Transport and mobility

Science topic n°10

The **rail system**: a central role in **transport**

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THE RAIL SYSTEM: A CENTRAL ROLE IN TRANSPORT

By Marion Berbineau,
Senior Researcher and Coordinator
of railway R&D activities at IFSTTAR

Ever since its creation, rail transport has left its mark on the different periods of contemporary history. It has often been the setting for major innovations, and it has provided increasingly fast and safe travel, both for people and goods. Nowadays, rail transport is facing new ecological, societal and digital challenges. Continued innovation requires contributions from a multiplicity of stakeholders within the railway system.

A constantly developing mode of transport

Although rail is seen as a mode of transport, it is also a powerful industry. However, the European rail industry's global leadership is currently being challenged[1] by the emergence of major industrial players in Asia, in China particularly. The industry in Europe therefore faces several major challenges, namely, to halve life-cycle costs, double rail capacity (the number of trains running at the same time), significantly increase reliability and punctuality, while maintaining the same level of safety and reducing time to market. To better respond to these competitive challenges, innovation is vital and must be addressed in all its complexity by involving all the stakeholders in the rail system and by mobilising a whole range of scientific disciplines and technical know-how. The autonomous train, breakthrough concepts such as Hyperloop[2] and Clip-Air[3], are major innovations that will revolutionize the entire rail system.

A rich but complex rail system

The rail system does not only consist of trains and infrastructure. It also includes signalling, and the management of traffic and timetables, telecommunications, surveillance, maintenance, etc. More broadly, it is a complex system that includes several subsystems in which a multiplicity of public and private actors, all with their own governance systems, interact. These include manufacturers, operators, managers, certification and homologation bodies as well as customers.
Safety is the cornerstone of the rail system and it is both its strength and its weakness. The system is subject to very stringent compliance and safety demonstration methods and processes that are currently hampering innovation.
Finally, the rail system, through its infrastructure and stations, is embedded in a territory which means it must be considered within the context of regional and urban planning.

An innovative research topic

The systems-based approach to the rail sector fosters exchanges between a number of organisations and universities. In the national context, the following should be mentioned: Railenium IRT, of which IFSTTAR is a founding member, and SystemX IRT[4]. At the European level, the Shift2rail public-private partnership has been set up to manage and coordinate all research and innovation activities in the field of rail transport.

> **IFSTTAR's systems-based approach takes into account the complexity of territories guided transport, the major engineering and innovation topics that the Institute is involved in, and in which human involvement plays a central role.**

Its research work is centred on the themes of infrastructure and engineering structures, geotechnical engineering, key components and systems (rail capacity, signalling, safety, communications, cybersecurity, maintenance, reliability, etc.) in order to meet the socio-economic, environmental and rail system development challenges.
To this end, IFSTTAR has a wide range of dedicated scientific facilities that enable it to conduct high-level research and expert appraisals

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1. Source https://shift2rail.org/about-shift2rail/
2. Le transport à hyper grande vitesse sous vide (Hyperloop) by Cédric Villani (2018).
3. Clip-Air, modular aircraft for flexible transportation.
4. Intended to support an industrial strategy of conquering profitable markets, the Technological Research Institutes (IRTs) are based on long-term partnerships between higher education and research institutions and firms. The Railenium IRT is focused on rail infrastructure and the SystemX IRT on the digital engineering of future systems.

Further readings

The Shift2rail multi-annual and annual scientific programme
https://rail-research.europa.eu/about-shift2rail/

Rail2050 published by the European Rail Research Advisory Council (ERRAC)
https://errac.org/publications/rail-2050-vision-document/

Credit : Epictura

1 COMMUNICATION, NAVIGATION AND SURVEILLANCE: ESSENTIAL FUNCTIONS FOR TRAINS

By Marion Berbineau et Juliette Marais,
COSYS[1] Department, LÉOST[2] Laboratory

The rail network must be modernised to meet the societal, environmental and technological challenges ahead. The necessary changes will involve communication, navigation and surveillance systems. IFSTTAR, with its partners, is involved in the development and management of these new technologies to enable autonomous driverless trains to operate safely by 2023[3].

Train-borne communications and location-tracking technologies

The railway network[4] is divided into sections called blocks. These portions of the track are equipped with balises that are physical today and that will be virtual tomorrow. These balises detect when the train enters and exits the block. The block therefore provides a safety bubble around the train. To do this, it restricts access to a block to a single train and thus prevents collisions between two trains that are following each other at different speeds.

Today, when the train enters the area, it communicates with the infrastructure by means of a track-to-train radio system. A short-range radio beacon also informs the train of the current speed limit as well as that on the next block and its position. This track-to-train radio system is vital for the safe management of rail traffic.

