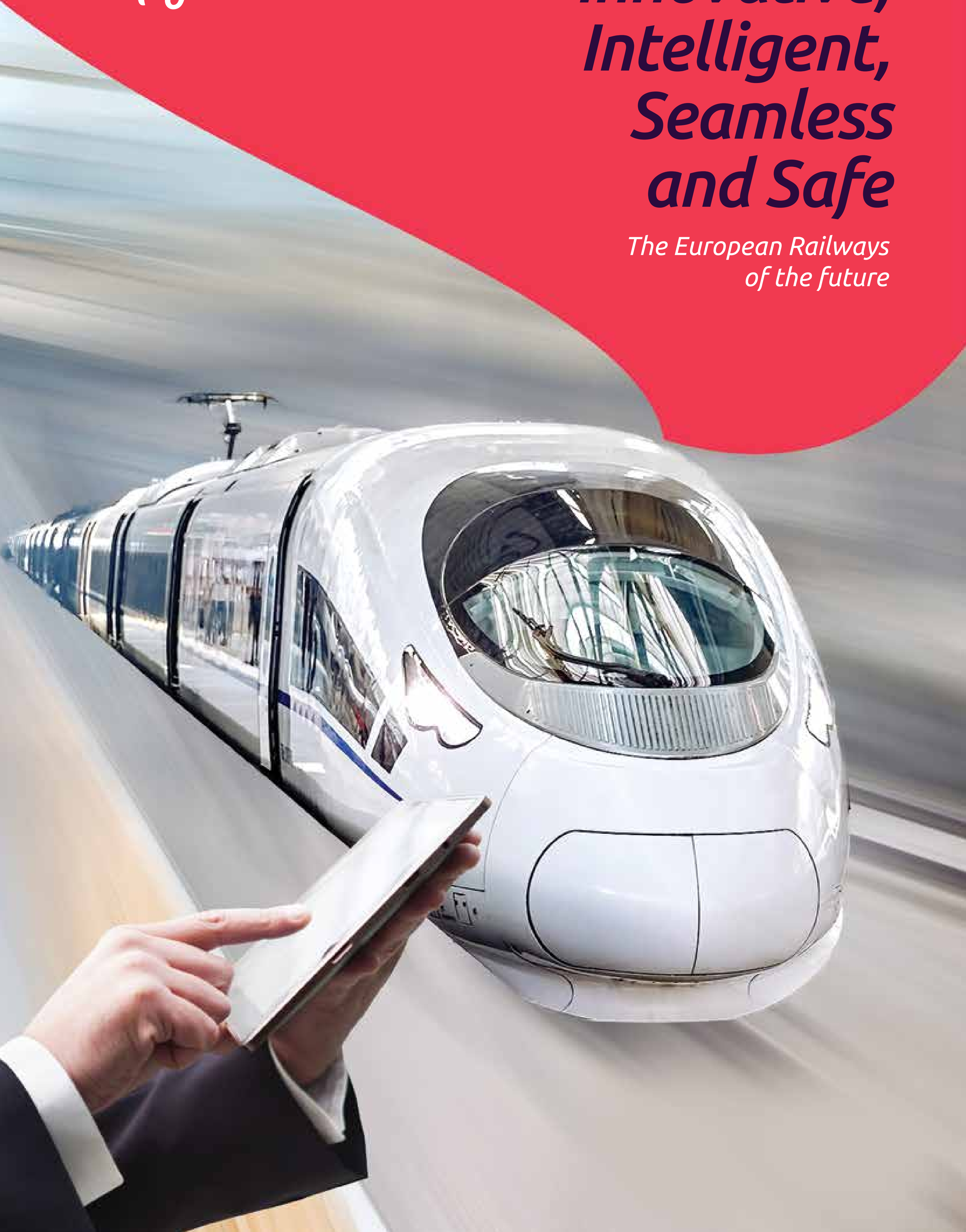
Innovative, Intelligent, Seamless and Safe

The European Railways of the future



Summary & Introduction

Railways have always played a crucial role in the social and economic development of a region. The European Railways Infrastructure evolved in phases, with each country approaching railways differently and at different times. The infrastructure across these countries is diverse both technically and structurally. What is common is the drive to embrace innovation and achieve improved efficiency, safer & undisruptive operations and a better and seamless customer experience!

