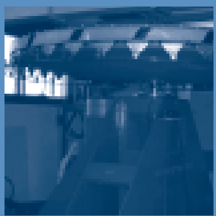
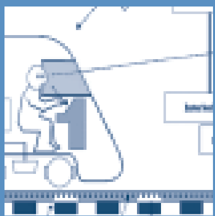
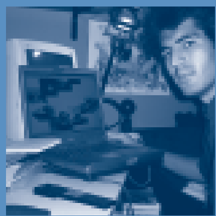
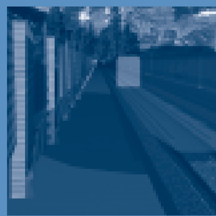
PROJECT 2









I-TRAILS

ITALIAN HIGH SPEED RAILWAYS

project 2

I-TRAILS - Italian High Speed Railways

Impact assessment of new technologies on the High Speed/High Capacity network, currently under construction and partially operating

PRINCIPAL ACADEMIC TUTOR

Stefano Bruni
Mechanics, Politecnico di Milano

ACADEMIC TUTORS

Bruno Dalla Chiara
Transport and Civil Infrastructures, Politecnico di Torino

Renato Manigrasso
Mechanics, Politecnico di Milano

EXTERNAL INSTITUTIONS

Gruppo FS - Ferrovie dello Stato
RFI - Rete Ferroviaria Italiana
Trenitalia

EXTERNAL TUTORS [TEAM A]

Biagio Costa [principal]
Umberto Foschi
Luigi Debertol
Chiara Iommazzo
Diego Schiavoni
Marta Stellin

EXTERNAL TUTORS [TEAM B]

Giovanni Costa [principal]
Lucia Coa

EXTERNAL TUTORS [TEAM C]

Gianfranco Cau [principal]
Francesco Romano

TEAM A

Andrea Maria Antigone Barbera
[Team controller, Project Communication Coordinator]
Aerospace Engineering

Christian Burrows
Computer Engineering

Gianmarco Gaviglio
Telecommunication Engineering

Tommaso Mandorino
Telecommunications

TEAM B

Daniele Tosi [Team controller]
Telecommunication Engineering

Daniele Andreola
Civil Engineering

Francesco Polidoro
Aeronautical Engineering

Alessandro Zurlo
Civil Engineering

TEAM C

Francesco Fumarola [Team controller]
Mechanical Engineering

Emmanuela Confalonieri
Mechanical Engineering

Daniel Tiago Guzzafame
Aerospace Engineering

Matteo Lombardi
Mathematical Engineering

Francesco Secondino
Electrical Engineering

PROJECT DESCRIPTION

THE CHALLENGE

The general aim of this project is challenging our teams with the application of some of the main concepts treated by ASP like, for instance, the management of complex systems, the theory of decision, the technical design of a High Speed (HS) line and network. The project is carried out under the tutorship of engineers and professionals working for the "FS" Group (the main Italian Railway company). A railway network – especially a HS one – is by nature a complex and multidisciplinary system where the evaluation and optimisation of safety, quality, performance and cost efficiency involves a variety of disciplines, such as: mechanical, electric and aerospace engineering for the train design; telecommunications and computer engineering for the signalling systems; civil engineering for the infrastructure design. Moreover, economic and management skills are required to achieve significant results.

THE TEAMS

Three teams formed by ASP students – each one focusing on a specific theme – dealt with the topics mentioned above.

Team A was assigned with the theme 'Safety and quality of the signalling systems'. Specific task of the team was to carry out a cost-benefit analysis of several technological options (ERTMS/ETCS Level 1 with or without infill, Level 2 and Level 3) for the signalling system of the Direttissima HS line connecting Rome to Florence.

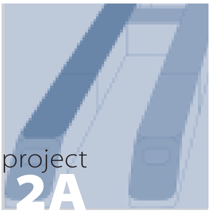
Team B dealt with the economic, environmental and public impact of the Mi-To HS line, including also the technical features (sleepers) and a comparison with an alternative option consisting in building a railway line mainly dedicated to freight transport instead of a HS line, as sometimes part of the public suggests.

Team C focused on the rolling stock, with specific reference to general vehicle architecture, the electric traction equipment, the mechanical performances and economical issues, such as the cost per passenger and per km travelled. Alternative HS train architectures, like those currently adopted in Italy, in France, in Germany and Spain were compared too.

THE RESULTS

The students achieved a thorough understanding of the HS as a whole: its strong and weak points, the critical role played by some disciplines and know-how and the potential of several enabling technologies. Furthermore all the evaluations, comparisons and cost benefit analysis performed by the teams offered a new and original point of view over these subjects, and thus they were highly appreciated by the FS group that ordered the project.

The Team A demonstrated on solid grounds that the ETCS Level 1 with double infill solution is able to provide good performances and, most important, to satisfy interoperability requirements with reduced costs. The Team B provided a detailed study of structure, acoustic and electromagnetic issues and proposed interesting solutions. The Team C completed a thorough overview and analysis of the existing and future HS trains and put forward strong arguments supporting the solutions for the train configurations that best suite the Italian HS Railways.