In the very near future, there will no longer be any physical balises or beacons to delimit the block, detect the presence of the train and transmit speed instructions. Everything will be based on on-board wireless communication and localisation technologies. This will drastically reduce the costs of infrastructure deployment and maintenance (only the rails will be fixed to the ground). In addition, it will improve the flexibility and efficiency of traffic management: the blocks will be of variable length and move with the train. This is the concept of the moving variable block.

To continue to guarantee traffic safety, the train's position will have to be known with great confidence and radio communication will have to be robust in all train environment conditions.

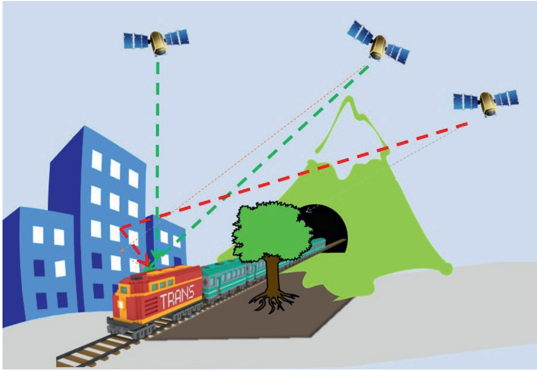
Supervising and operating driverless trains

The next revolution, starting in 2023, will be the introduction of driverless trains on the rail network. As with air transport, this requires the intelligent and safe combination of the three essential functions: communication, navigation and surveillance.

The radio communication system will have to adapt in real time according to the radio networks available in its environment. It will evolve seamlessly with emerging technologies such as 5th generation mobile networks (5G NR).

The train control-command system must be able to trust the train position information it receives regardless of the geographical environment and the presence of interference. This information will be based on a combination of technologies: satellite-based (GNSS), inertial systems,

Ultra Wide Band (UWB) systems or based on future radio communications systems when the train is in a tunnel.
To guarantee the safe operation of driverless trains, the train must be equipped with short- and long-range perception systems (as is the case with autonomous road vehicles). These anti-collision RADARs, cameras and LIDARs will have to operate both day and night. They will transmit real-time information on the tracks and the train environment even at very high speeds (obstacles on the track, level crossings, etc.)



▲ The reception of GNSS signals in a railway environment impairs localisation performance.

1. COSYS: Components and systems Department
2. LEOST: Laboratory on Electronics, Waves and Signal Processing for Transport
3. SNCF press release « Des trains autonomes d'ici 2023 » (FR).
4. "A rail network is a set of railway lines, stations and technical facilities (workshops, depots, marshalling yards, private sidings, intermodal hubs, etc.) that allow trains to travel in a given geographical area, whether a region, a country or a continent." Wikipédia

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2 MORE TRAINS, FEWER DELAYS THANKS TO OPTIMAL TRAFFIC MANAGEMENT

By Joaquin Rodriguez, Paola Pellegrini, Grégory Marlière,
Sonia Sobieraj-Richard and Pierre Hosteins,
COSYS[1] Department

Who has never experienced delays when travelling by train? Apart from extreme situations, such as strikes or major breakdowns, we can all remember an incident that has disrupted our daily lives. Perhaps the legendary punctuality of trains should be called into question when more and more of them are running on our infrastructure...
IFSTTAR scientists are studying the causes of these delays and proposing innovative solutions to increase the number of trains without reducing punctuality.

▼ Passengers in a London station blocked by a train breakdown.

Transport and mobility

First, understand the cause of the delays…

Although the punctuality of our rail system is fairly satisfactory, it is deteriorating in some parts of the network. This is mainly due to the increase in the number of trains, which automatically leads to more delays.

Breakdowns caused by increased stress on infrastructure and rolling stock (trainsets, locomotives and railcars) are the most significant source of delays. In other words, today many trains run on infrastructure that is at the limit of its capacity. Under these conditions, even a small delay can become more severe and cause numerous knock-on delays due to the “snowball effect”.

Reducing the number of trains or building new railway lines are not feasible solutions. The costs of new infrastructure are prohibitive, and the demand for new rail services is too high.

Developing new tools to manage traffic better

One solution, which is being studied at IFSTTAR, is to develop traffic optimization algorithms. This computational technique is designed to manage rail traffic in real time in order to limit the impact of perturbations. It allows “optimal” use of the available capacity and therefore answers the question: can more trains be run without reducing punctuality?

These algorithms are based on mathematical and computing techniques from the fields of operational research and artificial intelligence. They allow a very large number of alternative solutions to be explored in response to a problem.

It is possible to look in more detail at how trains use the infrastructure. The aim is to gain a better understanding of how trains can share the infrastructure without interfering with each other or, failing this, doing so as little as possible. In this case, we use the term “microscopic” optimization model.

These microscopic models can also be made available to staff several months in advance to facilitate timetabling. And each day, they will help to determine, in real time, the routes and sequence of conflicting trains in order to limit delays due to bottlenecks on the network.

