy consumption has been monitored during the test. This has to be further investigated in order to scientifically understand the motivation. It is possible that the distributed power with the second locomotive in the middle of the convoy allowed a more uniform and stable energy absorption. The train driver reported that the impression was for the **MARATHON** train to proceed effortlessly. The front locomotive rather than pulling the train appeared to be pushed by it with the second locomotive undoubtedly improving the trains stability in transit.

During the **MARATHON** Project lifetime the partners realized and experimented that the space in Europe is a limited resource. The freight mobility Infrastructures are also limited and because of this they are congested most of the time. The only mode of transport capable of handling containers in an industrial way in addition to the feeder vessels and inland waterways is rail freight and rail intermodality which can be operated between the Sea Ports terminals and the Dry Ports in the hinterland and in general along the TENT T corridors network. Moreover the giant CT vessels calling at an inferior number of Ports, are handling traffic into these Ports with less optimized overland distances compared to the final destination/origin points. This process is generating a demand for longer distance transportation with an increased competitive penetration to the hinterland to and from these ports. Road distribution alone is no longer capable of dealing with this traffic demand for longer distances at competitive costs. One recommendation which has been the driver of the **MARATHON** Project itself is that rail distribution must become central in any European Port for improving traffic fluidity as from now and up to the years to come. The traffic projections 2020 clearly indicate that the expected traffic volumes can be handled only if the rail performance from the ports to the hinterland is increased very substantially.

If the above recommendation of industrial transportation by rail to/from sea ports to/from dry ports is implemented then a new recommendation is becoming apparent. The road productivity will be enhanced by concentrating on last mile distribution from Dry Ports, Mega Hubs, Freight Villages and Terminals to final destination. This is the so-called “last mile distribution”. By implementing this business model, multiple deliveries can be performed in one day from the Dry Ports on short distances, fulfilling both the objective of productivity, equipment turn around, competitiveness, cost reduction together with environment protection by extracting the best possible performance from road (co-modality).

The individual European Government budgetary constraints dictate a much stricter selection of the investment priorities. Investments in new Mega-Infrastructural Projects are to be ruled out for the immediate future, which means that the limited resources are to be channeled towards projects capable of accruing immediate results and quick capital return. The applicable principle is “maximizing the expected results with the least amount of investments”. One recommendation is to start immediately the work for utilizing better the existing resources and the **MARATHON** Project fulfill completely this task by generating extra capacity on the rail tracks. The future of rail freight is described in a sentence of a leading top Rail executive who said” it is necessary to transport more with the existing resources.” The **MARATHON** trains are capable of delivering operating costs reductions up to 30% achieving at the same time enormous saving on rail track capacity thus eliminating congestion.

The other major freight multiplier in addition to the Dry Ports, Mega Hubs, Freight Villages, which are vital for traffic bundling, is represented by the technology dimension. The technology innovation has many facets. During the **MARATHON** Project lifetime three major technology families have been implemented: the braking technology, the radio transmission technology and the ICT, intelligent management software technologies. These software and hardware technologies alone are capable of delivering the desired results when applied in the right place and at the right time. The **MARATHON** Project has identified the equipment and places where these technologies deliver their optimal performances. One recommendation emerged from the **MARATHON** demonstrations is that it is necessary to implement on the rail transport chain a much higher degree of technology innovations capable of delivering immediate benefits in a relatively short period of time. Another recommendation emerging thereof is that the problem areas is not represented by the lack of technology itself but rather more by the lack of implementation. The transport sector fragmentation is not helping either however a major technological effort made by the leading operators not only could improve the traffic fluidity but also constitute a driver towards the transport sector consolidation.

Likewise a variety of hardware technologies have been identified, tested and implemented during the **MARATHON** development process. The testing locomotives have been a major asset utilized during the project lifetime. Both electric and diesel locomotives have been used with excellent results. These were supplied by AKIEM for ALSTOM electric locomotives and by VOSSLOH for the diesel ones. The wagons for the trains consists were of the latest generation for Intermodality. However in the **MARATHON** trains conventional wagons were included carrying conventional cargo. Five conventional wagons were added at the end of the train during the first trial with the electric locomotive and eight of them during the second trial with the diesel locomotive. This has proven the solution of another major paradigm which is that the **MARATHON** trains can indeed be mixed industrial trains capable of assembling different types of cargo and by so doing reducing substantially the operating costs. This operation constituted a major step change in rail freight and another defeat for the "it cannot be done syndrome". One emerging recommendation is to take as a permanent objective the progressive modernization of the hardware and software technologies which are instrumental for implementing the management and the monitoring of the service performances in real time and at reduced costs. Transport industrialization if the name of the game with the **MARATHON** trains opening up new horizons with step changes both in technologies innovations, management systems, operating rules, substantially reduced costs, and innovative business models.