The current day Railway system has evolved after over 200 years of development and innovation. Looking ahead, railways need to push the boundaries of imagination and creative thinking and leverage the immense potential that comes with the convergence of some of the most revolutionary emerging technologies, that will transform and change the way we operate today.

Now is the time to Start!

Increased Competition & Demand for Innovation

Growth in liberalization, diversification of labor markets and creation of open markets from 2019 onwards, will increase cost pressures as well as force market players to offer dynamic & competitive pricing and differentiated services to end consumers.

Consumers of today are growing in technical sophistication and demanding newer and better services, uninterrupted & safe operations, personalized experiences and increased engagement. They are also conscious of environmental issues and are demanding greater transparency from providers. It is estimated that the global consumption of resources will nearly triple to 140 bn tons per year by 2050 and the current resources may not sustain such high demands; making it pertinent for the industry to consider alternate sources of energy.

Urbanization and changing demographics

The increasing pace of urbanization is already straining regional infrastructures. it is estimated that by 2050, 68% of the population will be living in Urban Areas. Urbanization will be led not just by a strong population growth in Europe but also by a substantial shift in the demographic distribution of the world's population. It is expected that by 2050, more than 34% of the population in Europe will be over 60 years old.

Several security issues have also caused utmost concern for the railway industry. Most common accidents have been caused by rolling stock in motion or at level-crossings.

Bringing more passengers and goods to railways will require significant investments and upgrade of existing infrastructure, security and services.

Technology Disruption

Emerging technologies such as Artificial Intelligence, Robotics, IoT, Mixed Reality, and Intelligent Apps are disrupting all industries, including Railways. Railway organizations have started ideating and experimenting on these technologies. Change and advancement is prominent around the convergence of fields such as nanotechnology, information technology and cognitive sciences. Automation is being built on the application of different technologies, like robotics and AI, and the development of a digital enterprise for autonomous and remote operations.

What Capgemini foresees is the advent of the “Intelligent Railways”, an integrated ecosystem of people, businesses, devices, content and services; supported by agile, dynamic, distributed and more intelligent systems and infrastructure. The railway infrastructure of the future will be intelligent and safe – autonomous, integrated, more standardized, energy efficient and fatigue & wear resistant.

In this paper, we will take a closer look at one of the most important topics in Railways and how Capgemini is driving transformation for some of the early adopters from the industry.

According to the International Transport Forum, by 2050 passenger mobility will increase by a staggering 200-300% and freight activity by as much as 150-250%

The New Age Maintenance – Predictive

Is predictive maintenance on track and is maintenance on a predictive track?

The rail sector in Europe is at the brink of implementing condition-based maintenance at large scale and is experimenting with predictive maintenance. The impact of disruption increases with the growth in traffic, thus decreasing the time available for maintenance or for implementing new maintenance strategies. The sector is already too late to keep ahead of availability and performance demands. Some real accelerators are needed.

*"**Network Rail** is transforming how it manages its infrastructure assets. We are moving from paperbased working, time-based asset renewals and a 'find and fix' approach to asset management to a proactive digitally-enabled ' predict and prevent'. This requires insight into how different assets work and perform together as an asset solution, along with historical condition and work bank data that enables reliable analytical predictions to be made. The Linear Asset Decision Support solution developed and implemented by Network Rail's £330m ORBIS programme does just that. Our track engineers across the country can now access critical asset-related data where and when they need it most, enabling them to better target the most appropriate type of work to the right place. Getting our asset interventions right first time saves cost and helps us run an even safer, better performing railway."*

- Patrick Bossert,
Director of Asset Information, Network Rail

In the Netherlands Capgemini has worked with **ProRail** to deliver a mobile inspection App that speeds up process of loading asset condition data into the SAP maintenance system, which in turn improves the analysis of new and existing data and hence drive more efficient use of resources for maintaining the railway.

Is the glass half full or half empty?

