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DIGITAL TWINS:

Accelerating the digital transformation in the rail sector

Tommaso Spanevello, Public Affairs Manager at UNIFE, explores the opportunities for digital twins in the rail sector and highlights how continued Research & Innovation to develop this technology is pivotal in driving forward rail's digital transformation.

FOSTERING DIGITAL transformation is an objective higher than ever on the European Union's (EU) political agenda and has been identified as key for unlocking future growth in Europe. All sectors are experiencing a fast-paced evolution as the businesses, products and services fostered by digital technologies grow in sophistication. Transport is no exception, with the rail sector increasingly acknowledging its assets and importance in Europe's successful 'digital leap'.

The European Commission's (EC) Executive Vice-President for A Europe Fit for the Digital Age and Competition, Margrethe Vestager, and Commissioner for the Internal Market, Thierry Breton, have been given the responsibility of crafting 'a digital Europe that reflects the best of Europe'. Such an ambition necessitates a bold approach towards digital technological development and sets out how these innovations will be used to meet our climate neutrality objectives. The 'Shaping Europe's digital future' masterplan, presented in 2020, aims to establish

Europe's technological sovereignty, affirm its global leadership, safeguard European values across the world and consolidate the EU Digital Single Market.

It is undisputable that the twin challenges of green and digital transformations go hand-in-hand. The EC has made it clear that technological innovation needs to also be carried out in a way that contributes to a sustainable, climate neutral and resource-efficient economy. Digital components, in this regard, will also be key in reaching the European Green Deal and Sustainable Development Goals (SDGs) ambitions.

The European rail supply industry fully acknowledges that these digital tools can be powerful enablers of the transition towards an economic and social model based on whole sustainability. This vision has been enshrined in the 'Rail fit for digital age (2020)'¹ paper recently published by UNIFE. Digital twins are one of the many trends thoroughly examined in the document, as the technology clearly displays how digitalisation is essential to strengthening the sustainability-related assets of rail – energy efficiency, circularity and capacity.

“European rail manufactures see digital twins as a great enabler of technological advancement for rail transport, interacting as much with big data as with artificial intelligence (AI) and blockchain.”



TOMMASO SPANEVELLO

Tommaso is Public Affairs Manager at UNIFE, responsible for innovation policy, digitalisation and sustainable and urban mobility. Between 2018 and 2021, Tommaso was also the Executive Secretary of Rail Forum Europe, the Members of the European Parliament's Association dedicated to rail transport. Prior to joining UNIFE, Tommaso was in charge of the policy department of the European Rail Infrastructure Managers Association (EIRI). With a background in international law, Tommaso studied and worked in Italy, the United States, Finland and Hungary.

REFERENCES

1. https://ec.europa.eu/publications/en/communication/shaping-europe-digital-future_en
2. https://ec.europa.eu/publications/pdf/publication/17_enfile_vision_paper_en_digitalisation-second-chapter.html
3. <https://ec.europa.eu/digital-single-market/en/digitalisation-rail-transport>
4. <https://ec.europa.eu/digital-single-market/en/digitalisation-rail-transport>
5. <https://ec.europa.eu/digital-single-market/en/digitalisation-rail-transport>

Digital twins in the rail sector: which opportunities?

Digital twins are one of the most talked about topics in transport, because it promises to leverage innovation to improve design, visually enhance collaboration and increase both asset reliability and performance. Many other industries have opened their eyes towards this technology – the rail supply industry is no exception. From healthcare to smart city management, digital twins are becoming essential tools for optimising entire manufacturing value chains and innovating new products.

At the EU-level, the EC has explicitly stressed on the importance of digital twins in the framework of the Green Deal. With the goal of radically improving climate change mitigation and adaptation strategies, as well as crisis management capabilities, the EC has been setting the Destination Earth initiative (DestinE)² as an important area of application of its digital decarbonisation plan.

European rail manufactures see digital twins as a great enabler of technological advancement for rail transport, interacting as much with big data as with artificial intelligence (AI) and blockchain. One of the true advantages of digital twins technology lies in its ability to anticipate key developments on rail systems and subsystems, deriving insights about the future performance of the physical asset and, eventually, enabling test-driving solutions before taking on the actual applications.