MORE TRAINS, FEWER DELAYS THANKS TO OPTIMAL TRAFFIC MANAGEMENT (END)

Foreseeing developments on the rail network

More than fifteen years ago, IFSTTAR pioneered the use of microscopic models for rail traffic management. Since then, other teams have followed suit and this type of model is even beginning to be adopted in professional circles.

Today, the quality of the results obtained, both in terms of reducing delays in highly disrupted situations and running more trains through the infrastructure, is well established.

However, there are still many challenges to be met in order to coordinate several microscopic models and thus extend geographical coverage.

> **“The forthcoming autonomous trains also raises new questions about the management of mixed traffic consisting of driverless and manually operated trains.”**

1. COSYS: Components and systems Department

Transport and mobility

Video (FR)

▲ Find out about the work of Grégory Marlière for the congestion reduction project on the RER A line in the Paris region.

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3 SEEKING SECURITY AND SAFETY IN RESPONSE TO CYBER ATTACKS

By Virginie Deniau, Christophe Gransart and El Miloudi El Koursi,
COSYS[1] Department

The railway system is constantly changing. Today, automation, remote control and train control functions are mainly based on radio communication technologies (e.g. GSM-R, LTE).
However, the use of such wireless technologies opens up the rail network and makes it dependent on robust communications. To protect it from malicious intrusion, IFSTTAR is carrying out work targeted on the security[2] and safety[3] of these systems.

To guarantee travel safety and security...

The security of rail transport systems is a critical strategic issue for ensuring efficient and safe travel. Safety and security measures have been implemented by industry, operators and the authorities to make the systems more attractive and to continue to meet public transport's fundamental requirements for availability, accessibility, safety and openness.
To meet these challenges, new technologies and the digital revolution are being implemented. They have to cope with new threats in the form of cyber attacks. The problem of cybersecurity, which was almost non-existent in the early 2000s, is omnipresent today because the interconnections between people, terminals and objects have made them into potential targets for malicious attacks.

New risks must be identified

In recent decades, trains, the railway signalling system and the train seat reservation system have become computerised. As a result, a train can now be seen as a network of mobile computers. Like any computer system, the railway computer system can be the target of cyber attacks. Various attacks have already occurred, for example, information theft, blackmail to obtain money[4], a seizure of control of the switching system (in the case of the tram in the Polish city of Lodz).
In this context, rolling stock manufacturers and railway operators are counting on innovations that are robust and resilient to attacks. They are deploying new methods to analyse cyber risk and mechanisms to monitor and detect malicious activities. All the functions of rail transport must be protected, especially trackside to train communications[5] and railway signalling, which manages signals and switches.

Innovative cybersecurity solutions

Ifsttar is working on the detection and prevention of two types of cyber attack. These are electromagnetic attacks that directly impact wireless networks and attacks on communication protocols. Our scientists are then able to propose innovative solutions.
For example, a dual communication system means that when a communication link is attacked the backup system is automatically activated. This innovation guarantees continuity of service and means that trains can continue to run.

1. COSYS: Components and systems Department
2. Safety is a question of preventing unintentional accidents, which most often involve technical, physical, chemical and environmental risks.
3. Security is a question of preventing deliberate actions such as malicious acts, terrorism and other antisocial behaviours.
4. On November 26, 2016, in San Francisco, the use of malicious software in the form of ransomware made bus, metro and tram ticket vending machines unavailable for a period of 24 hours. Consult a newspaper article in Le Figaro at lefigaro.fr
5. Trackside to train communication allows the train to receive movement commands via wireless networks.

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4 DESIGN INFRASTRUCTURE ACCORDING TO THE NATURAL SOIL

By Christophe Chevalier, Thierry Dubreucq and Jean-Pierre Rajot,
GERS[1] Department

Did you know that the ground beneath a railway line has to be carefully chosen and assessed before the track is built? To guarantee the safety of the people and goods carried, its behaviour must also be predicted, monitored and maintained over time. To do this, geotechnical engineers study, among other things, the interaction between the soil and structures. In this context IFSTTAR is developing and perfecting innovative techniques and tools to enable new rail lines to be laid in what are sometimes challenging environments.

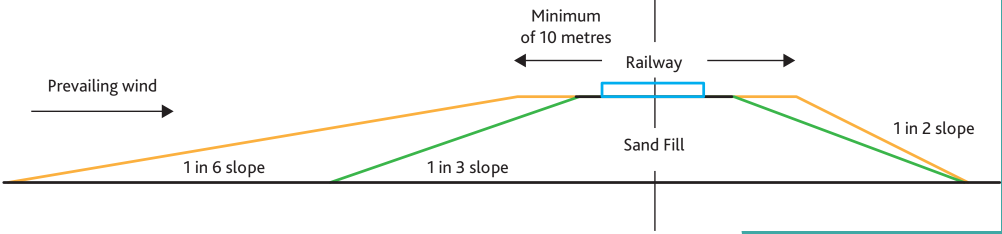
Adapting and shaping the environment to accommodate rail infrastructure

In an environment where not enough space is available, it is occasionally necessary to design a specific geotechnical structure.
For example, a retaining wall is being built here to allow two railway tracks to be laid side by side. The innovative "terre armée[2]"© process is being used. This consists of inserting metal strips into a soil mass. These strips are positioned horizontally and fixed to the reinforced concrete scales that make up the facing. A mainly granular material is then spread on these strips and compacted to obtain a dense layer that will withstand the shear caused by dynamic loads in particular. The operation is repeated until a strong retaining wall is obtained. Using sensors, IFSTTAR will check that it continues to perform properly in the long term.
In some situations, the environment itself must be shaped to accommodate these infrastructures.