Interoperable signalling system on the Direttissima Roma-Firenze

_I-TRAILS_Italian High Speed Railways

ABSTRACT

When dealing with railways, the most important aspect to be considered is safety. Signalling systems have been created exactly for this purpose: they communicate the drivers that the way is clear and alert them if obstacles are approaching so that they have all the time and space needed to brake. In particular, trains running at 250 km/h may require more than 5 km to stop, therefore drivers cannot rely merely on their sight to detect obstacles. The Direttissima is a high speed railway connecting Rome to Florence; it uses a domestic proprietary signalling system, so foreign trains are not equipped for travelling on it. In order to allow transport of people and goods through international corridors, a standardized European signalling system – known as ERTMS/ETCS – has been developed, but several levels of implementation exist. The main task of the team is to compare these levels of implementation and understand which one best enhance the Direttissima. Two levels of implementation are taken into account: level 2 (L2) and level 1 (L1) with radio infill. The choice is based on the following analysis: performance, norms, telecommunications, technology and economics. A great importance is given to the performance analysis, carried out with qualitative, theoretical and simulative approaches, that employs also a numerical train simulator developed by the team. The ultimate solution is L1 with radio infill, because its only negative aspect concerns to the standards. Finally, the report indicates how the system can be concretely applied to the Direttissima.

TASKS & SKILLS

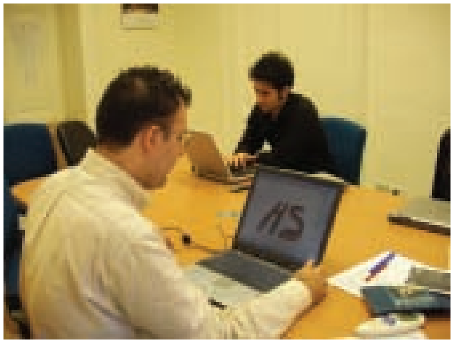
Andrea Maria Antigone Barbera programmed the capacity simulator and was the group budget manager.

Christian Burrows was responsible for Signalling and Technology along with Gianmarco Gaviglio. He took care of the theoretical aspects of line capacity and studied in depth the current Rome-Florence railway line.

Gianmarco Gaviglio was responsible, along Christian Burrows, for Signalling and Technology. Moreover, he studied toroughfully ERTMS/ETCS and took charge of the economical analysis.

Tommaso Mandorino, experienced in telecommunications engineering, contributed to the compiling aspects related to the technical norms of the project.

1 *Front view of an ETR 500, the most famous interoperable train running on Italian High Speed Railways*



2 *Andrea Barbera and Tommaso Mandorino at work in the central RFI offices in Rome, at the Ministero dei Trasporti.*

UNDERSTANDING THE PROBLEM

When dealing with railways, the most important aspect to be considered is safety. Signalling systems have been created exactly for this purpose: they communicate the drivers that the way is clear and alert them if obstacles are approaching so that they have all the time and space needed to brake. In particular, trains running at 250 km/h may require more than 5 km to stop, therefore drivers cannot rely merely on their sight to detect obstacles. The Direttissima is a high speed railway connecting Rome to Florence, that was completed about 20 years ago. It allows trains to run at speeds up to 250 Km/h, but it uses a domestic proprietary signalling system known as BAcc (with the addition of SCMT), so foreign trains, not equipped with the required onboard hardware, cannot travel on the line.

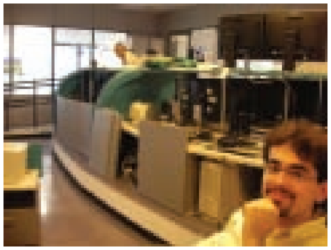
Since 1992 Maastricht Treaty, the European Union has been promoting interoperability to allow transport of people and goods through international corridors; for this purpose a standardized European signalling system has been developed. This system is known as ERTMS/ETCS (European Rail Traffic Management System / European Train Control System), but several technological level of implementation exist (Levels 1 to 3, abbreviated in L1 to L3). Our project work consists mainly in comparing these levels of implementation and understand which one would best suite the Direttissima. Note that the new Direttissima should be able to support trains equipped with either BACC/SCMT and/or ERTMS/ETCS, i.e. the new interoperable signalling system should coexist with the old one.

EXPLORING THE OPPORTUNITIES

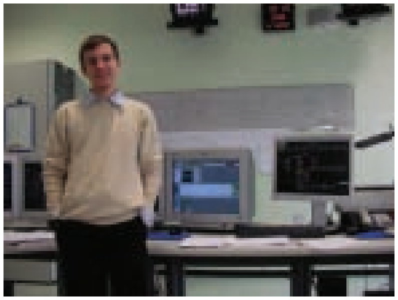
ERTMS/ETCS employs both onboard interfaces and external trackside equipment, which communicate in different ways.

For L1 this communication occurs through antennas, known as *balises*, positioned along the track between the rails. As balises are positioned at a certain distance from each other (for example 1350 m) the information stream towards the train is not continuous. According to Italian standards, it is not safe to allow a train driver to rely only on the information displayed onboard, so he/she has to look also at the trackside signals (lights and signs), that must be present. Due to this fact and to normative constraints, trains equipped with L1 cannot safely reach the highest speeds the Direttissima was designed for, being limited to 150 km/h. As a consequence, plain L1 was immediately discarded from the available options.

