

The rail sector's changing maintenance game

How rail operators and rail OEMs can benefit from
digital maintenance opportunities

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Introduction and key insights

The rail sector is no exception when it comes to disruptive changes through digitization. In a sector where fleet reliability is a key lever for increasing efficiency and reducing total cost of ownership (TCO), big data and advanced analytics solutions such as condition-based maintenance and predictive maintenance represent a great opportunity to yield the next big efficiency leap in maintenance – reducing the number of failures, the amount of unplanned maintenance and, eventually, the required level of reserve asset capacity for rail operators.

From a sector-wide perspective, this seems to be good news. For one segment of the rail sector, however, digitization provides a specific opportunity. For rolling stock OEMs – who increasingly experience competitive pressure from new entrants and heavy consolidation in the new fleets business – big data and advanced analytics can be the platform for delivering revenue-boosting, intelligent, turnkey (complete system) solutions. Innovative solutions such as condition-based and predictive maintenance can help rolling stock OEMs target more elements of the value chain with intelligent maintenance solutions.

Against this backdrop and based on the findings from our extensive research (see text box), we will discuss in the report's three chapters,

1. The forces behind the shift in rail maintenance
2. What digitization of the maintenance regime in rail is all about and how it will likely impact the sector's maintenance ecosystem and overall landscape
3. How individual companies can prepare effectively for capturing value from the new opportunities in the emerging digital maintenance ecosystem.

In doing so, we mainly focus on the European rail operator perspective, but also include examples from around the world – and incorporate the perspective of rolling stock OEMs where relevant.

Methods and sources for deriving insights in this report

- Extensive interview series with over 25 international rail COOs and executives in charge of maintenance in rail and other experts in Q3/Q4 2017
- Extensive client expertise in the rail sector and in comparable industries, especially regarding condition-based and predictive maintenance
- Recent survey on digital manufacturing conducted with more than 400 executives from the US, China, Japan, and Germany

Five key insights can be derived concerning the changes to be expected in the rail sector's maintenance ecosystem:

- Advanced analytics is going to make condition-based maintenance an attractive lever for increasing maintenance efficiency. With efficiency gains of 10 to 15% expected, it is estimated that the global maintenance market can save up to -EUR 7.5 billion per year by moving towards condition-based maintenance.
- The additional jump from a condition-based towards a predictive maintenance scheme, however, requires further investments. The maximum additional savings are not significant enough yet (currently estimated at a maximum of 10%) to be aggressively pursued.
- Roles in the new maintenance ecosystem will change, as a significant share of maintenance-related activities will be automatable.
- In order to compensate for a flat value pool in the new fleets business and to address consolidation, rolling stock OEMs will find it increasingly attractive to enter the service business, in particular through offering train-as-a-service models guaranteeing the train availability.
- For urban/regional rail operators and cargo rail operators, an overhaul of their maintenance system through condition-based maintenance is a must as increased competition will be felt most prominently in these rail segments, making an efficient maintenance system key to remaining competitive.

What is more, these findings in combination with our observations of the most successful players in adjacent industries with similar challenges have allowed us to derive pragmatic recommendations that can help rail operators as well as rolling stock OEMs optimally and effectively prepare for the upcoming changes:

- Defining the desired strategic target state and developing a partnering strategy upfront is key to success with respect to condition-based maintenance. An assessment along key parameters such as market position, fleet characteristics, and operating contexts can help rail players assess their fitness for condition-based maintenance.
- Success in the new maintenance scheme is all about which party owns what kind of data and what they are able to do with it. Thus, rail operators and rolling stock OEMs need to negotiate data access with each other and build the analytical capacities that enable success within their chosen operating models.
- Rail operators/rolling stock OEMs need to find a way to effectively couple and co-locate rail engineering expert knowledge and analytics power to develop powerful analytics models.
- In order to realize impact, the entire value chain in maintenance needs to be addressed; equipping locomotives and cars with sensor technology and building analytical capabilities is only the first step.
- A component-by-component rollout of condition-based or predictive maintenance should be pursued only for business-case-positive components.

The forces behind the shift in rail maintenance

With fleets being operated for 30 to 50 years and maintenance accounting for ~50% of overall cost, the main goal of rail operators is to cost-efficiently increase fleet availability and reliability.