▲ Retaining wall next to the track

▲ Retaining wall on SEA HSL[3]

▼ Aerodynamic profile of a sand embankment for a railway in a desert.



This is the challenge posed by the tricky task of installing a railway track in an environment that is constantly moving, like sand dunes in a desert.

In the Arabian peninsula, under the action of a prevailing wind, a sand dune is formed into a crescent shape. We know from experience that the higher the dune is, the less it moves.

To build a railway line here, it is necessary to connect the existing dunes together. In the same way would nature would do it, sand fill must be designed with an aerodynamic profile that helps prevent sand grains from being blown away. In addition, semi-permeable screens can be installed on the crest to trap and fix the wind-blown sand grains as far as possible.

1. GERS: Geotechnical engineering, Environment, Natural hazards and Earth sciences Department
2. Reinforced Earth
3. The Southern Europe Atlantic High Speed Line (SEA HSL), which was also given the commercial name of LGV L'Océane by SNCF in April 2016 is a French high speed line that is 302 kilometres long, of which 38 kilometres consists of new connections. It was opened on 2 July 2017 (Wikipedia).

Credits: SNCF, Ifsttar

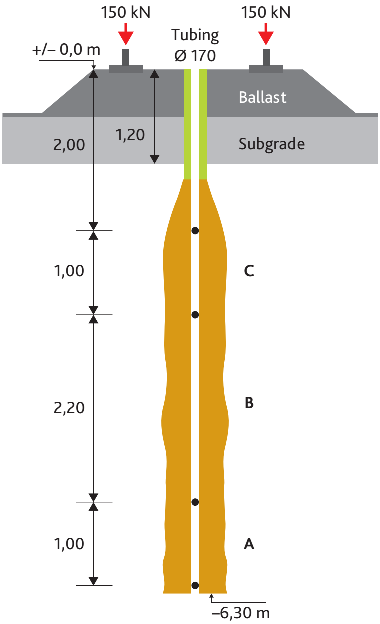
DESIGN INFRASTRUCTURE ACCORDING TO THE NATURAL SOIL (END)

Maintaining and preserving geotechnical structures

Like bridges and tunnels, geotechnical railway structures have a certain lifespan and require regular maintenance. Also, occasionally, the foundations suffer from fatigue and settlement occurs under repeated loads (train passages) and climatic factors (rain, drought, frost).

The "Soil Mixing" technique provides an effective way of slowing down the settlement of the rail track in such cases. It consists of using an auger to incorporate a cement slurry into the upper part of the foundation. It mixes with the soil to form vertical inclusions, which can transfer loads to stronger soil below.

During an exceptional flood event, currents can weaken the bridges that cross a river. The most violent of these remove the soil from around the foundations of the piers that support the bridge.



▼ Strengthening a railway subgrade with «Soil Mixing» technology. ▲

This is known as foundation scour, and it is the most frequent cause of failure in this type of structure.

In the framework of the French Research Agency (ANR) project SSHEAR (Soils, Structures and Hydraulics: Expertise and Applied Research) in partnership notably with Cerema and SNCF Réseau, Ifsttar is designing and testing devices which monitor changes in the height of the riverbed, to improve our understanding of the phenomena involved and to develop warning systems to inform managers in the event of excessive scour.

Further readings

http://terrassementnovateur.ifsttar.fr/

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◀ Failure of the foundations of the Saint-Etienne Bridge on Reunion Island, following the 2007 flood.

Credits: SNCF, Cerema

5 ECODESIGN OF HIGH-SPEED RAILWAY LINES

By Pierre-Olivier Vandanjon, Agnès Jullien, Alex Coiret, Michel Dauvergne and Tristan Lorino

Can we make trains and their infrastructure more environmentally friendly? To answer this public interest question, it is necessary to carry out an environmental assessment of the entire life cycle of the infrastructure under consideration. This work allows researchers to identify the phases where improvement is needed. This provides some innovative research results that assist the ecodesign of high-speed railway lines.

Decision-making tools for the creation of high-speed lines

To carry out the environmental assessment of transport infrastructure, IFSTTAR researchers apply the Life Cycle Assessment (LCA) methodology. This allows them to make a comprehensive assessment of the infrastructure's life cycle, from construction and use through to maintenance.