Since digital twins technology spans the asset's entire lifecycle, one of the major areas of potential is rail infrastructure and rolling stock, especially with regard to predictive maintenance. In fact, the use of digital twins in asset simulation can be very helpful for the prediction and identification of components in tracks and vehicles that pose the risk of failure. This ensures that the lessons learned thanks to these digital solutions contribute to design enhancement in line with operational requirements, and that they are applied to future products and systems. Furthermore, during the planning and construction of a new railway or rolling stock – as well as upgrade or renewal processes – digital twins can contribute to the prediction of changes occurring in the project execution, as well as the risks brought by non-conformant construction. Therefore, using digital twins can help to drive maximum value from infrastructure and rolling stock investments, avoiding cost increases and delays.

Furthermore, a digital twins ecosystem can be much broader than the core rail-related systems and subsystems. In fact, if we consider large rail infrastructure projects, such as 'Le Grand Paris Express', these ecosystems can be extended towards construction and civil work industries, as well as infrastructure planners and real estate managers.

This digital tool can be relevant also from a resource efficiency perspective. By allowing for the tracking of a rail asset's lifecycle, from the design phase through

to the recycling stage, it answers the demand for the increased sustainability of process and products. The use of digital twins can, thus, enable rail to further comply with the circular economy requirements set forth by the European Green Deal.

Finally, the strict relationship between digital twins and big data should be looked at carefully. Digital twins tap into real information systems, producing and consuming large volumes of data, bringing in the issue of access to and ownership of that data. UNIFE stresses, once again, the importance of setting a framework for efficient data-sharing in the rail sector – including urban rail – to overcome questions pertaining to data access and ownership. We look forward to the upcoming 'common mobility data space' to be set up in the context of the Data Governance Act³.

The role of Research & Innovation

Research & Innovation (R&I) has been playing a pivotal role in driving forward rail's digital transformation. Collaborative research, through the Shift2Rail Joint Undertaking – led by Executive Director, Carlo Borghini – has brought the whole sector's innovation ecosystem together to stive towards a forward-looking and long-term path. Shift2Rail projects have examined the potential of digital twins-related applications for various subsystems, such as control command and signalling (X2Rail projects), rolling stock (Pivot projects), infrastructure (In2Track projects) and energy (In2Stem project). R&I activities on digital twins carried out within Shift2Rail have contributed to the implementation of a more efficient way to predict and control the present and future performance of rail assets.

Work on digital twins will be continued by Shift2Rail's successor, Horizon Europe. Europe's Rail Joint Undertaking. In the ERRAC's recently released 'Strategic Research and Innovation Agenda (SRIA)', one of the proposed transforming projects is 'Railway Digital Twin, Simulation and Virtualisation'. Applied to several areas with high impacts on business performance, the transforming project would tackle all modules of relevant subsystems – i.e., vehicle, infrastructure, power supply, signalling – with their interfaces and interactions. The objective will be to truly develop a framework 'railway digital twin', based on Shift2Rail outputs, which would cover the entire railway sector and system.

Through the transforming project, the representation and detailing of digital twins will be allowed to continuously improve over time and in areas where positive effects are foreseen. The digital twins' capability will be not just help to understand asset histories and present situations, but also simulate scenarios with continuation and forecast alternatives for use and maintenance evolution/change. This approach will lead to huge benefits and impacts in designing the significant evolution of the rail system. 

Developments and opportunities for digital twin technology on the French railway network

Colleagues Jean-Christophe Michelin, Bruno Landes, Jean-Philippe Riant and Hugues Gigueux share details about the five projects currently relating to SNCF Réseau's Digital Twin Program and the potential gains in rail network performance offered by deploying such technologies.

AT A TIME WHEN numerous strategy consulting firms are excited about digital twin models being the next technological and digital breakthrough, and before addressing in this article: the projects relating to the SNCF Réseau's Digital Twin Program undertaken for the French railway network, we feel that it would be useful to answer the following question:

Is it seriously possible to envision that a digital twin model could be constructed for a 150-year-

old industrial system, made from a wide range of materials – such as steel, wood, concrete, electrical systems and automated equipment – with a complex computer infrastructure, and which has evolved over different rejuvenation and rebuilding periods – and to feasibly identify new performance goals thanks to innovative uses?