Balises information may be however integrated with continuous information, thereby making lineside signals optional and allowing trains to run at higher speed. This integration is called 'infill' and can be sent through radio waves (Euroradio), a codified electric current through the track (Euroloop), or additional infill balises positioned between the main balises (in this case infill is only semi-continuous). As to the choice of the infill to adopt in case of L1, we can say that it is a simple task, because Euroloop has a good chance of interfering with the existing signalling system and a radio coverage on the Di-



3 *Gianmarco Gaviglio in the central control room in Roma Termini station, where the entire High Speed Rome-Naples Railway is supervised*



4 *Christian Burrows in front of the monitors of an interlocking*

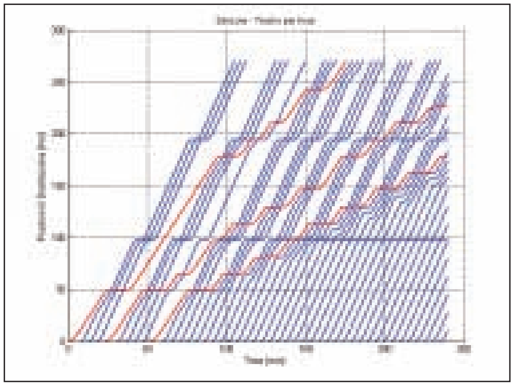
5 *The cockpit of an ETR 500 during our educational run of the Turin-Novara High Speed Railway*

rettissima is already present, while the semi-continuous infill given by additional balises is inadequate to allow high speeds according to Italian regulations. The most reasonable option is then the employment of Euroradio Infill.

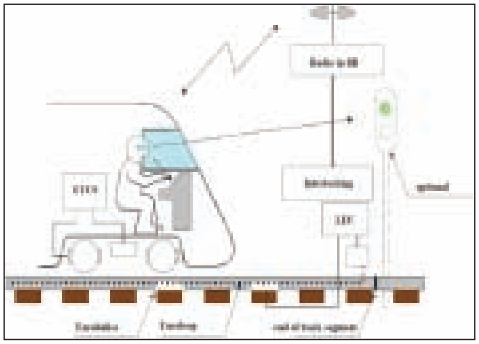
L2 also uses balises along the track, but these have a minor role, since most data are transferred through GSM-R, a centralized telecommunication system, based on the GSM wireless communication technology. This allows a continuous trains supervision.

Although ERTMS L3 significantly differs from previous levels and greatly increases the line capacity through the so called "mobile block", it is not a viable option at the moment, because of the huge costs that would be involved to warrant not only adequate safety but also technological and normative changes. It is important to understand that for RFI safety always comes first, so the least changed the better, especially to assure that the strictest safety levels are observed. Finally, between L1 with radio infill and L2 we chose ERTMS/ETCS L1 with radio infill, after having carried out an accurate analysis of some important aspects reported below.

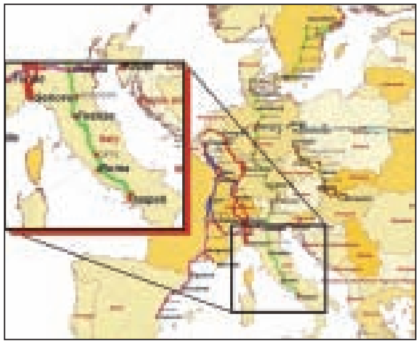
- **Performance** We estimated it by qualitative, theoretical and simulative analysis. As far as theoretical analysis is concerned, it is interesting to note that our results are quite different from those reported previuosly in literature, as we do not agree with many simplistic assumptions made in the past. Quantitative performance evaluation was undertaken by a numerical simulator (SimLine) written by the team to model practical situations over the Direttissima as a whole, including both cargo and passenger trains. These three evaluation methods gave adequately coherent results: L1 with radio-infill guarantees a performance very similar to that of L2, at least in a standard situation. L1 and L2 differ substantially in case of degradation: if the radio resource (Euroradio) is unavailable, L2 cannot work at all, dramatically impacting on traffic circulation since trains must run at speeds of 30 km/h or less, if they cannot resort to other alternative traditional signalling systems. On the other hand, L1 with infill can work even if infill is temporarily unavailable, although speed is limited to 150 km/h.
- **Standards**: this is the only negative aspect. Norms have been already written for L2 but not for L1 yet, so it is necessary to write them starting from scratch. However, it is possible to exploit the experience made in writing L2 standards to shorten the whole work. Note that for level 2 a significant problem is the possible discordance of the existing trackside signalling from the information displayed on the train. We indicated several solutions to this problem even though not in details, because this was not the level we decided to examine.
- **Telecommunications and technology**: balises currently installed on



6 *An output graph of our simulator SimLine, with time traces of freight (in red) and passenger trains (in blue)*



7 *Scheme of the European Rail Traffic Managment System / European Train Control System Level 1 with radio infill, our selected interoperable signalling system for the Direttissima Roma-Firenze*



8 *The Direttissima Rome-Florence Railway as a part of the European interoperable network*

the Direttissima for the SCMT signalling system can be reused for both L1 and L2. The current radio coverage is sufficient for L1 with infill but not for L2. On the other hand, L2 has already been tested and applied on other Italian High Speed lines, such as the “Roma-Napoli” and the “Torino-Novara”, while it would be the first application of L1.