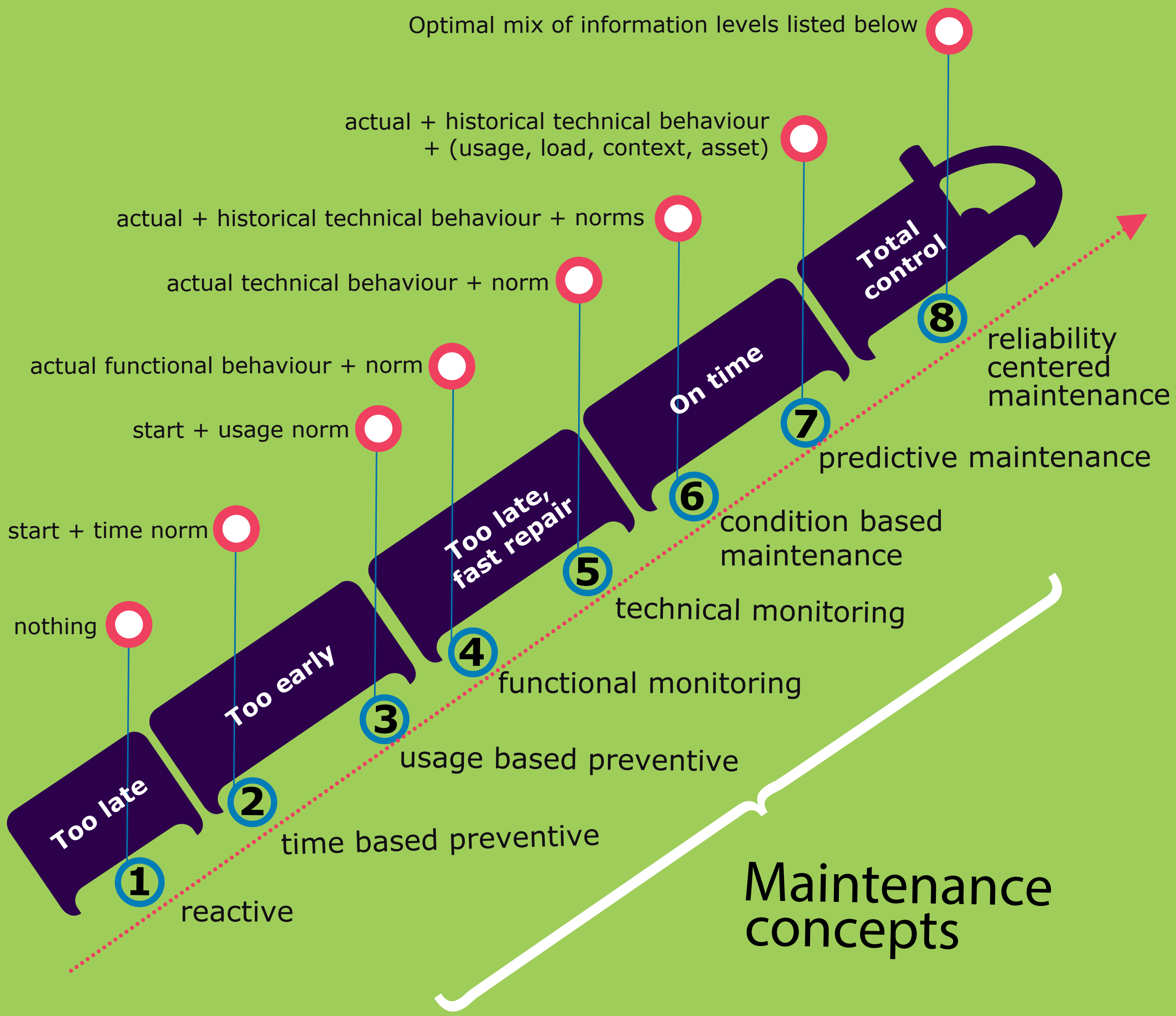
Let's understand the urgent need for predictive maintenance. Rail passenger and freight demands are rising in the economic upturn. When we add sustainability into the equation, rail has some real advantages over road and air transport. The evolving green energy transition will lead to an even higher growth rate of rail traffic resulting in an increased pressure to expand the rolling stock and infrastructure, while ensuring uptime at least at the current levels. Denser train schedules leave less time for maintenance which impacts both rolling stock and rail infrastructure maintenance. Moreover, this pressure builds up to critical levels during the European standardization of the train control systems (ETCS / ERTMS) on tracks & trains. It requires to take the rolling stock and tracks out of production during this immense control system makeover. When ERTMS becomes operational at level 3, the rail infrastructure capacity for trains will grow as much as 40%, leading again to tighter maintenance schedules. In fact, this is a major digitalization step of the primary train control infrastructure. At the same time there is an increasing growth of operational technology and infrastructure applied in trains to make these assets smarter. Think of high tech toilets, HVAC, bogies, engines, etcetera in rolling stock and smart switches, PLC based signaling, electric point heating in the rail infrastructure.