The **MARATHON** trains tested during the two executed trials were capable of assembling three traditional trains originating from Germany and destined to Spain. The trains were put at disposal by Kombiverkehr so that the tested trials could be executed not on theoretical trains but on effective traffic moving from Germany to Spain across France. Due to the fact that the tests were carried out in January and April which do not represent a high traffic season the trains were shorter that 500m long. The **MARATHON** team had to plan the addition of flat empty intermodal wagons to reach the full length of 1500m representing the **MARATHON** Project objective. During the second trial the number of empty wagons added to the **MARATHON** convoy was inferior since in April the traffic volumes had improved. In conclusion while the **MARATHON** train was planned for assembling two 750 m long trains, in practice only very few freight trains are today 750m long which means that a train of 1500 m can in fact assemble as many as three conventional or intermodal trains of up to 500 m long achieving enormous costs and capacity savings. One recommendation is to promote the extensive diffusion of The **MARATHON** TRAIN. today the technology is available for managing these trains on major European Corridors.

During the two **MARATHON** tests as described above the **MARATHON** train resulted from the assembly of three intermodal trains to which further empty flat intermodal wagons were added as well as conventional full wagons in order to reach the desired 1500 m length. The tested trial took place between Sibeling (Lyon) and Nimes in a stretch of corridor of about 300 km. The convoy travelled at speed of 100 up 120 km/h performing a series of braking operations as planned according to all possible operating conditions. The train behavior was excellent without any problem being developed. The trains constituting the marathon train were assembled in Sibeling and disassembled in Nimes. In Nimes the **MARATHON** convoy was disassembled into the original three trains formation for prosecuting the journey up to final destination in Spain. One vital and major recommendation is emerging from this very important exercise. The **MARATHON** train proved the point that the assembly and disassembly of intermodal or conventional trains or mixed trains is a very simple operation to be performed in half an hour. Such innovative approach allows that ordinary freight trains can converge in one terminal or marshalling yard for being assembled into the **MARATHON** train. The **MARATHON** train can perform the intermediate distance from terminal to terminal along a major European corridor in the same way an aircraft is linking two airports, or a vessel two sea ports. In the arrival terminal or yard the **MARATHON** train can be disassembled to form two separate trains of 750m or three trains of inferior length for prosecuting their journey to final destination. This represent an enormous flexibility and a completely new element in rail freight allow to extract the maximum benefits from transport industrialization.

One of the major problems affecting rail freight has been and still is the fragmentation of operations compared to a door to door service which can be offered by a road truck. Such fragmentation is originating from both historic and psychological barriers. Due to the continuous compression of the Supply Chain, the ultimate customers do not accept any longer that a component of their Supply Chain represented by rail is having within its own perimeter elements of disruptions. Such disruptions are caused by operations, actors, intermediaries which today do not have cause to exist. Reference is made in particular to maneuvers, handling operations, transshipment, stoppages, local rules, conflicts between governing bodies or Authorities, trade unions or private sidings consortiums. In such a confused operating theatre, each intervening actor is claiming a right of authority and a right of claiming operational dues generating costs with no value for the ultimate customers. The end results for rail are inefficient and costly operations with consequential traffic loss. All of this represents a negative heritage from the past which must be totally cancelled if rail freight is to become competitive now and in the future. The **MARATHON** Project is contributing to simplify considerably the operating theatre since the **MARATHON** train is being created for traffic industrialization. Therefore only industrial partners be them Intermodal operators, outsourcers, conventional specialized operators in steel, chemicals, cereals, minerals etc have an interest participating. One recommendation emerging from such a **MARATHON** experience is to adopt measures during the planning phase of rail freight or intermodal services capable of compacting the whole rail process into one work flow where one single operator managing the **MARATHON** train is accountable both for costs and services during the terminal to terminal operations. During the **MARATHON** tested trial SNCF took charge of both the assembling and disassembling of the three trains and of the time plan needed in order to make sure that the three original trains arrived in Spain as per their scheduled time. The end customers whose cargo was on the MARATHON train did not even imagine that their containers or conventional cargo was involved in the **MARATHON** pilot test. All the operators participating to the **MARATHON** train have a converging economic and service interest for making the success a common objective.