- **Economics**: installation and maintenance costs estimate. It must be noted that this project involves large amounts of money, close to national financial acts. Global costs, including installation process and 20-years maintenance, are much lower for L1 with radio infill: 90 M€ versus 138 M€ for L2.

A further comparison concerns slowdowns. While with L1, even with infill, it is necessary to send a maintenance team onto the track to position signals or balises that alert incoming trains of the presence of slowdowns, for L2 all slowdowns can be remotely set up from the central station as soon as they are needed, and can be removed as quickly. We thought of an alternative solution that employs additional permanent balises, connected to a dedicated central apparatus, to offer a performance similar to L2, but it is too complex and costly to be a viable slowdowns management system.

GENERATING A SOLUTION

The last part of our project focused on the migration strategy required to adopt the new signalling system, exposing in details, from a technical point of view, what can be kept and what needs to be changed.

- **To be changed/new**: radio infill units.
- **Not to be modified**: telecommunication system, central apparatuses, thermal survey equipment and trackside signalling.
- **Might be varied**: balises and power supply.

We then proposed how to write dispositions and technical specifications for L1 with radio infill, based on the existing norms for L2. The number of norms is titanic but we focused only on those that needed to be modified. Where possible, we suggested modular parts in order to exploit them also for other uses.
Finally, we used our SimLine software to find the best strategy for cargo transport, and closed the report with our conclusions.

project
2B

The impact

ABSTRACT

In the recent years, high Speed Railway Lines has represented one of the most important technological and socio-economical challenge. Considering the European background, the realization of the Lisbon-Kiev Corridor V - a fast transportation track interconnected with all the principal poles through an efficient mobility network - requires the integration of the Italian railway system with a new High-Speed/High-Capacity line across the Turin-Milan-Venice route, the AV/AC – Alta Velocità/Alta Capacità. The aim of this project is to perform a feasibility analysis of the Turin-Milan AV/AC railway line, from the social, economical and environmental impact point of view.

Firstly, considering the reduction of travel durations along the route (-33%) and the increased capacity of the transportation system, we outlined a new scenario including the transportation improvements due to the High Speed railway introduction. Hence, we were able to determine the social and economical effects, both in short and long time, on the Turin-Milan bipole and the surrounding territories: the AV/AC allows a large scale rearrangement of the mobility network, paves the way for a more efficient exploitation of people's services and raise the competitiveness of Italian industries by speeding up goods transportations.

Then, we focused on the environmental impact of the AV/AC, investigating the nature of acoustic noise and the sources of vibration, and designing a set of specific countermeasures to minimize its impact. Our goal was to jointly optimize several aspects (noise barriers, anti-vibration sleepers, noise reduction on the rolling stock) by analyzing the cost related to every component and their impact on the overall noise reduction. In particular, this analysis relies on the design of a new kind of noise barrier, allowing an excellent noise reduction with a low aesthetic impact. We were then able to define an intervention strategy to be applied for minimizing the environmental impact of the High Speed railway line.

TASKS & SKILLS

Daniele Andreola dealt with the socio-economic impact of the AV/AC and with the noise pollution perception and its countermeasures.

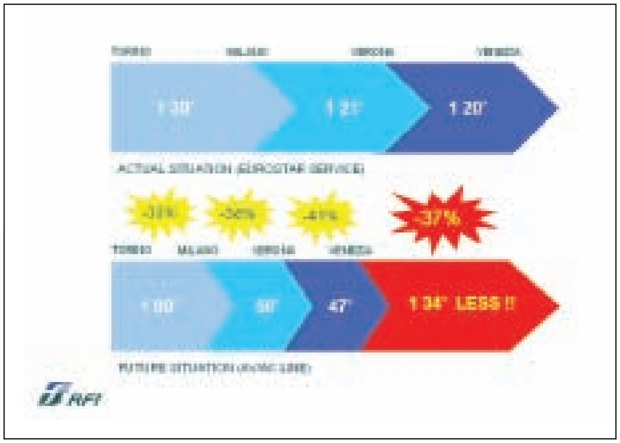
Francesco Polidoro designed, simulated and characterized our high-quality noise barriers and assessed a cost-benefit analysis for environmental impact.

Daniele Tosi investigated the electromagnetic interference of AV/AC system and subsystems, and studied the social benefits and the catchment area of the infrastructure.

Alessandro Zurlo dealt with the structural problems of the railway line and analyzed the environmental noise impact.