This approach advocates the optimization of design parameters in order to reduce the consumption of resources and environmental impacts. It also shows that the use phase can have a significant environmental impact. Its evaluation must be sufficiently sensitive to design parameters. This explains why the researchers have developed a consumption model for high-speed trains. This provides a way of assessing energy consumption and greenhouse gas (GHG) emissions during the use phase of high-speed lines (HSL). This model was validated during the acceptance tests of the Rhine-Rhône high-speed line.

With the assistance of a large number of experts, other models were tested during the construction and maintenance phases. The methodology, known as PEAM (Project Energy Assessment Method), brings together all these models. It has been applied to compare two alternative routes for the Montpellier-Perpignan high-speed line project, and, via interaction with SNCF Réseau, helps to inform public decisions before they are finally made.

▼ High-speed Train (TGV) Set 707 Dasye.

Optimising energy consumption from the design phase

The speed required for a high-speed line is a sensitive design parameter. A TGV cannot cope with tight bends and requires a route with wider curves. Construction works are required to integrate the line within the landscape, and these require a large amount of energy.
Furthermore, much of the energy dissipated by high-speed trains is due to aerodynamic forces, which increase in proportion to the square of the speed. Consumption, during the use phase, increases significantly with this parameter. However, if the speed is reduced, travel time will increase, modifying the service provided to the user.
Energy consumption can be reduced while still maintaining compatible schedules. The scientists propose that the train operation instructions for drivers should incorporate eco-driving objectives. These acceleration, deceleration and stopping instructions must be considered in relation to the layout, from the design phase.

PEAM therefore makes it possible to predict the energy used and the greenhouse gas emissions produced by a high-speed rail project. It is an ongoing topic of research that is evolving to take into account new environmental indicators.

Contact : Pierre-Olivier Vandanjon , AME Department,
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Credit: Frédéric Trindillière
Report: Cnam Pays de la Loire

6 HOW CAN WE IMPROVE RAIL FREIGHT TRANSPORT?

By Patrick Niérat
Researcher in transport economics
AME[1] Department, SPLOTT[2] Laboratory

At a time when man's footprint is having a significant impact on the environment, major decisions must be taken to make our society more sustainable. Some spatial planning decisions give greater importance to rail transport.
IFSTTAR researchers are analysing the provision of rail freight services and proposing measures to stimulate them in France.

▼ Shunting railcars in Neuville sur Saône.

The current state of rail freight transport in France

Rail traffic was at its peak in 1974, but rail now transports only 40% of the tonnage it did then. Its market share of total tonne-kilometres transported has fallen from 40% to 10%, to the benefit of road transport. The success of the road is largely based on its ability to transport small quantities quickly and its rapid responsiveness. We can gain some important insights by examining the modes of rail production. There are three types of situation.

> **Case 1** - Customers have private sidings that allow them to have railcars on their premises. Their business provides large volumes of goods.
With a 50% market share (in tonne-kilometres), this is the case when a full train is well filled from when it leaves the shipper to when it reaches the receiver. As an area of excellence for rail transport, it provides the lowest costs and shortest transport times.

> **Case 2** - Rail customers possess private sidings but only generate small volumes of freight.
This second case (25%) is called single railcars. Railcars are loaded at the shipper's site and unloaded at the receiver's site when the latter is connected to the network. Routing therefore consists of at least five steps.
A local service to take the railcars to a marshalling yard. A sorting process performed to group together railcars with destinations in the same region. Long-distance transport by full train. The railcars are then sorted and delivered to each of the recipients.
This organisation makes it possible to obtain good results on the long distance route, but the sorting stages and local services are often costly. The service becomes too expensive and this type of transport takes time.

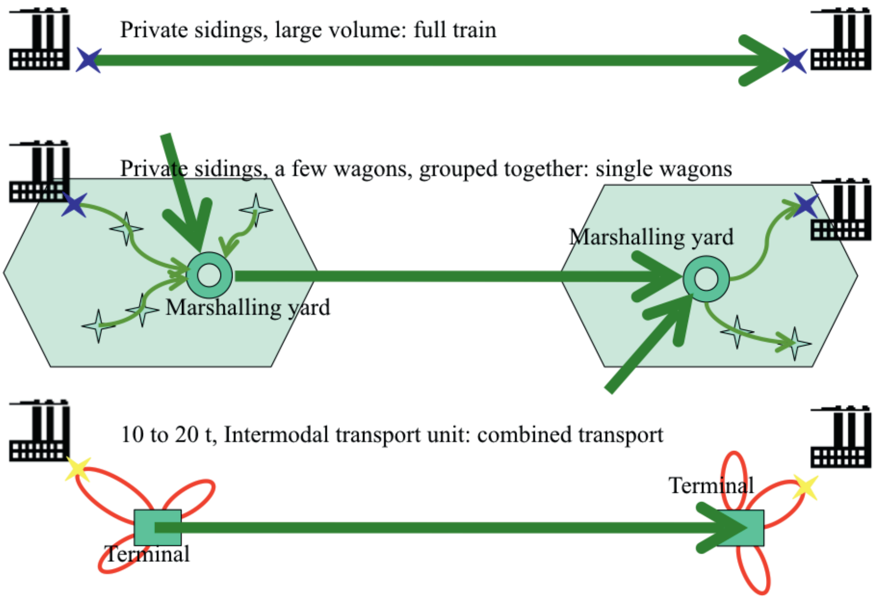
1/2>

HOW CAN WE IMPROVE RAIL FREIGHT TRANSPORT? (END)

> **Case 3** - Clients do not always have or use private sidings.