During the **MARATHON** Project Pilot demonstration between Terminals to Terminals it was appreciated the need to have in place repair workshops for rolling stock. In particular the efficient up-keeping of the rolling stock is an indispensable element for equipment turn around and for preventing any train stoppages while in transit. Any disruption of a 1500 m long train could be very expensive. One recommendation is therefore the presence in such terminals or marshaling yards of essential rolling stock maintenance facilities for verifying the preventive efficiency of the wagons and any emergency measures. By so doing the rail traction company in charge of moving the train, is confident that the rolling stock deployed on the service is at the required standard for performing the traction in safe condition and according to the train schedule.

The "**MARATHON**" Project has the objective of testing on the operational field longer, commercially faster and heavier trains. This will be possible thanks to new radio communication technologies, innovations on rolling stock, double traction with a second "slave" loco in the middle of the convoy, innovative braking and signaling systems. Only by lengthening the trains, the transport costs are reduced and additional capacity is generated with marginal investments. Originally the **MARATHON** Project idea was conceived thinking about the new market conditions generated by the maritime sector. During the project lifetime it was discovered that the transport industrialization is existing already in many other European economic fields which unfortunately do not communicate between themselves. They remain confined in their own specialization ignoring that the cargo they are managing can generate a lot of unexpressed value when assembled into the **MARATHON** industrial train. One recommendation is that indeed longer, commercially faster and heavier trains must be implemented on the European network not only between sea ports to/from dry ports but also by assembling in terminals and marshalling yards different types of trains going along the same corridor up to another destination terminal or yard where the disassembly can be operated for each train to reach its final destination. Industrial trains such as mineral water, beverages, steel, chemicals, plastic materials, cereals, scraps, coal, raw materials and commodities in general appear to be particularly suitable for the **MARATHON** train operation constituting mixed types of traffics converging into transport industrialization. The participating operators derive economic benefit from this initiative.

The above shows the opportunity experimented positively during the **MARATHON** Project lifetime is the cooperation amongst various actors of the Rail freight transport chain. In different geographical operational theatres several kind of cooperative approaches have been experimented with very successful results. This cooperative approach is very common and largely implemented in other modes of transport. In the maritime field slot charter agreement are common place between competitors. A similar situation is applied since decades by the airlines both in the passengers as well as in the freight traffic. Also competing organizations participate to the efficient co-loading of trucks in the LCL business. In rail freight this practice is almost unknown. One recommendation emerging thereof is the need in rail freight or intermodal traffic to adopt a much stricter cooperation amongst the key actors of the rail transport chain which is necessary for modernizing the sector. The cooperative approach is capable of managing more efficiently the available capacity and introducing new practices in the marketing and commercial organization. The commercial approach must evolve from mono-channel to a multi-channel distribution Business Model capable of achieving an effective service segmentation and a much more efficient selling penetration.

All the above recommendations equate to a major step change in the management of the rail freight traffic. In order to implement these recommendations it is necessary to adopt a new business model based on transport industrialization, economy of scale, traffic bundling and cooperative approach between the key actors of the rail transport chain. The efficient loading of the trains, the capacity management, the ICT and intelligent system technologies are all ingredients for achieving seamless transportation to an industrial scale. The multi-channel distribution approach is capable of understanding much better the ultimate customers' needs for producing services, which are instrumental for the users' problem solving have characterized rail freight up to now. One recommendation is emerging from the **MARATHON** Project. A new offer-driven Business Model is necessary compared to the old fashioned demand-driven. In the service industry, services must be available if one wants the customers to buy them. When services are not available, which is the prevailing situation in rail freight, the customers are not in a position to purchase services that do not exist. In rail freight it takes months to produce a new service being rail freight a "closed system". During such lapse of time the customer is finding new solutions, new routings which do not consider rail as a viable proposition. This still is and has been the prime cause of continuous rail freight decline. In all other transport modes be them for passengers or freight, the prevailing Business Model is offer driven. It is almost impossible to understand while in rail freight the European rail system has adopted the long term losing demand driven approach which is not responding to the customers' needs. Once the offer driven Business Model has been adopted the immediate consequence is the need to implement the "selling of capacity" through the multi-channel distribution approach and innovative marketing techniques capable of extracting from the services produced the differential value perceived by the customers. The rail operators have within their own system a very evident example of their own creation. The passengers new high speed services are offer driven, high capacity services and sales segmented with outstanding market success. These services have eliminated the airlines on medium distances through fair and effective service competition. This Business Model must also be applied to freight. The **MARATHON** train is a major step change in rail freight industrialization. It has created the same market condition similar to the change of scale in the airfreight business from ordinary plane to wide body jumbo aircraft, or in the maritime traffic between 3/4000 TEU up to 15000 TEU vessels. The **MARATHON** train of 1500 m long multiply effectively by a factor of 3 the prevailing train length in Europe of 500 m since 750 m trains are not yet so common. The step change is quite colossal.