1 *Corridor V from Lisbon to Kiev*

SOURCE: RFI



2 *Reduction in time thanks to the AV/AC railway line*

THE AV/AC SOCIO-ECONOMICAL IMPACT

The considerable reduction in travelling time is the most evident aspect related to the AV/AC railway line infrastructure. The actual Eurostar service requires about 4 h 10' for going from Turin to Venice – 1 h 30' from Turin to Milan – and the introduction of the High Speed service would save approximately 1 h 30', i.e. the 37% of the whole travelling time – from Turin to Milan the reduction is about 30' (–33%). Yet, the other peculiar feature is the High Capacity of the infrastructure both for passenger and goods transportation. The introduction of the 25 kV line, as a matter of fact, allows the creation of a more powerful system that makes possible the use of a greater number of trains with a larger towed weight that can go all over Europe thanks to the interoperability of the new system of transportation.
As a result, the decrease of travel duration and the increase of line capacity, that reduces the average waiting time, allow to achieve a very fast transportation vector between the Milan-Turin bipole. The availability of an efficient mean of transport yields also an enlargement of the railway catchment area. Furthermore, as the train-traveller number will increase, the transportation by road and by air will gain efficiency, leading to a global equilibrium of the transportation network. Since Turin and Milan represent two of the most advanced poles, the enhancement of mobility network constitutes a necessary support for further internal development. Moreover, considering long spans, High Speed lines allow to dramatically cut travel duration down, offering a valuable alternative to air transportation. The High-Speed line supports also a better accessibility to services, enhancing the attractiveness of the territory and making it a tourism resource. Our analysis documents how the implementation of the AV/AC line will contribute to social improvements in the involved region, raising the competitiveness of Italian industries as well.

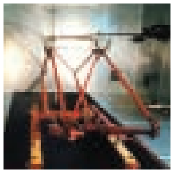
ACOUSTIC IMPACT AND COUNTERMEASURES

Acoustic noise is probably the most critical factor in the analysis of the environmental impact of High Speed railway lines. While European normative provides emission limits regulating the acoustic impact, the goal is to define an intervention strategy capable of attenuating the overall noise so that it undergoes the limitations.
Dealing with noise emission requires particular attention to the physical phenomena involved and how countermeasures work. Noise reduction could be applied on rolling stock, by reducing the noise generated by wheels and the aerodynamic noise of the pantograph, on structural elements of the line, by attenuating vibrations of the sleepers, and on fixed installations outside the line - the noise barriers. Each of these interventions implies variable costs, depending on the number of trains, the number of residents within the noise crit-

3 *The AV/AC line benefits the long range travels, goods transportation and commuters*

4 *Device used for testing ATR95 pantograph*

5 *The ATR95 pantograph*



6 *Shielded room for testing electromagnetic interference related to the pantograph*

7 *50 Hz filter used for reducing induced EMI in 3 KVcc railway lines*

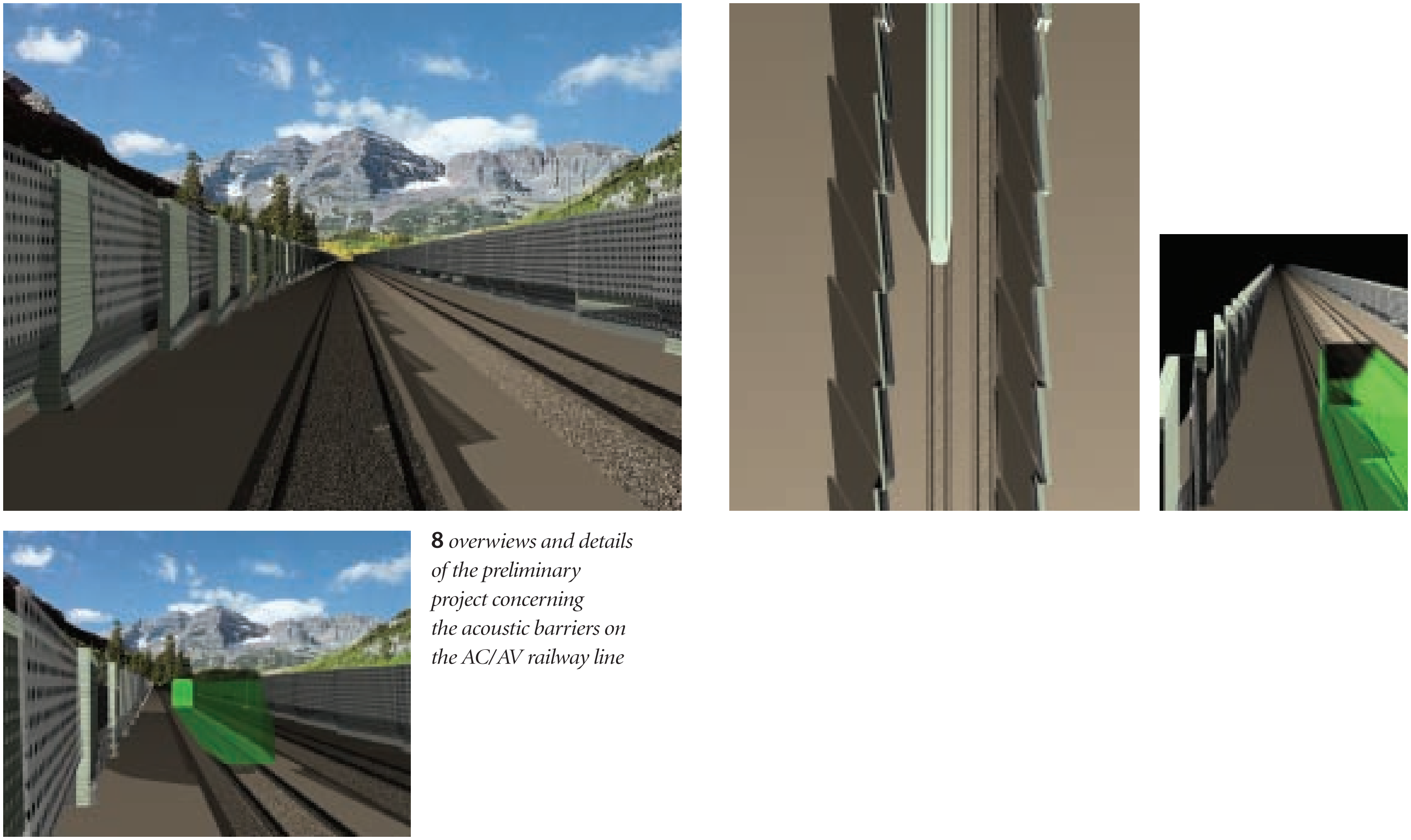
ical range (±250m across the railway line) and the extension of the critical zones along the line. The combined employment of these interventions requires a process of optimization that reduces the overall costs and assures the observance of the limitations; our proposal is based on the design of innovative noise barriers.