The third case (25%) involves rail-road transport. The goods are loaded into an intermodal transport unit (ITU) (container, swap body, etc.) on the shipper's premises. The ITU is transported by truck to a rail-road terminal where it is transferred to a railcar. A train provides long-distance transport to a second terminal from where the UTI is driven by road to the consignee.

Today, this solution is only available on main routes on which traffic flows are large enough for trains to be well filled and frequent and therefore offer costs and delivery times that are comparable to those of the road. The road services often account for more than half of the total cost. This approach theoretically allows transport between any two places, but in practice it is only competitive between locations that lie within terminal market areas.



▲ Organizational diagram of the railway.

Solutions that are consistent with territory needs

The use of full trains is restricted to large flows from large customers. But it does not meet today's varied needs that are dispersed throughout the country and involve small quantities. To gain market share, it is therefore necessary to rely on the solutions proposed in cases 2 and 3. Spatial planning measures exist to reduce the cost of local services and improve the situation.

In case 2, it is necessary to increase the number of railcars in order to reduce the unit cost of services. To do this, it is necessary to locate companies which are potentially interested in rail transport along certain existing small lines in order to consolidate traffic and reduce costs.

For case 3, it is essential to locate the terminals appropriately in relation to the existing potential. Poorly located terminals do not capture traffic. There are undoubtedly other technical solutions, but it must be borne in mind that the location of clients in relation to infrastructure is of major factor with regard to results. A superb technical solution in the middle of the desert serves no purpose...

1. AME: Planning, Mobilities and Environment Department
2. SPLOTT: Production Systems, Logistics, Transport Organization and Work Laboratory

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IFSTTAR'S COLLECTION
September 2019

7 WHAT FUTURE FOR SMALL RAILWAY LINES?

By Philippe Poinsot
Researcher in transport economics and regional economics
AME[1] Department, LVMT[2] Laboratory

The future of "small lines", or the capillary network, has been the subject of much debate following the Spinetta report on the future of rail transport in France (2018). The debates are often heated, involving a conflict between those who see these lines as unnecessary public expenditure and those who see them as a necessity to ensure spatial equality.
To inform public decisions, researchers can propose a more refined, updated, classification of the lines.

What do we mean by "small railway lines"?

Each line of the French rail network is classified according to a standard defined by the *International Union of Railways* (UIC). This identifies nine groups, ranging from UIC Group 1, the lines with the highest traffic, to UIC Group 9, the lines with the lowest traffic. Small lines are lines that are classified as between UIC 7 and 9. They represent about 40% of the network with a total length of more than 12,000 km and carry mainly freight, with a few passengers.

> **At the European level, the French rail network has the most small lines.**

There are three reasons for this. The first is that, before the rise of the automobile and road transport, the goal of the rail network was to provide very dense coverage of the regions, which resulted in a very extensive network. The second is that railways are a French public service, and whatever the cost for public finances, some lines have not been closed, in contrast to the situation in our European neighbours. Finally, the third reason is that the policy of the operator SNCF[3] has been to concentrate traffic on a small number of routes and hubs, thus limiting the use of the rest of the network.
Today, the condition of a significant part of the network is a cause for concern: the track is in poor condition, the signalling is ageing, etc. Several questions arise about the best choices to make. And the UIC group is a criterion taken into account in this context.

1. AME: Planning, Mobilities and Environment Department
2. The LVMT is a multidisciplinary laboratory which is jointly managed by the École des Ponts ParisTech, IFSTTAR and UPEM. It deals with major social issues relating to the city, mobility and transport.
3. The Société nationale des chemins de fer français (SNCF) is the French public railway company, officially created by an agreement between the State and the pre-existing railway companies, in application of the Legislative Decree of 31 August 1937.

1/2>

WHAT FUTURE FOR SMALL RAILWAY LINES? (END)

Towards a new classification of lines

Despite many criticisms, the fact that a line belongs to a particular UIC group has major implications, particularly in terms of financing. For example, the recent Performance Contract between the State and SNCF Réseau indicates that the infrastructure manager must focus its investments on UIC groups 2-6, thus prohibiting any depreciable investment on small lines.