© Vossloh

05. TABLES OF FIGURES & CHARTS, GLOSSARY, BIBLIOGRAPHY

European Commission

SEVENTH FRAMEWORK PROGRAMME

FIGURES & CHARTS

Figure 1:	Alstom Locomotive BB 37000 in service with AKIEM. - Source: Akiem for MARATHON	9
Figure 2:	Radio Rack & Slave Brake Panel. - Source: MARATHON	10
Figure 3:	Front Face Plate of MARATHON Configuration. - Source: MARATHON	11
Figure 4:	Command and Control into the Cab. - Source: MARATHON	12
Figure 5:	Operations for Coupling Two Trains. - Source: MARATHON	13
Figure 6:	Locomotive Status from Master Locomotive. - Source: MARATHON	16
Figure 7:	Train Data Selection. - Source: MARATHON	16
Figure 8:	Pantograph and Locomotive Data. - Source: MARATHON	17
Figure 9:	Electric Power Supply. - Source: MARATHON	17
Figure 10:	Strengths & Opportunities. - Source: NEWOPERA	28
Figure 11:	Weaknesses & Threats. - Source: NEWOPERA	29
Figure 12:	Functional Integration of Supply Chain (Adapted Model of Robinson). - Source: Naples Port Authority	30
Figure 13:	Containers Vessel Size Groups. - Source: Port of Hamburg Marketing	31
Figure 14:	Cellular Ship Delivery Program 2009-2013. - Source: HHM, data: AXS-Alphaliner	31
Figure 15:	World CTS Traffic Evolution. - Source: Port of Hamburg	32
Figure 16:	Port Duty Cycle Graphic Representation. - Source: NEWOPERA	33
Figure 17:	High/Medium/Low Scenario Based on CAGR and GDP for Port of Hamburg. - Source: TIGER Project	34
Figure 18:	High/Medium/Low Scenario Based on CAGR and GDP for Bremerhaven Port. - Source: TIGER Project	34
Figure 19:	High Medium Low Scenario Based on CAGR Methodology for the Jade-Weser-Port. - Source: TIGER Project	35
Figure 20:	High/Medium/Low Scenario Based on CAGR and GDP for Genoa Port. - Source: TIGER Project	35
Figure 21:	High/Medium/Low Scenario Based on CAGR and GDP for Gioia Tauro Port. - Source: TIGER Project	36
Figure 22:	High/Medium/Low Scenario Based on CAGR and GDP for Taranto Port. - Source: TIGER Project.	36
Figure 23:	Megahub & Dry Ports Envisaged Service Solutions. - Source: TIGER Project	37

Figure 24:	Mega Hub & Dry Ports Service Solutions. - Source: TIGER Project	38
Figure 25:	Hamburg Rail Service reach & Dry Ports “Distant Approach”. - Source: NESTEAR	38
Figure 26:	Hamburg Rail Services and Dry Ports “Near Approach”. - Source: NESTEAR	39
Figure 27:	Genoa Rail Service Reach and Dry Ports Approach. - Source: NESTEAR	39
Figure 28:	Taranto & Gioia Tauro Rail Services and Dry Ports approach. - Source: NESTEAR	40
Figure 29:	NEWOPERA Rail Network & Intermodal Terminals. - Source: NEWOPERA Project.	41
Figure 30:	Traditional Flows North-South Supplemented by East-West. - Source: NEWOPERA	42
Figure 31:	VR with PGK Rail Network towards Russia. - Source: VR	42
Figure 32:	Transport Modal Split in Europe. - Source: Eurostat	43
Figure 33:	ROUTE Asia-Europe. - Source: TRACECA	43
Figure 34:	Intermodal Traffic Projections to 2020. - Source: KV	44
Figure 35:	Potential Products Description & Growing Potential. - Source: Newopera Project	47
Figure 36:	Basic Steps to MARATHON Asset Based Business Model. - Source: Newopera Aisbl	50
Figure 37:	From Status Quo to End Results of MARATHON Asset Based Business Model. - Source: NEWOPERA Aisbl.	51
Figure 38:	Old Conventional Traffic Scheme Compared to New Industrialized Approach between Hubs. - Source: NEWOPERA Aisbl.	53
Figure 39:	Industrialized Single Wagon/Group of Wagons Service Applied to Real Business Case. - Source: NEWOPERA Project.	53
Figure 40:	Visualization of the Advantages of the Future Cooperation Strategy in the Full Transport Chain. - Source: NEWOPERA Aisbl.	55
Figure 41:	MARATHON Proposal of Trans European Corridors for Longer, Commercially Faster Heavier Trains. - Source: MARATHON	59
Figure 42:	Geographical Position of the 3 Corridor Case. - Source: SNCF	61
Figure 43:	Capacity Assessment on Selected Corridors - Baseline Scenario. - Source: MARATHON	62
Figure 44:	Capacity Assessment on Selected Corridors –104 Scenario. - Source: MARATHON	63