DESIGN OF INNOVATIVE NOISE BARRIERS

Our intervention strategy for reducing the invasiveness of the High-Speed line on the surrounding territory relies on the project of innovative top-quality noise barriers, that combine a strong noise attenuation with a low aesthetic impact for travellers. This project follows the guidelines based on the most recent scientific articles on this problem and on the experiences of our partner RFI – Rete Ferroviaria Italiana; the shape of the barriers has to be designed following a deep analysis on the nature, according to the intensity and the position of the different noise sources and considering the structural strength problem.

The project, developed in compliace with these guidelines, led to the preliminary design of a holed panel that can be simply added to the barriers already built. The convex shape of these additional barriers has been chosen to maximize the reduction of the noise coming from the wheels and the lower part of the train, while the holes reduce aerodynamic noise at low frequencies. The room between the panel and the barriers helps to reduce the noise level acting as the double glasses of the windows of our houses.

The panels are less afflicted by structural problems both because they



8 *overwiews and details of the preliminary project concerning the acoustic barriers on the AC/AV railway line*

can rotate on their longitudinal axis, which link them to the old barriers, and the pressure load is decreased by the holed surface. The movement of the panels is smoothed and limited by a dumper on the longitudinal axis and by the pressure losses through the holes.

COMPARING DIFFERENT SOLUTIONS

Our cost-benefit analysis clearly shows that the employment of the top-quality noise barriers that we have designed, exhibiting excellent performances in terms of noise reduction and minimize aesthetic impact, is the best way to achieve the project goal. Even though these components have higher costs compared to the standard barriers, they are particularly suitable for our proposal, because these barriers yield such a strong noise-reduction that they don't need further interventions on the other elements of the railway infrastructure, allowing to reduce the overall cost. Fostering the development and application of fixed components, that not only usually require less maintenance and adaptation costs but also can be flexibly employed, avoids difficult and time-consuming interventions on rolling stock and tracks to be performed. Moreover, this intervention strategy is based on the development of a high technological component, and follows the path to innovation and high-quality that the realization of AV/AC should undertake.