The limitations of a fleet primarily comprised of legacy equipment determine the current maintenance regime:

- For security components, which are highly regulated, components that can lead to train failure (e.g., brakes), and highly visible quality components (e.g., air-conditioning), planned preventative maintenance based on time or usage is being conducted.
- For all other components, unplanned reactive repair – i.e., fix when broken – is the maintenance strategy.

This approach to maintenance, however, cannot prevent certain failures, making system stoppages inevitable.

Sensor technology and data analytics will change the maintenance paradigm: from time- and usage-based maintenance today to condition-based and predictive maintenance

Sensor technology and data analytics are going to change this: automation and advanced analytics solutions can be a big lever for rail operators, rolling stock OEMs, and others in planning and optimizing maintenance.

In that context, the concept of “condition-based maintenance” is named as a promising lever to increase maintenance efficiency. It mainly measures one specific parameter of the real-time condition of a train component. Historic failure data helps identify a critical parameter threshold where the component should be scheduled for maintenance to avoid failure.

In contrast, “predictive maintenance” is also usually named as a major driver to increase maintenance efficiency in rail under given reliability and availability ratios. Predictive maintenance aims at using multivariate data inputs and analyses to be able to replace equipment components after alarms from machine learning systems are raised but before those components actually fail.

The likely shape and potential impact of digital maintenance in the rail sector

The maintenance landscape in rail is being reshaped. By observing current trends, McKinsey has derived insights regarding the pace of change, the role of the players in this emerging ecosystem, and the evolution of its business models.

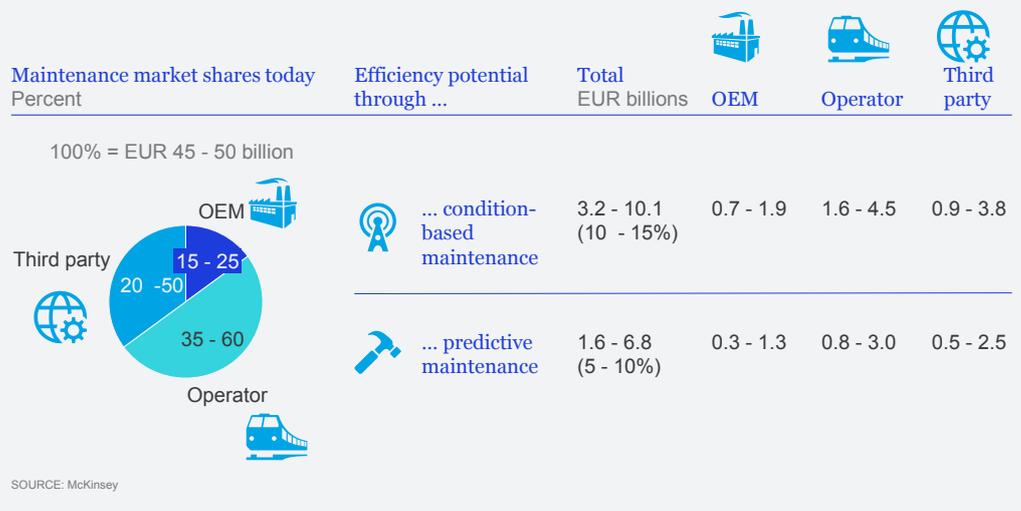
Condition-based maintenance can lead to an overall reduction of at least 10 to 15% in maintenance costs

1. Condition-based maintenance will yield positive ROI, while systematic predictive maintenance is still far from “ready to implement”

The business case for condition monitoring and condition-based maintenance is a no-brainer: currently, hardly any repair-related work is done before a maintenance job takes place, and ~30% of the time trains spend in the workshop is taken up by manual failure diagnostics. Condition-based maintenance can lead to significant efficiency gains because diagnostics are conducted continuously in real time or via near-time analytics schemes while the train is in operation. Maintenance workers know exactly which equipment and which spare parts to bring to which location in advance of (and in preparation for) the moment that the train is commissioned for maintenance. Thus, it is estimated that condition-based maintenance can reduce manual diagnostics by at least 60%. Furthermore, planned maintenance jobs require less time compared to unplanned jobs, as, for example, spare parts are readily available. Experts estimate, thus, that condition-based maintenance can lead to an overall reduction of at least 10 to 15% in maintenance costs (Exhibit 1). With the global maintenance market currently estimated at ~EUR 45 to 50 billion per year and expected to remain steady in the upcoming years, different players can benefit from the savings potential of condition-based maintenance.¹ Also assuming a steady market share split between rail operators (currently with a market share of ~35 to 60%), rolling stock OEMs (currently with a market share of 15 to 25%), and third parties such as suppliers (currently with a market share of 20 to 50%), we estimate maintenance cost reductions of up to EUR 4 billion for rail operators, up to EUR 2 billion for rolling stock OEMs, and up to EUR 4 billion for third parties.