While this development and focus on smart infrastructure, makes operational data available for maintenance purposes, it also emphasizes on the need for OT & IT skills (notably cyber security) in the maintenance processes. Predictive maintenance for the rolling stock or infrastructure assets will improve uptime by decreasing unplanned and planned maintenance and by that improve rail system safety, passenger comfort and total costs. However, the real challenge is that there is simply too much equipment outside and too much scattered data inside to implement predictive maintenance reliably. What also doesn't help is that the rail sector has very robust assets which makes it hard to learn from failures. This paper will shine a light on the potential pitfalls and best practices to accelerate the adoption of predictive maintenance.

Predictive maintenance as uptime improvement accelerator

How does predictive maintenance improve maintenance outcomes both in terms of effectiveness and efficiency?

Predictive maintenance is often projected as the way to go. In theory it should: [1] circumvent outages by predicting the assets condition trends and act upon them just prior to the upcoming outages, [2] also provide insights to adjust planned maintenance intervals of the assets based on these condition trends, and [3] add to that, a long-term replacement plan that can be adjusted based on forecasts of condition trends. The figure below shows how predictive maintenance fits in the list of maintenance approaches that can be applied to your assets and what kind of data you need to apply these concepts properly.



(simplified model created by author to discuss various concepts in terms of effect and required information)

It is good to mention that reliability centered maintenance at the top is the all-encompassing maintenance strategy that devises per asset type / asset application area, what maintenance concept does apply best. It's not the end state for each asset under your control.

The Linear Asset Decision Support (LADS) project delivered by Capgemini for **Network Rail** provides the UK rail industry with a view of asset condition across band 1 track based on track geometry condition data, rail degradation models and a multitude of other data including weather, geology and rail traffic usage data.

An accelerator for uptime - but not all the fruit is hanging low

The bad news is that it is tough to achieve the potential benefits of the predictive maintenance, but the rewards waiting out there are well worth going for. We present as an example of such benefits, a predictive maintenance case Capgemini implemented for a large German car manufacturer. We analyzed with IoT and Big Data technology the uptime of 600 high tech robots of the car manufacturer in four of their plants worldwide and created a forecasting model that improved the availability of these robots on average 14 days a year by predicting when maintenance was due so there was still time to take preventive measures.

So, what are the hardest nuts to crack?

1 It's far from easy to achieve **high quality predictions** so that preventive actions are followed up. The predictions when failures are likely to occur, should be far enough into the future so that there is still time to properly plan preventive maintenance actions. This also results in changes in the maintenance processes to shift short term workloads from ad hoc outage management to preventive maintenance.

2 Another challenge to overcome is **getting real asset knowledge on board** while developing predictive analytics models. Subject matter experts are needed to assess the degradation behavior of your assets (types, varieties, usage patterns, contexts, …). Before you know it, the predictive maintenance system recognizes preventive maintenance actions as outages, e.g. regular train door closing checks are detected as an outage. Or one is seeing things in the data that an expert instantly recognizes as an example of seasonal influences on asset behavior, e.g. as for a switch the outside temperature is of importance when comparing over time how long it takes a switch to reach to other side (a few seconds normally). Asset expertise is one thing but knowing what good indicators are of asset degradation and how to measure these is another: through thermal, vibration, tribology, electrical or ultrasound analysis.