Figure 45:	Cross Matrix: Modifications Impact towards System Functions. - Source: MARATHON	66
Figure 46:	Preliminary Brake Architectural Overview. - Source: MARATHON	72
Figure 47:	Conductor Actions. - Source: MARATHON	73
Figure 48:	A Radio System RCU: Communication between Two Trains Sections. A Distributed Control Power Unit DPCU in Charge of Ensuring a Gateway between Existing Locomotive Certified & Radio Data Transmission System. - Source: MARATHON	76
Figure 49:	Electrical Interfaces between Sub-systems. Interfaces Between Radio RCU-1 and DPCU. - Source: MARATHON	77
Figure 50:	System Attributes(RAMS). - Source: MARATHON	78
Figure 51:	The Antenna connections. - Source: MARATHON	80
Figure 52:	Serial Link for Cmd & Control LOCOMOTIVE. - Source: MARATHON	80
Figure 53:	The Serial Link for Cmd of Brake System Adapted with Specific Ethernet Cable between DPCU-1 & DPCU2 Modules with M12 Connection. - Source: MARATHON	81
Figure 54:	Safety Loop. - Source: MARATHON	82
Figure 55:	System Evolution. - Source: MARATHON	82
Figure 56:	Experiments report. - Source: MARATHON	96
Figure 57:	Examples of Different Transmission Commands in a MARATHON Train. - Source: MARATHON	99
Figure 58:	Example of communication between two locomotives via MARATHON. - Source: MARATHON	100
Figure 59:	Traction Command Interfaces. - Source: MARATHON	101
Figure 60:	Brake Command Interfaces. - Source: MARATHON	103
Figure 61:	Put into service & manage modes. - Source: MARATHON	103
Figure 62:	Control high Voltage Power Supply. - Source: MARATHON	104
Figure 63:	Architecture Alstom BB3700. - Source: Faiveley for MARATHON Project	107
Figure 64:	Traction signals - Lead Locomotive. - Source: MARATHON	108
Figure 65:	Traction Signals - Trail Locomotive. - Source: MARATHON	108
Figure 66:	Pantograph Management Signals-Lead Locomotive. - Source: MARATHON	109
Figure 67:	Pantograph Management Signals – Trail Locomotive. - Source: MARATHON	110
Figure 68:	Traction Demand – Lead Locomotive. - Source: MARATHON	111

Figure 69:	Traction Demand – Lead Locomotive. - Source: MARATHON	112
Figure 70:	Architecture Vossloh. - Source: Faiveley for MARATHON Project	113
Figure 71:	Hardwired signals – Lead locomotive. - Source: MARATHON	114
Figure 72:	Hardwired signals – Trial locomotive. - Source: MARATHON	115
Figure 73:	MARATHON Brake System. - Source: MARATHON	116
Figure 74:	MARATHON Brake Panel. - Source: MARATHON	117
Figure 75:	Compatibility I/Os to SIL2/SI. - Source: MARATHON	120
Figure 76:	LocCom 102. - Source: Faiveley for MARATHON Project	121
Figure 77:	CAN interface. - Source: MARATHON	122
Figure 78:	Configuration and Telegrams transmission. - Source: MARATHON	123
Figure 79:	DCPU network. - Source: MARATHON	123
Figure 80:	DCPU Interfaces. - Source: MARATHON	124
Figure 81:	Measured Results. - Source: MARATHON	124
Figure 82:	Alstom Signals. - Source: MARATHON	125
Figure 83:	Vossloh Signals. - Source: MARATHON	126
Figure 84:	Composition. - Source: MARATHON	133
Figure 85:	Composition. - Source: MARATHON	135
Figure 86:	Train Simulation lay-out. - Source: MARATHON	136
Figure 87:	Distributor Valve. - Source: MARATHON	137
Figure 88:	leak test procedure. - Source: MARATHON	137
Figure 89:	Brake Application. - Source: MARATHON	138
Figure 90:	Brake Application. - Source: MARATHON	138
Figure 91:	Brake Application. - Source: MARATHON	139
Figure 92:	Brake Application. - Source: MARATHON	139
Figure 93:	Brake Application. - Source: MARATHON	140
Figure 94:	Brake Application. - Source: MARATHON	140
Figure 95:	Brake Application. - Source: MARATHON	141
Figure 96:	Brake Application. - Source: MARATHON	141
Figure 97:	Brake Application. - Source: MARATHON	142
Figure 98:	Main Drivers for Change. - Source: MARATHON	144