Exhibit 1

In the rail sector, the combined efficiency gain through condition-based and predictive maintenance is expected to be around 15 - 25%



¹ McKinsey (2016): Huge value pool shifts ahead – how rolling stock manufacturers can lay track for profitable growth

Most likely, predictive maintenance will not be a priority for rail operators or rolling stock OEMs in the near future

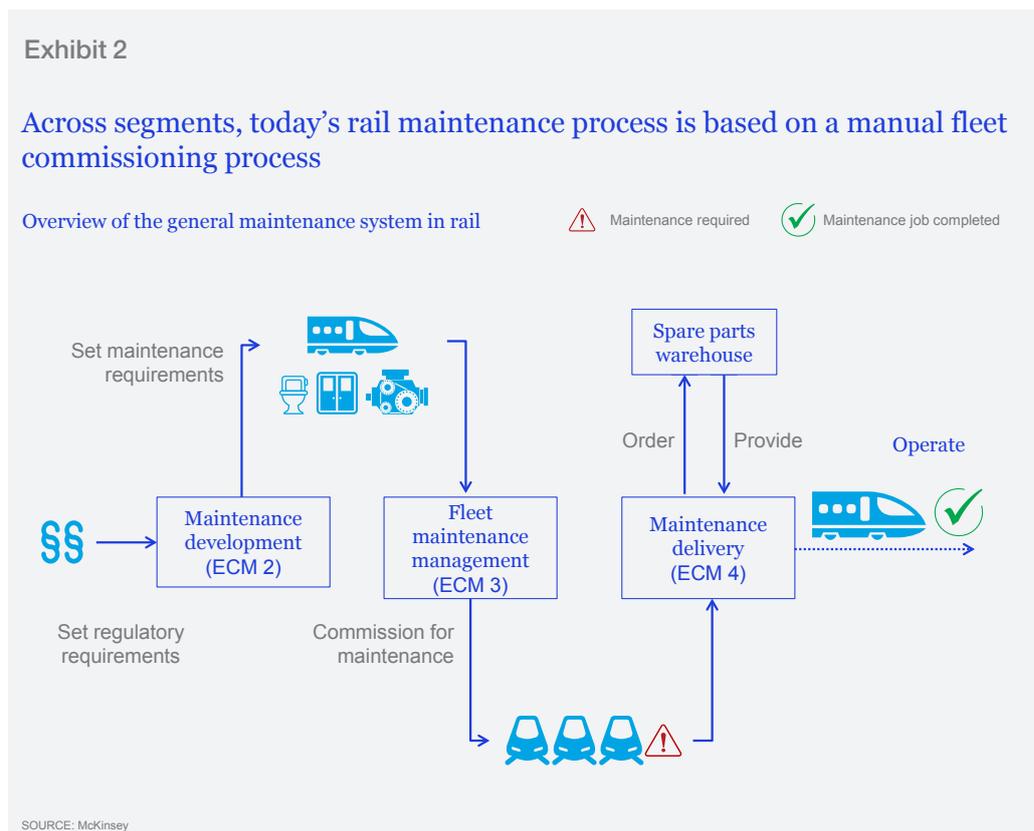
While the implementation of condition-based maintenance already requires investment in sensor technology as well as analytics capabilities along with a change of fleet scheduling and shop floor management methods, following a component-by-component approach ensures a positive use case from the start.

In contrast, the jump towards a predictive maintenance scheme would require additional efforts with small incremental returns. Predictive maintenance requires monitoring of not only the condition of the components themselves but also the condition of factors influencing the components (e.g., weather or the power flow on track). On top of this, additional data sources need to be tapped into and managed, and analytics capabilities that allow for the development of advanced prediction models either need to be built up in-house or through partnerships. Given the additional resources it requires, we estimate that the additional benefit from moving towards predictive maintenance would only be an additional 10% savings in maintenance costs at maximum. Keeping all other assumptions the same compared to our condition-based maintenance business case, this would lead to a maximum additional annual savings for rail operators of ~EUR 3 billion, ~EUR 1 billion for rolling stock OEMs, and ~EUR 2 billion for third parties (depending on the market share). Real savings are likely to be much smaller as no additional investments are considered in this estimation; therefore, we think that predictive maintenance will not be a priority for rail operators or rolling stock OEMs any time soon.