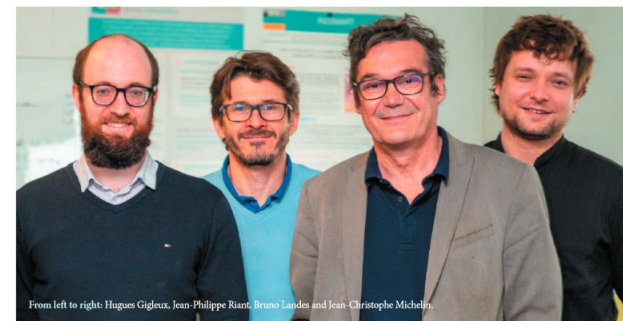
For a long time, a digital twin has been considered to be a 3D model representing objects as realistically as possible. However, in the case of

a railway system, when modelling the area close to railway lines, the surrounding environment changes throughout the seasons, which requires the ability to acquire and manage a digital representation that can evolve over time for a network of over 50,000km of railway lines, as in the case of the French railway network. However, this purely spatial representation does not consider the functional dynamics of the railway network, such as the train circulations, management rules or operating processes. There are, therefore, additional layers of data required to translate the lifecycle of the network at a daily, weekly and monthly scale. Different sources of information can be added, representing varying levels of complexity, arising from potential incidents affecting various systems or subsystems of the network.

A national railway system is inherently highly complex. A digital twin must, therefore, be capable of absorbing these different levels of complexity at

various scales of consideration, both spatially and temporally: from a minute's delay to the years of the century-old work of art, from the management of the catenary geometry over the millions of kilometers travelled each day to the record-keeping of the maintenance operations, to the financial planning for new projects. Herein lies the challenge which can only be addressed through, on the one hand, being capable of having a global systemic and inclusive vision, to allow future evolutions to be potentially integrated, while at the same time being able to deliver concrete gains for the infrastructure manager through the introduction of levers to create improved performance based on the digital transformations of the network.

It is, therefore, based on these two axes that SNCF Réseau has approached digital twin modelling since 2018: globally, by the conceptualisation of the existing and future uses through to the use of a new systemic data



From left to right: Hugues Gigueux, Jean-Philippe Riant, Bruno Landes and Jean-Christophe Michelin.

HUGUES GIGUEUX

Hugues is a Mines ParisTech engineer who started as an innovation project manager for SNCF Réseau in 2012. After gaining operational experience as a logistics unit manager, he is now in charge of the Digital and Innovation Division in the Engineering Department, where he works on leveraging data to benefit the railway network.

JEAN-PHILIPPE RIAnt

Jean-Philippe is a computer engineer and data scientist with an MBA and a PhD in management sciences, with a thesis on process optimisation. As a consultant, Jean-Philippe is responsible for the SNCF Réseau digital twin incubator offers. He is also the Lead Data Scientist of the IT team at SNCF Réseau.

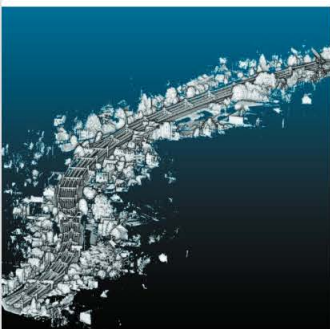
BRUNO LANDES

Bruno is a major player in the digital transformation of the SNCF network through piloting the deployment of digital twin technology for the French railway system and is Head of a 38-person Railway Engineering Division. With a PhD in Geology, Bruno is a member of Synapses, SNCF's network of scientific and technical experts.

JEAN-CHRISTOPHE MICHELIN

Jean-Christophe is Head of the Digital Twin Incubator for SNCF Réseau. Jean-Christophe has set up a platform to share the point clouds (several Peta Octets) with the whole company (600 users). He is also a professor of probability-statistics (including artificial intelligence) at the ESTP Paris Engineering School.

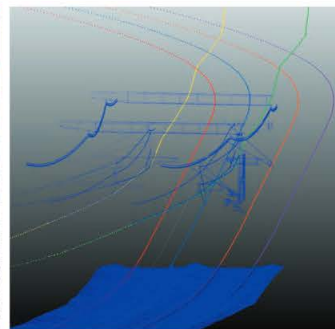
“A national railway system is inherently highly complex. A digital twin must, therefore, be capable of absorbing these different levels of complexity at various scales of consideration, both spatially and temporally.**”**



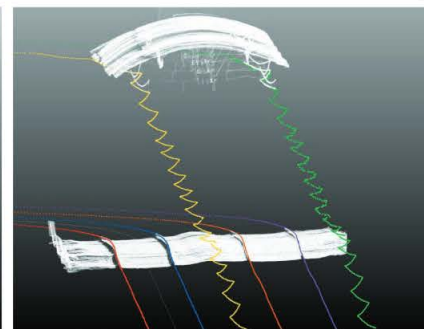
Sample of LiDAR scan processed for automated object detection



Automated detection (in red) and measurement (green bounding box) of objects which may be unintentionally left on the track following repair work



Automated catenary detection and 3D visualisation, ready for measurements



model named ARIANE, through the digitalisation and development of the transversality of work data historically stored in silos in their computer information systems, but also, at another operational level, through the development of concrete applications delivering measurable value by using a digital approach to create new processes, which will create enhanced performance today.