Figure 99:	Stakeholders Benefits and Advantages. - Source: MARATHON	147
Figure 100:	Basic Steps to MARATHON Asset Based Business Model. - Source: Newopera Aisbl	148
Figure 101:	The MARATHON Train Composition. - Source: MARATHON	149
Figure 102:	Railways Operators Cost Category. - Source: MARATHON	150
Figure 103:	Infrastructure Managers Costs Category. - Source: MARATHON	150
Figure 104:	Rolling Stock & Equipment Manufact. Cost Category. - Source: MARATHON	151
Figure 105:	Users Cost category. - Source: MARATHON	151
Figure 106:	Theoretic MARATHON Scenario. - Source: MARATHON	154
Figure 107:	Business Case scenario. - Source: MARATHON	155
Figure 108:	Wagons Charact. on MARATHON Train Coupling. - Source: MARATHON	156
Figure 109:	The MARATHON Train Exemplary Corridor. - Source: MARATHON	157
Figure 110:	MARATHON Train Characteristics. - Source: MARATHON	157
Figure 111:	Theoretical MARATHON Scenario. - Source: MARATHON	158
Figure 112:	Open Track Process: Input – Simulation – Output. - Source: MARATHON	160
Figure 113:	Example of a Station Network. - Source: MARATHON	160
Figure 114:	Train Diagram. - Source: MARATHON	162
Figure 115:	Speed-distance profile. - Source: MARATHON	162
Figure 116:	Theoretical MARATHON Scenario. - Source: MARATHON	163
Figure 117:	Theoretical MARATHON Scenario. - Source: MARATHON	163
Figure 118:	Open Track MARATHON Simulation Scenario. - Source: MARATHON	163
Figure 119:	Simulation Scenario 1. - Source: MARATHON	165
Figure 120:	Possible Timetable Scenario 1. - Source: MARATHON	165
Figure 121:	Simulation Scenario 2. - Source: MARATHON	166
Figure 122:	Possible Timetable Scenario 2. - Source: MARATHON	167
Figure 123:	Simulation Scenario 3. - Source: MARATHON	167
Figure 124:	Possible Timetable Scenario 3. - Source: MARATHON	168
Figure 125:	Simulation Scenario 4. - Source: MARATHON	168
Figure 126:	Possible Timetable Scenario 4. - Source: MARATHON	169
Figure 127:	Theoretical MARATHON Scenario. - Source: MARATHON	169

Figure 128:	MARATHON Case Personnel & Infrastructure Costs. - Source: MARATHON	171
Figure 129:	MARATHON Case Total Costs. - Source: MARATHON	171
Figure 130:	Marginal ENPV SC-A. - Source: MARATHON	172
Figure 131:	ENPV SC-A. - Source: MARATHON	172
Figure 132:	ENPV SC-B. - Source: MARATHON	173
Figure 133:	Surplus generated by MARATHON. - Source: MARATHON	173
Figure 134:	MARATHON Supply & Demand Estimation. - Source: MARATHON	174
Figure 135:	MARATHON Solution, Personnel & Infrast. Costs. - Source: MARATHON	174
Figure 136:	MARATHON Solution, Total Costs. - Source: MARATHON	175
Figure 137:	MARATHON Case, Invest: Costs & Train Numbers. - Source: MARATHON	175
Figure 138:	Marginal ENPV SC-B. - Source: MARATHON	176
Figure 139:	ENPV SC-B. - Source: MARATHON	176
Figure 140:	Financial ENPV Comparison. - Source: MARATHON	177
Figure 141:	MARATHON Surplus for Price Reduction. - Source: MARATHON	177
Figure 142:	MARATHON Case Supply & Demand. - Source: MARATHON	178
Figure 143:	MARATHON SC-C, Personnel & Infrastructure Costs. - Source: MARATHON	178
Figure 144:	MARATHON SC-C, Total Costs. - Source: MARATHON	179
Figure 145:	MARATHON SC-C Invest. Costs & Train Numbers. - Source: MARATHON	179
Figure 146:	Marginal ENPV SC-C. - Source: MARATHON	180
Figure 147:	Financial ENPV SC-C. - Source: MARATHON	180
Figure 148:	Environment Costs per Scenario. - Source: MARATHON	181
Figure 149:	Environmental Relative ENPV Comparison. - Source: MARATHON	181
Figure 150:	MARATHON Environmental ENPV Comparison. - Source: MARATHON	182
Figure 151:	Climate Change Road Versus Rail. - Source: MARATHON	182
Figure 152:	Air Pollution Road Versus Rail. - Source: MARATHON	183
Figure 153:	Noise Pollution Road Versus Rail. - Source: MARATHON	183
Figure 154:	Marginal Environment ENPV. - Source: MARATHON	184
Figure 155:	Environment ENPV. - Source: MARATHON	184
Figure 156:	Accident Costs. - Source: MARATHON	185
Figure 157:	Social Relative ENPV Comparison B) & C). - Source: MARATHON	185