However, a study (DISLAIRE & al., 2018) conducted in the framework of the New Economic Approach towards Mobility chair (LVMT/SNCF), has shown how inadequate this classification is for representing the current characteristics of the lines in the New Aquitaine region[4]. For example, Figure 1 shows that a great deal of diversity exists within the UIC groups 7-9. In order to inform public decisions on short lines, the assessment of current characteristics can be improved. It should take account of the potential, particularly in terms of demand, and possible ways of reducing the overall cost of small lines. Several studies recently undertaken with Cerema, the Normandy and PACA Regions, and SNCF Réseau, aim to develop methods for a more accurate evaluation.

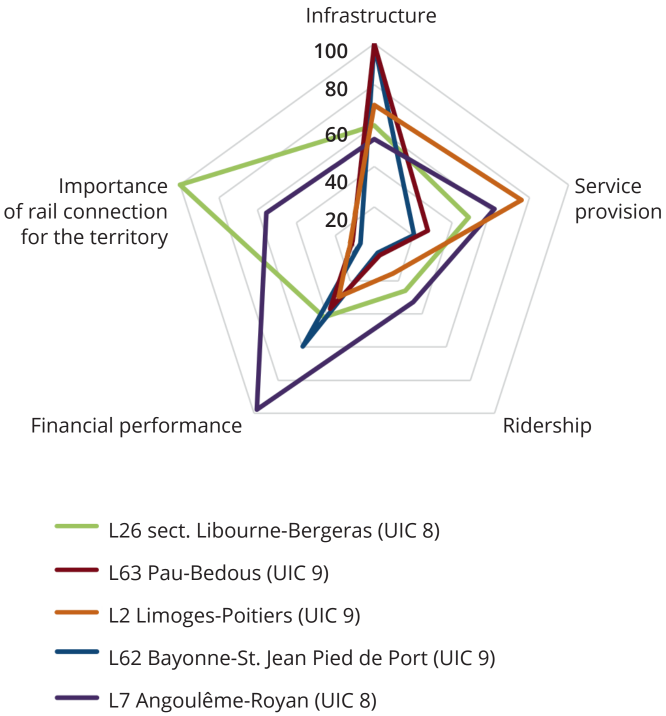
4. This is hardly surprising given the initial objective of this classification, which was to facilitate the formulation of a network maintenance policy.

Further readings

Deraëve S., Mimeur C., Poinsot P., Zembri P. (2018). Les petites lignes : de la nomenclature UIC à un classement par les enjeux et les potentiels, Transports urbains, n° 133, pp. 3-8.

Dislaire C., Guerrinha C., Mimeur C., Poinsot P., Zembri P., Deraeve S. (2018). Qu'est-ce qu'une 'petite ligne' ferroviaire ? Une analyse à partir de la Région Nouvelle-Aquitaine, Paper at the first Francophone transport and mobility meeting (RFTM), Lyon, 6-8 june 2018.

Meignien B., Vernier A. (2016). Quelles modalités d'organisation pour les petites lignes ferroviaires ; Case study in the Centre Val-de-Loire, Limousin and Brittany regions, CEREMA, 43 p.



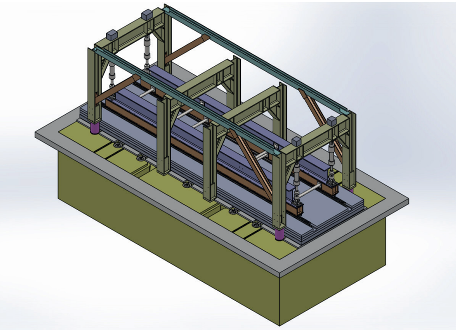
▲ Figure 1. The situation with regard to five UIC 7 to 9 lines in the New Aquitaine Region
Interpretation: each line of the rail network is represented by five main characteristics: infrastructure, service provision, ridership, financial performance and length of line. Each characteristic is assigned a score from 0 to 100: the higher the score, the better the characteristic of the line.

Credit: Ifsttar - LVMT

8 EXCEPTIONAL FACILITIES FOR BETTER UNDERSTANDING AND FOR TESTING

**Over the years, IFSTTAR has set up and maintained several software and hardware platforms to evaluate the performance of a variety of technical systems.
These original and often unique tools are essential for carrying out the Institute's research. They have, in general, received financial support from the State, the regions in which they were developed, Europe or the French National Research Agency.**

The SYSIFE Platform



▲ Dynamic loading device SySIFe.

- **Localisation :** Bouguenais campus
- **Purpose:** Conducting static and fatigue testing of models of innovative railway structures up to the scale of 1:1 in order to extend their service life.

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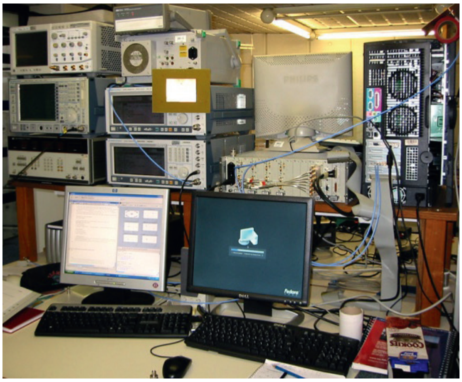
Article 4 - Railway geotechnics

The Telecommunications Evaluation and Testing Platform



▲ Evaluating the performance of a multi-antenna transmission system.