3 **Alignment and assessment** of the various condition indicators of assets becomes important to ensure that preventive actions can be bundled into maintenance schedules. Doing this right means that maintenance schedules are planned smartly and combine predictive or normal preventive work with corrective work to be done in the same area. This allows engineers to only fix/improve the immediate thing that was advised by predictive analytics when they are out there. This is also about combining linear asset management of slowly degrading assets, like tracks or train wheels and bogies, and fixed location-based condition monitoring of faster degrading equipment, like train engines or switches (a.k.a. points for the UK readers).

4 Availability of **reliable configuration and maintenance data** of your assets cannot be ignored. This (configuration) data is fed into the monitoring and analytics systems. However, organizations do not need to wait to achieve a 100% of data availability before starting to implement predictive maintenance. An 80% data availability is good enough to kick start your initiative. What is important to remember is to deal with data problems as soon as they arise. And while we are at the subject, what about proper maintenance data so that this can be used in the prediction models. Is that properly registered in a reusable way in your organization?

5 80 - 90% of time of a typical analytics team is **lost in getting and cleaning the data** instead of doing analytics. Think of poor quality master data off the rail infra assets and poorly documented monitoring systems (what does this signal really measure?). This challenge is also about the significant lead times it takes when rolling out monitoring equipment (goes for both train and wayside monitoring equipment) to measure relevant aspects of your assets including loss of uptime due to safety regulations when installing this monitoring equipment.

6 Last but not the least, **free your resources to implement** predictive maintenance amidst all other CAPEX surging initiatives. There is a paradigm shift needed within your asset management and operations organization: culture change from the old days of preventive maintenance and firefighting like outage management to the brave world of predictive maintenance where one does the right things just in time.

Capgemini have worked with **SNCF** to create a new business solution to optimize interventions, increase the availability of infrastructure, participate in improving traffic, and ensure technical security by freeing up time for analysis and interventions. This was a major contribution to SNCF's vision of a homogenous and new generation system by 2020 to ensure monitoring and supervision missions in the maintenance field and strengthen security, agility, and operational efficiency in a highly constrained environment

Different requirements and approaches on data modeling, maintaining and use of railway infrastructure data through the departments of **DB Netz AG** required huge efforts to keep all these data pools consistent to each other and to the reality. Consistent, Accurate Master Data across the railway company's various departments became an imperative to ensure seamless operations and achieve improvement in business performance.

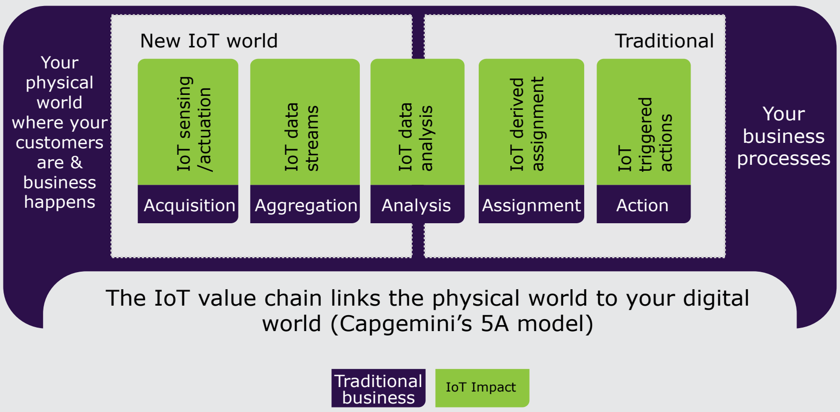
Capgemini assisted Deutsche Bahn by implementing a master data management approach for infrastructure data with a data governance framework inclusive of role definitions and end to end process design across data management and quality. This resulted in improvement of data quality supporting core business processes and consistent reporting across the organization.

A success factor of master data management of this huge infrastructure network is to take care of the consistency of the data – e.g. network-wide consistency of branches of right and left railway tracks. To take this into consideration a Master Data Management system with high data modelling flexibility was selected.