project 2C

Innovative Architectures of High Speed Trains

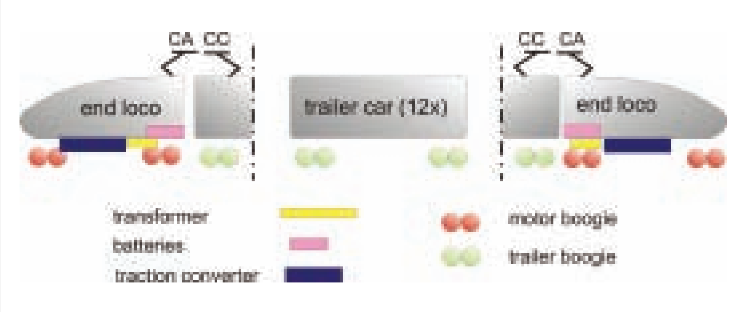
_I-TRAILS_Italian High Speed Railways

ABSTRACT

The aim of the project was assessing the problem relevant to the selection of a high speed (HS) train configuration for the future HS railways (HSRs) in Italy. The performed analyses, dealing with the most important and influencing aspects, can be considered as an overview of the problem as a whole. For some cases, the study is more detailed, in order to give an accurate idea of the way it could be developed. Because of the particular characteristics of the Italian HSR and the new European requirements, a general introduction over these subjects (basically the TSI) was mandatory. Six HS trains configurations were selected and a general comparison on their basic characteristics was done, e.g. TSI requirements fulfilment, weights and composition, traction characteristics, number of seats, etc. The configurations were then compared on the basis of their traction performances (travel duration, speed, acceleration, etc) on the Milano-Napoli HS line. The Simtre program developed by Trenitalia was used for this purpose. The trains were modelled according to the constructors' data. The comparison also provides some considerations on the adhesion limits and on the running in degraded conditions – thus accounting for a traction failure. An algorithm for the energy consumption optimization was also proposed. A specific analysis of the electric tension and a thermal study of the engine were performed for the current Italian HS train (the ETR 500) in a critical working point along the HS railway. An on-purpose developed program was used. The train configurations' benchmark concluded with a Life Cycle Cost (LCC) of the different options. On the basis of all the examined factors, some conclusions were drawn and the most fitting train configuration for the Italian HSR was identified. Finally, the HSR solution was compared with other transportation systems (both on-ground and on-air). The focus was on the advantages and disadvantages of the options, basically the travel duration, the costs per passenger and the environmental issues. Social consequences and transformations are briefly discussed too.

TASKS & SKILLS

Emmanuela Confalonieri was responsible for the individuation of the critical working point for the traction system of the ETR 500 configuration. She took care of Technical Specifications for the Interoperability (TSI) requirements analysis.
Francesco Fumarola collected HS trains data, selected the configuration to be analyzed and carried out the Life cycle cost analysis.
Daniel Tiago Guzzafame developed the train models and Traction performance analysis as well as the comparison of the HS railway with other transportation systems.
Matteo Lombardi was responsible for the energy consumption optimization algorithm and the development of the dedicated code; he assessed the influences of energy consumption on the life cycle cost as well.
Francesco Secondino performed a detailed analysis of the electric voltage and current of the electric drive; he carried also out a thermal study of the engine as well as the development of the dedicated codes.



1 *The ETR 500 simplified configuration used for the analyses*

HOW WE PERCEIVE THE PROBLEM

The characteristics of interoperability for the new generation HS trains are defined by the TSI. The first approach to the problem was the understanding of the requirements that affect the train's configuration. In order to come to a choice among the different configurations, we identified the following parameters:

- Interoperability, reliability and safety (TSI and UIC/EN standards)
- Technical performances
- Comfort and travel duration, seating capacity
- Life cycle cost
- Train image (speed, brilliance, comfort, beauty, etc.) and flexibility according to client's exigencies.

Today the Italian railway network is mainly based on 3 kV DC power supply. Because of the speed limitations posed by this system, the new dedicated HS lines are built using the 25 kVAC power supply system. Due to lines interaction, the train must be able to run also on the 3 kV DC system. A technical evaluation of the proposed configurations was based on the traction performances analysis and a data collection concerning speed, power, travel duration, resistance, adhesion limits, etc. The energy consumption optimisation during the execution of a certain task was also of interest: the train speed can be lowered if the train is running early. The question was how to save the maximum amount of energy, and which train configuration performed best. We decided to undertake a specific analysis of thermal and electric performances of the current Italian HS train – the ETR 500 – using a dedicated program. The benchmark of the different configurations was completed with a life cycle cost (LCC) study. Finally, an analysis of other means of transportation was included and some considerations about the impact of a new HS railway (HSR), considering environmental, economic and social issues, were added as well.

OUR PROSPECT

HS trains can be distinguished based on their general design:

- concentrated traction, with one or two end power locos, or distributed traction, with the technical equipments under the car bodies
- conventional train, with two bogies per car, or articulated train, with bogies shared between every two cars
- tilting train (with active or natural tilting systems) and variable gauge trains

The distributed traction is characterized by:

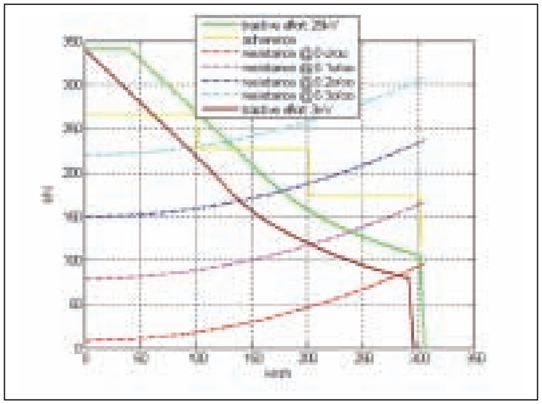
- higher passenger capacity per fixed length
- higher number of driving axles and hence higher acceleration and better adhesion
- possibility of installing a higher traction power and of maintaining the same commercial speed independently from the length of the train

The concentrated traction is characterized by:

- increase of trains availability, separating locomotives maintenance from cars' one
- areas for energy conversion and utilization separated from those assigned to passengers
- better performance in cross wind conditions, due to the higher weight of the leading vehicle.