- **Location:** Villeneuve d'Ascq campus
- **Purpose:** To evaluate and test wireless telecommunications systems that are currently being developed, in particular those using high frequency signals.
- **Example of a task:** Evaluating new telecommunications systems in the laboratory before full-scale trials.

Further readings

http://www.emulradio4rail.eu/

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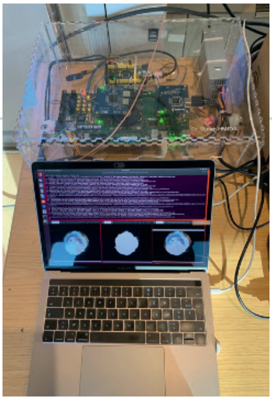
Article 1 - Communication, navigation and surveillance

The PREDISSAT Platform

▲ A fish-eye camera on a train roof during a trial



Further readings

Marais J., Tay S., Flancquart A., Meurie C., Weighting with the pre-knowledge of GNSS signal state of reception in urban areas, ENC GNSS 2015, 9 avril 2015, Bordeaux.

- **Location:** Villeneuve d'Ascq campus
- **Purpose:** The PREDISSAT platform (Predictive software for satellite availability in the field of transport) performs obstacle detection on reception of GNSS signals obtained from the synchronised processing of 360° fish-eye images and raw GNSS data.
- **Example of a task:** Improving GNSS systems for railways.

Article 1 - Communication, navigation and surveillance

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The Cybersecurity Laboratory

▲ Experiment to investigate the effects of a variety of electromagnetic attacks on the LTE system.

- **Location:** Villeneuve d'Ascq campus
- **Purpose:** To identify and analyse the impact of electromagnetic attacks on communications systems in order to develop surveillance, detection, warning and countermeasure systems.

Further readings

http://www.secret-project.eu/IMG/pdf/white_paper_security_of_railway-against_em_attacks.pdf

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Article 3 - Cybersecurity and safety in the railway industry

EXCEPTIONAL FACILITIES FOR BETTER UNDERSTANDING AND FOR TESTING (END)

The ERTMS traffic simulation platform

▲ ERTMS platform facilities.

- **Location:** Villeneuve d'Ascq campus
- **Purpose:** Simulating train driving, traffic and signalling for the ERTMS (European Rail Traffic Management System).

Further readings

https://estas.univ-gustave-eiffel.fr/

Article 2 - Microscopic traffic optimization

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The Recife Software Platform

▲ Screens showing graphic representations of railway traffic optimisation algorithms.

- **Location:** Villeneuve d'Ascq campus
- **Purpose:** Developing and evaluating railway traffic management algorithms in order to help operators reduce delays.

Further readings

https://estas.univ-gustave-eiffel.fr/

Article 2 - Microscopic traffic optimization

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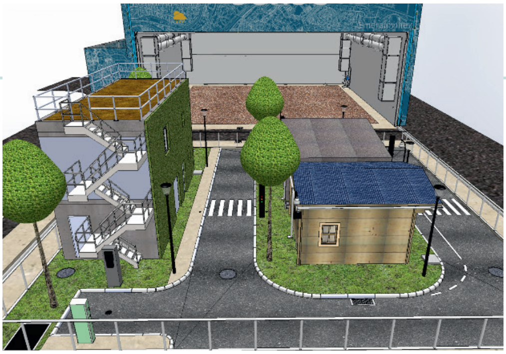
The Sense-city Equipex



▲ The sense-city miniature laboratory.

Article 1 - Communication, navigation and surveillance

> **Location:** Marne-la-Vallée campus
> **Purpose:** To conduct a true-scale evaluation, under extreme conditions, of the behaviour of the sensors and sensor networks that can then be deployed on railway infrastructure.

Further readings

https://cosys.univ-gustave-eiffel.fr/faits-marquants/moyens-experimentaux/sense-city

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The Pavement Fatigue Carousel

▲ The Pavement Fatigue Carousel.

> **Location:** Bouguenais campus
> **Purpose:** Performing accelerated testing of real structures under the effect of heavy loads. Although it was initially designed to test road infrastructure, it is also used for rail infrastructure.

Article 4 - Railway geotechnics

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Further readings

Brochure of the pavement fatigue carousel (FR) : https://lames.univ-gustave-eiffel.fr/equipements/le-manege-de-fatigue

Credits: Ifsttar

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reflex science

https://reflexscience.univ-gustave-eiffel.fr

Ifsttar has become Gustave Eiffel University
from the 1st of january 2020

Université Gustave Eiffel

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