The end result of predictive maintenance is as good as acting on the predictions and gaining trust in these predictions

IoT - an enabler for predictive maintenance

The figure below depicts Capgemini's 5A model for analyzing and developing IoT value chains: **A**cquire, **A**ggregate, **A**nalyse, **A**ssign and **A**ction. This model specifically applies to our predictive maintenance case. It breaks down the mentioned challenges into focus areas to achieve the wanted predictive maintenance. It depicts how to get from the realities of the outside world to adequate actions neatly fed into the cleanly designed maintenance business processes. It is about combining the new technologies like IoT and Big Data and more traditional technology like GIS, enterprise asset management to make predictive maintenance work for you. This is certainly not a greenfield situation, but brownfield situations with lots of legacy in the rail infrastructure and rolling stock as well as IT legacy that smudges your lenses towards the clear predictive maintenance goals. The green boxes below show where IoT adds benefits and costs / complexities to existing processes. The model is therefore also applicable for drafting the cost side of the predictive maintenance business case.



The IoT value chain links the physical world to your digital world (Capgemini's 5A model)

Current state in Europe

Currently the number of rail assets under a predictive maintenance regime in Europe is a small but growing number. Less than 10% are under condition-based maintenance (one maturity level below predictive maintenance as shown in figure 1). However, there are several Europe improvement projects addressing the need for large scale predictive based maintenance within rail sector as can be seen in the table below.

Country	Rail infra or rolling stock projects	Maintenance concept	Specialties
UK	Intelligent infrastructure and linear asset management (Network Rail) Various rolling stock online monitoring applications (Alstom, Hitachi)	Condition based	> 40,00 rail infra assets on line by Network Rail Company owned condition based maintenance platforms Alstom Hub and Hitachi Lumada
Germany	Monitoring of train bogies (DB) Monitoring and diagnostics of switches (DB Netz) Monitoring of elevators and lifts at stations (DB Station & services)	Condition based	Impressive bogies expertise readily available. DIANA platform making big waves for rail infra along with ADAM for stations
France	Monitoring of power and signaling of rail infrastructure (SCNF Réseau)	Condition based	After thorough testing on the most complex track, deployment was rolled out faster than originally planned
Spain	Monitoring of interlocking @ high speed lines (ADIF)	Condition based	Integral part of DaVinci infra control platform
Italy	Monitoring of rail infrastructure power distribution (RFI)	Condition based	Including augmented reality for safer and faster maintenance
Nether-lands	Real time monitoring of rail infrastructure assets (ProRail) Real time monitoring of rolling stock (Dutch Rail)	Condition based	Both nationwide and in roll out phase
Belgium	Condition monitoring of switches and power distribution	Condition based	Degradation models created by data science team

Capgemini participated in the UK (network rail) and Dutch (ProRail) condition-based maintenance implementations. The other business intelligence is from our extensive rail network.

Best practices from Capgemini rail experts that accelerate the implementation and make the roll out more predictive

1. **Look before your leap** - One of the key needs today is to make the implementation of predictive maintenance itself a predictive growth path for the involved organizational entities. It should be clear in **what areas what asset types are under predictive maintenance** and require another way of working. Communicate this clearly upfront and deliver upon these promises. So, decide if the **implementation strategy** will be depth first (one asset type / small area in full depth) versus breadth first (all asset types, but only initial steps) => both are in their own way consistent for the maintenance organization, i.e. make it predictable for which assets and areas predictive maintenance is in play.

2. **Condition based first** - Another best practice is to **start with condition-based maintenance** first and grow towards predictive maintenance. Chances of success of success are low when the condition-based maintenance maturity level is skipped altogether. That is why it is a smart idea to start with assets that are already hooked up to central systems, for example SCADA control systems and work with true experts of these SCADA controlled assets at hand with tacit knowledge of the wear and tear of these assets.

3. **Choose wisely** - Make sure that a technology **hides the measurement complexity** from the assets condition metrics, and prediction logic is used. The latter gets easily cluttered with measurement details like linking sensor inputs to logical measurement points, unit of measurement conversions, combining inputs to derive better indicators, achieving temperature invariance. This is even more so when IoT is applied to go further into the field, get a sharper image of the state of your assets and learn with the experts to interpret this new data.