Six HS trains were considered: five with distributed traction (two conventional configuration (DTCC), one articulated configuration (DTAC), two HS conventional configuration with max speed at 250km/h (DTCC_250), and the ETR 500, with concentrated trac-

2 *The ETR 500 in the new "Alta Velocità" design*



3 *ETR 500 traction characteristics and adhesion curves examples*

tion and conventional configuration (CTCC). They were compared on the same task profile (Milano-Napoli) in terms of traction performances using Simtre, a dedicated code implemented in C++ /Matlab by Trenitalia. Its usage implied some previous analyses:

- task profile features (Trenitalia source)
- settings for the simulation
- trainmodelling:
  - composition
  - weight estimate of composition, number of passengers and rotating mass
  - traction characteristics and breaking effort of each motor car/loco
  - different adhesion test-sets, taking into account different meteorological and wheel conditions
  - resistance to vehicle motion, both of mechanical and aerodynamic nature.

The trains were compared based on traction / resistance curves, travel duration, speed and required power. A proper algorithm was developed for the energy consumption optimisation, with the aim of decreasing the traction when the maximum loss of energy occurs. Then the study case of the ETR 500 was considered, analyzing the motors traction drive performances over a stage. The simulation program, realized in Matlab Simulink, takes as inputs the train speed and power given to motors axis. The program evaluates the steady state point of the converter and the motor, the phase voltages and the phase currents instantaneous values, the latter corresponding to the traction inverter output currents. Outputs are also the stator chopper and the stator steel losses: another thermal model of the motor stator gives the windings and the steel temperatures over a stage. The outputs of the thermal model define the admissibility and the safety criteria of the traction motor. The LCC study considered the overall costs related to the product during its life time, including manufacturing (train price), operation (energy, staff, cleaning), maintenance and disposal costs. It was possible to identify the driving costs influencing the different train architectures. For what concerns other transportation systems, the advantages and disadvantages of airplane and highway with respect to HSRs were considered, mainly focusing on travel duration, costs per passenger/ km and environmental issues.

OUR SOLUTIONS

The DTCC resulted to be the most suitable configuration in terms of general characteristics (weight, seats,TSI requirements, comfort, reliability) for the Italian HS railways. As to the traction performances analysis, the achieved results are the following:

- Travel duration and speed performances:
  - the DTCC_250 configurations show almost no difference relative to the other HS trains on a 25 kV line with max imposed speed of 250 km/h (Fi-Rm)
  - ETR 500: on the 3 kV line performances comparable to the other HS configurations. Worse performances on the 25 kV line
  - best performing is the DTCC, small differences with DTAC.
- Power consumption:
  - DTCC_250 configurations apart, the power of which is limited to 5.5 MW, DTCC trains are the least consuming, closely followed by DTAC.
- Adhesion limits on the theoretically achievable traction: the train configurations can react differently in terms of maximum performed acceleration on a certain slope. Our tests resulted in the expected successful performances of a distributed traction configuration.
- Breakdowns: because of the different compositions, the configurations show different sensitivity to a defined fault. The entire task profile can be completed by any of the trains with only 50% of their power.
- TSI / terms of contract requirements:
- Exceptional conditions: with 75% of their power DTCCs and DTACs are able to start on a slope of 3.2% and reach a speed of at least 30 km/h in the first 800m.
- TSI: all trains fulfil the TSI requirement of minimum speed and acceleration with a traction module out of order on the maximum railway slope (2.1%).

The energy consumption optimization confirmed that the best way to operate is decreasing the traction in presence of the maximum passive resistance, reducing the maximum achieved speed. The thermal and electric analyses for the ETR 500 were performed in a critical point of the Rm-Na, at 280 km/h and with a power of 8.8MW. The nominal values were observed. The LCC study demonstrated that a DTCC is less costly over its life time.

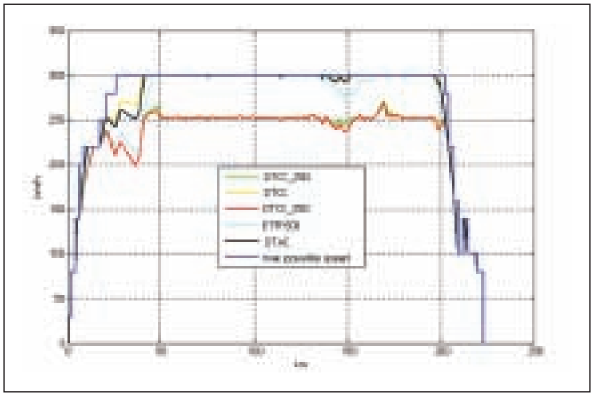
In the light of all the requirements and the needs that were enucleated, and taking into account all the approximations done in the different analyses , our team came to a double conclusion:

1 The most suitable option for the ItalianHSRs is a train with distributed traction and conventional configuration

2 The team deems one of the DTCC_250 options appropriate for the integration of the HS trains Italian fleet.

The comparison with other transportation systems showed:

- Environment: HS trains are more environmental friendly than cars and planes.
- Costs: the internal monetary costs for infrastructure, carrier, and vehicle operating costs are the highest for HSR, but social costs – congestion, air pollution, noise, accidents are the lowest.
- Comfort and better time usage: HS trains provide excellent travel duration for short/medium distances.



4 *Speed comparison on the route Rm-Na (25 kV)*