Figure 158:	Social ENPV Comparison B) & C). - Source: MARATHON	186
Figure 159:	Accident Costs. - Source: MARATHON	186
Figure 160:	Marginal Accident Costs Savings. - Source: MARATHON	187
Figure 161:	ENPV. - Source: MARATHON	187
Figure 162:	Marginal ENPV SCV-A. - Source: MARATHON	188
Figure 163:	ENPV SC-A. - Source: MARATHON	188
Figure 164:	Marginal ENPV SC-B. - Source: MARATHON	189
Figure 165:	ENPV SC-B. - Source: MARATHON	189
Figure 166:	Marginal ENPV –SC-C. - Source: MARATHON	190
Figure 167:	ENPV SC-C. - Source: MARATHON	190
Figure 168:	Overall ENPV. - Source: MARATHON	191
Figure 169:	Overall Relative ENPV Comparison. - Source: MARATHON	191
Figure 170:	Overall ENPV Comparison. - Source: MARATHON	192

GLOSSARY

ABS	Ausbaustrecke (Upgrading of existing lines)
ARA Range	Antwerp - Rotterdam - Amsterdam range ports
CAGR	Compound Annual Growth Rate
CEFIC	European Chemical Industry Council
COMEXT	EUROSTAT Database
CTS	Containers
DB	Deutsche Bahn
DBNetz AG	German Railway Infrastructure
EDP	Electronic Data Processing
ESS	Extra Slow Steaming
ETA	Expected Time of Arrival
ETCS	European Train Control System
ETD	Expected Time of Departure
EUROSTAT	European Statistic Organization
FP	Framework Program
GDP	Gross Domestic Product
GNP	Gross National Product
GPA	Genoa Port Authority
HHLA	Hamburg Hafen und Logistik AG
HHM	Hamburg Hafen Marketing
HPA	Hamburg Port Authority
IMCO	International Maritime Organization
LKW-MAUT	Truck toll in Germany
MRTH	MARATHON project code on the repository
NBS	Neubaustrecke (New Rail Line)
NEWOPERA	FP6 European Commission Project - New European Wish: Operating Project for a European Rail Network
O/D	Origin/Destination
OSS	One Stop Shop
RFI	Rete Ferroviaria Italiana

Ro/Ro	Roll On/Roll Off
S&C	Signal and Control
SPC	Single Point of Contact
SWOT	Strength, Weaknesses, Opportunities, Threats
TCT	Taranto Container Terminal
TEN-T	Trans European Transport Network
TEU	Twenty Too Foot Equivalent Unit
TIGER	Transit via Innovative Gateway concepts solving European intermodal Rail needs
TRACECA	TRAnsport Corridor Europe-Caucasus-Asia
UIC	Union Internationale des Chemins de fer
UIRR	Union internationale des sociétés de transport combiné Rail-Route
WP	Work Package