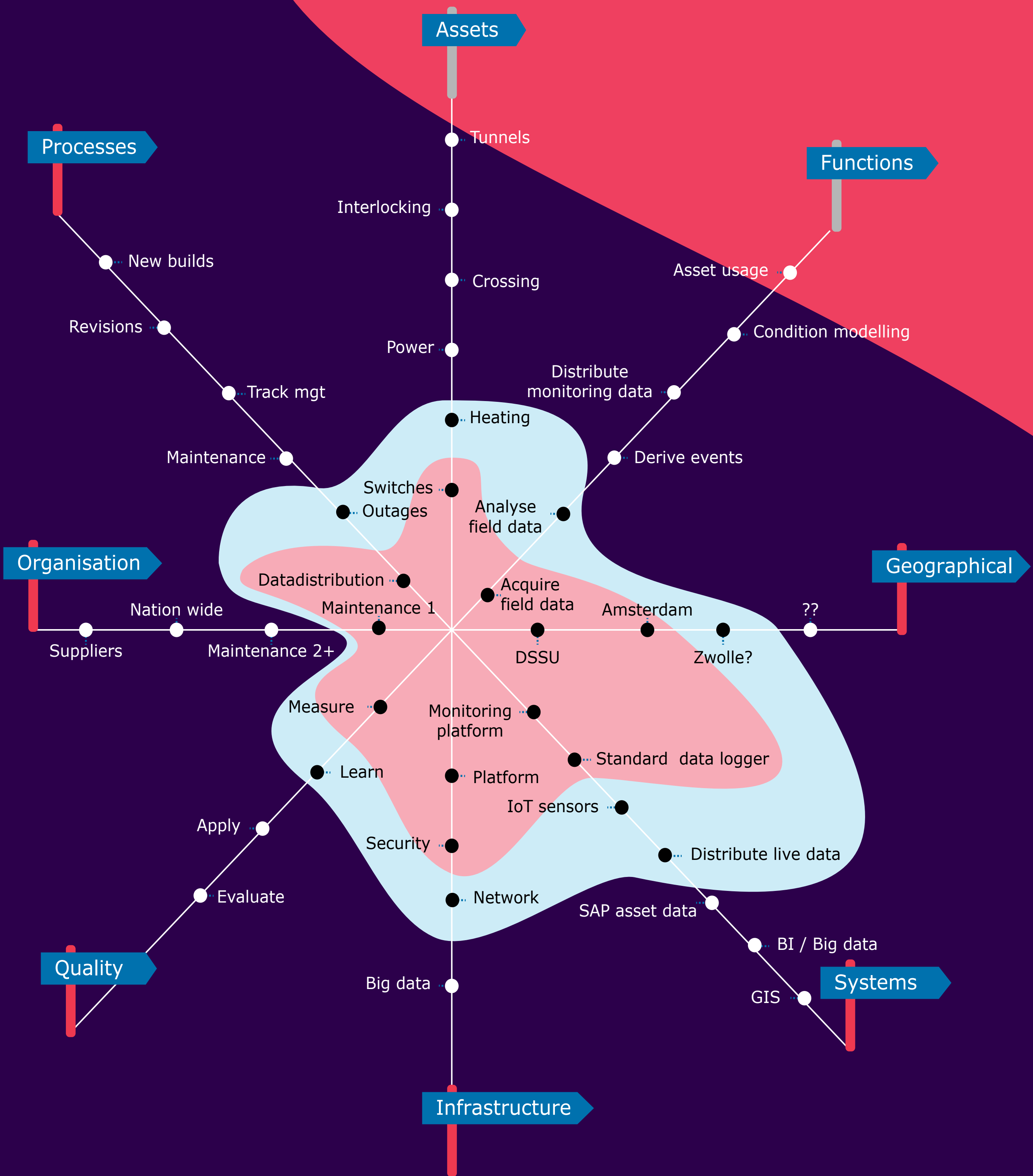
4. **Invest in Expertise** - Create a **predictive maintenance expertise** center that oversees the complete information chain and manages the roll out of technology across asset types. Make it easy for revision / overhaul projects (infra or rolling stock) to implement predictive maintenance when they are at it. An example of such a predictive analytics expertise center was implemented by Capgemini for Network Rail in the UK.