For us, the digital twin modelling for SNCF Réseau must rely on the sum of interconnectivity between the diverse digital and application initiatives currently being undertaken within the company. Before imagining all of the possible new uses of the technology, we consider it essential to identify the projects which are wholly ready to be orientated towards the digital twin approach. A railway network sells one, and only one, product en masse: train slots. A train slot is, in today's day and age, essentially numerical data contained within a computer information system. A slot has a complex lifecycle which, for SNCF Réseau, is provisionally created by predicted client demand of up to three years before it is used. There are, therefore, different phases involved: conception, operation, maintenance and the archiving of the train slot, or rather the data of which this slot represents within the computer system. So, here is a central product which exists almost completely in a digital universe except for its brief consumption phase, where it is transformed into an actual train journey. It is very interesting to understand how historical and centralised processes can be digitalised and approached through a system of data management throughout the lifecycle of this product within the complex computer systems. Admittedly, the digital twin

has not yet been adopted at the same speed throughout SNCF Réseau, though we are working to identify and promote new uses, which will provide inspiration for all new projects.

However, for the potential performance gain to be translated into a functional programme, or as the foundation for numerous applications, success needs to be demonstrated on a case-by-case basis, which should encourage everyone to say, "It's possible, and I would like to get involved with my own projects".

To follow are five current projects being undertaken which contain the potential for important performance gains offered by a digital twin approach:

1. Information continuity – rapid reaction maintenance

In the context of the European Shift2Rail programme, SNCF Réseau is developing, in partnership with other industries, 'an augmented As-Built record' following rejuvenation work undertaken in the network by in-house construction trains. The objective is to ensure the digital continuity of information gathered between the construction phase and the subsequent entry into the maintenance and operating phases. We will deliver structured data, which is easily accessible and fully digital, to all of the staff, who will be able to utilise it within the railway system lifecycle.

2. Artificial intelligence (AI) for the management of train clearance on the entire network - the Omega2N project is also undertaken on behalf of Network Rail

The detailed understanding of clearance on railway installations (platforms, bridges, inter-axes etc.) is a fundamental element for ensuring railway safety. To improve performance and safety, we

are developing an approach based on a complete digitalisation of our infrastructure using LiDAR 3D cloud point data, which represents a reference clone. Through the development of complex algorithms, which can process this data, we are able to digitalise the entire process of verifying the conformity of our installations. In addition, we have also implemented this method for the UK's infrastructure manager, Network Rail, who are also investigating the potential of point cloud data processing for updating their internal clearance database.

3. Automated computation and monitoring of catenary geometry

The measurement and control of the catenary height, as well as misalignment, are key elements in railway network performance in order to prevent tension problems. Geometry measurements are achievable at a precision level of one centimeter through a continuous automatic algorithmic analysis of LiDAR point cloud data, allowing several hundred kilometers of line to be surveyed in a few hours. The detection of catenary posts also allows for the automatic generation of location plans over large distances for work operatives.

4. Ballast recycling through the calculation of surplus or deficit zones

The ballast profile is a key reference indicator, which is verified during the replacement process. We calculate from LiDAR data the real ballast profile and subsequently compare it to the reference profile, which can then identify ballast zones of surplus or deficit. These are georeferenced and their volume is calculated to allow the infrastructure manager to proceed with recycling or relocating surplus ballast areas. This represents an

important economic gain while, at the same time, developing an internal circular economy.

5. Evolutions between two-point cloud datasets – detection of objects on railway lines

We are currently working to improve network safety through the monitoring of objects which may be unintentionally left on the tracks following repair work, for example. The detection of these objects, which could be, for example, sections of rail or ties, are detected by comparing the differences between two-point cloud datasets acquired a few weeks apart. In this way, it is possible, after filtering, to identify and characterise the type of object. The type and location can then be sent to the on-site staff for them to remove and recycle the object. The rapid automatic detection allows for ever faster reaction times and reduces the risk of safety issues and delays due to this type of incident.

SNCF Réseau has heavily invested in digital twin technology to allow for the modelling of the railway network, but also to be used as an interconnectivity tool for its many different computer systems, ensuring the circulation of data and allowing the possibility for calculating, simulating, predicting and disseminating this information to all of the staff concerned, which then allows a case-specific response to be developed, which creates value for the infrastructure manager through new digital processes. ■

REFERENCES ①

1. The authors would like to thank Mark Leatham for his help on this article.



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