BIBLIOGRAPHY

- NEWOPERA Project Final Report Book, Editor Franco Castagnetti, 2008.
- TIGER Project Final Report Book , Editor Franco Castagnetti, 2012
- TIGER DEMO Project Final Report Book, Editor Franco Castagnetti 2013
- Prof. Peter Klaus(em) D.B.A./Boston University M.Sc.(Transp) MIT/Cambridge/Mass. Dipl.-Kfm FRIEDRICH-ALEXANDER UNIVERSITAT Erlangen-Nürnberg
- Naples Port Authority, 2010
- ESPO "Economic Analysis of the European seaport system", Prof. Dr. Theo Notteboom, ITMMA 2009.
- European Freight and Logistics Leaders Forum F&L, Working Group on Port Congestion Report, 2009
- EUFRANET Project Final Report, 2001
- HHM, "The Principle of Traffic Growth", 2010
- IMF "World Economic Outlook Update", 2009
- HHM, "European Ports Container throughput 2003-2008", 2010
- AXS-Alphaliner, 2010
- Hamburg Port Authority 2009
- Bremen ports, www.bremenports.de, Germany, 2009
- Ports Handbook Bremen & Bremerhaven, Imprint: Bremen ports, 2008
- Valencia Port Authority, 2010
- Genoa Port Authority, 2009/2010
- Medcenter Container Terminal, 2010
- Assologistica Report, 2010
- Taranto Port Authority, 2010
- Gioia Tauro Port Authority, "The three-year operational plan 2010-2012"
- EUROSTAT Database, 2000/2007
- EUROSTAT COMEXT O/D Databases, 2009
- NESTEAR Mathematical Model 2010
- German Trade and Invest, 2010
- Süddeutsche Zeitung, Chinas Export boom, 2010
- China national customs authority statistics, 2010
- China Ports Statistics, 2010
- Deutsche Bank Research, 2010
- Rheinisch-Westfälische Institut für Wirtschaftsforschung, 2010
- Handelsblatt, 2010
- Hamburger Abendblatt, 2010
- ISTAT, 2010
- Der Senator für Wirtschat und Häfen, Freie und Hansestadt Bremen , Hafenspiegel 2009
- Neue Presse, 2010
- Deutsche Verkehrs Zeitung, 2010
- SPD "Bahnanschluss für Jade-Weser-Port", 2010
- International Transport Forum, Leipzig 2009

- EU Economic projections 2010
- World Bank economic projections, 2009
- EUROPEAN COMMISSION Mobility Policy Documents and Literature
- DG ECFIN, 2009
- EU White Paper projections 2010/2020
- DG TREN scenarios 2007 up to 2030
- ISEMAR, 2009/2010
- MARATHON Project partners' contributions of intelligence, technological discoveries innovations, operating guidelines and operating solutions for applied technologies

This **MARATHON** Handbook is aiming at providing data, facts, figures, freight mobility researches, traffic projections, suggestions and recommendations for supporting European institutions, Governments, Decision makers, Infrastructure managers, Operators, Port management, Railway undertakings, Dry Ports and Service providers as well as Intermodal operators in making the correct choices towards the fulfillment of an efficient and effective European freight mobility policy, it is hoped that this objective has been achieved.

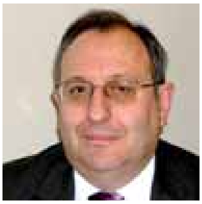
Franco Castagnetti
MARATHON Project Leader

Armand Toubol
MARATHON Technical Coordinator

→ **Franco Castagnetti**
MARATHON Project Leader
NEWOPERA Aisbl President

NewOpera Aisbl founder and President, F&L founder. Former Director of Procurement & SC Management of Polimeri Europa Milano (ENI Group), Former Managing Director of CNM shipping line, Former COO of Merzario forwarding Group. Former member of the EU Freight Freeways Kinnock's advisory Team, + EU /USA Task Force Intermodality. ERRAC Steering Committee Member, Former BAC NorthWestern University Evanston USA. Alumno of the Columbia University-Business School, New York.

NEWOPERA FP6 Project Manager, FP7 Tiger-Tiger Demo MARATHON Spider Plus Projects leader.



→ **Armand Toubol**
MARATHON Project Technical Coordinator
NEWOPERA Aisbl Vice-President

NewOpera Aisbl founder and Vice President F&L Honorary member. Chairman of Rail Transport Sub Committee for 2030/2050 vision under the French Prime Minister Authority. Former Freight Director of SNCF Former Chairman and CEO of SNCF Participations. Former Chairman of CNC and CEO of SNCF Armement Navale Board member of GEODIS, ERMEWA, TRANSFESA, Ex Director of Dunkirk Port Auth. ex V/chairman of Intercontainer/ Interfrigo. Chairman Of PREDIT for Transp. Technology. Graduate in Civil Engineering at the Ecole Nationale des Ponts et Chaussées. Alumno of Polytechnique Paris.

NEWOPERA Aisbl – BRUSSELS
www.marathon-project.eu

NEWOPERA

Akiem

Faiveley

UNIFE

FS LOGISTICA

Réseau Ferré de France

Kombiverkehr

Schweizer Electronic

SNCF

TOR VERGATA

Alstom

Royal Institute of Technology

Createch

D'APPOLONIA

UIC

Vossloh

TRAFIKVERKET