5. **The 5A Approach** - Proof of concepts are valuable, but the challenge lies in **scaling up** and this requires experience in the mentioned areas (5A's). This also includes business implementation aspects like change the KPI's for the maintenance organization that fit with predictive maintenance and shift focus from solving outages quickly to outage prevention.

6. Finally work from a maintenance vision that clearly defines where and when to apply predictive maintenaance.

An example of a growth model for new maintenance concepts is shown in the diagram below. A proper program develops reliably along these shown axes of growth. The colored "stains" define phases for a program that makes sense business, asset and technology wise.

Implementing condition based maintenance –analysing phases



What phases are feasible

The Next Steps?

Technology is changing so fast these days that new ways of inspecting some remote assets becomes feasible. The ability to have real time asset condition data in predicting faults and the use of machine learning and AI, become part of everyday maintenance planning. The 'holy grail' of asset maintenance is to have all key assets inspected on a frequent basis so that any potential failure can be anticipated and tackled before it interrupts passenger services.

The challenge for the rail industry is to take this rapidly changing technology and apply it to the internal business functions so that value and benefits can be realized. This is not a simple task as the existing business functions are often hard to change with employees who have been with the company for many years and have much knowledge of the asset they maintain.

As rail infrastructure is either replaced or renewed, intelligence monitoring systems are being added and the intelligent railway of the future has become a reality in 2018. The challenge facing maintenance engineers in the future is gaining information on the condition of remote and historical assets and adding this data in real time into the predictive maintenance systems in use across the railway.

At Network Rail, a UK wide survey of track and track side assets has been conducted by flying a helicopter along the entire track. The 3D LIDAR digital surface model and the digital terrain provide a dataset that can be viewed by engineers using specialist viewers to understand the area around the track being maintained before they visit the site.

The emergence of solar powered sensor technology that can send a data stream of condition data back to monitoring systems enable engineers to gain insight on remote assets. The ability to monitor land movements on embankments, the monitoring of water levels in tunnels and the heat sensing probes on key track side assets all play their part in building a picture of the condition of the railway.

The collection of this data is a key component in the building of a Railway 'Digital Twin' for key railway assets. The modelling of these key assets with real time condition data, predictive models of asset degradation, external data on weather and geology of the region will give planning and maintenance engineers the insight they need to operate a railway in the future.

Increasing a whole life asset approach is being taken by the rail industry with a view across the whole asset management lifecycle being required from a cost and safety point of view. The emergence of the Common Data Environment (CDE) for Assets will focus on the digital asset from design, through construction into operate and maintain. The models and data collected during design and construction will play an ever-increasing part in the investment planning for the lifecycle costs for the railway. The digital twin is a key component for a Rail Industry CDE approach

The deployment of remote sensing technology and the use of the Intelligent sensor devices will extend the number of assets which can be included in predictive asset maintenance. This in turn will enable European Railways to run improved timetable with more frequency trains leading to greater passenger service.

Conclusions

Capgemini brings with it more than 30 years of experience in the rail sector. Our strength lies in our expertise, experience, tested approaches, proven accelerators and ability to co-innovate with our clients to begin and expand their transformation journey.

Capgemini's Applied Innovation Exchange (AIE), our central innovation hub, has been enabling several enterprises to discover relevant innovations; to contextualize and experiment with them within the specific industry. Our close collaboration with alliance partners, open source communities, academia and consortiums is focussed towards bringing the best in class solutions, innovation and thought leadership to our clients.

It is time to grow towards predictive maintenance and intelligent infrastructure to meet the new demands. Large scale deployments of condition-based maintenance are available or in roll out (Network Rail, DB, ProRail, SNCF). The assets themselves become smarter and a source for maintenance planning. Be ready to reap these benefits! Get ready to start on this journey with us now! This digitalisation of maintenance is the next logical and at the same time challenging and rewarding step.

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