2. As roles in the ecosystem are about to fundamentally change, the balance of value in rail maintenance will shift to agility in rules and algorithms

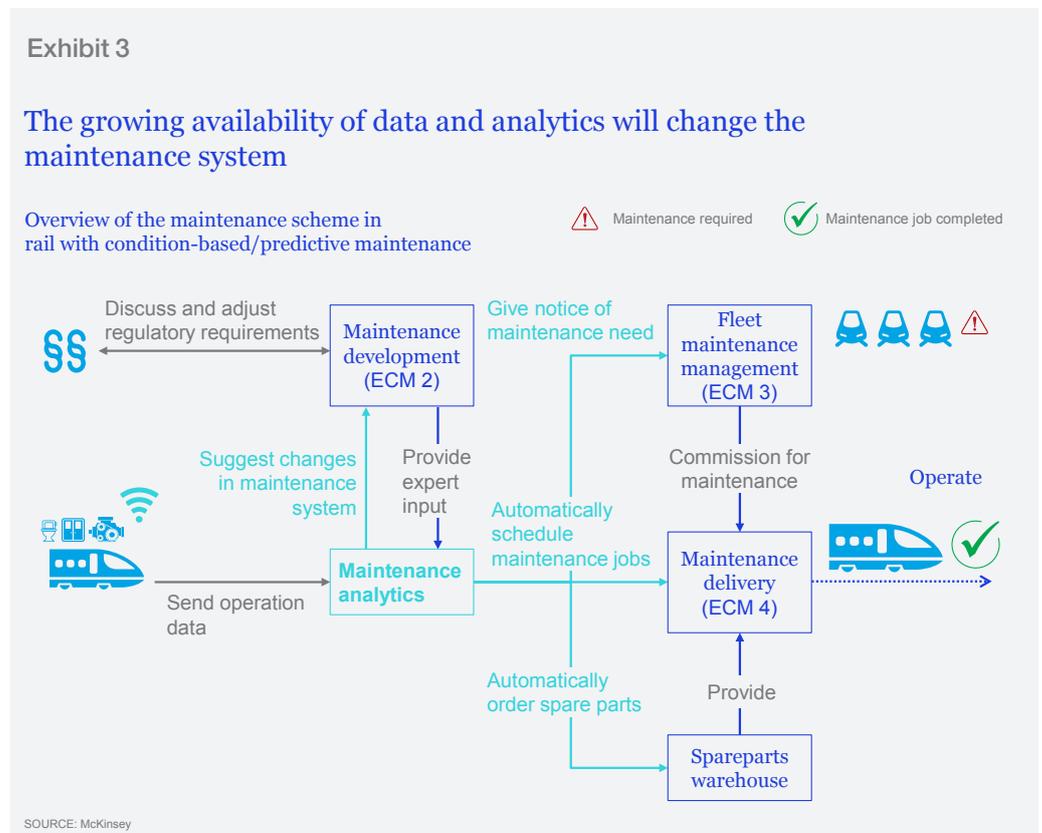
Today's maintenance process is based on a manual fleet commissioning process

The maintenance system today is structured fairly similarly across operating segments due to regulation. There is a function responsible for the safe operation of a fleet (in Europe and parts of Asia/Africa called ECM 1 – Entity in Charge of Maintenance), and another function plans and



sets maintenance standards (ECM 2, in Europe). A third function (ECM 3) manages the fleet and schedules maintenance jobs – and lastly there is ECM 4, which executes the maintenance (Exhibit 2).

With the advent of condition-based maintenance (or predictive maintenance in the end state), the roles within the maintenance system change. In a fully automated condition-based or predictive maintenance scheme, the ECM 3 function will be automated (Exhibit 3). This means that once a potential failure of a train or equipment in operation is detected, an automatically created maintenance job is delivered to the workshop, and the train is automatically commissioned.



However, for the medium term at least, maintenance schemes will be a mix. Continued demand for manual commissioning is triggered by regulatory requirements for legacy equipment without sensor technology. Furthermore, manual commissioning will also be required for newer fleets, as condition-based or predictive maintenance will not be able to cover all components from the start. Manual commissioning will therefore remain an important element within ECM 3.

Maintenance development and fleet maintenance management will potentially merge into a single maintenance analytics and scheduling function

Along with incorporating additional analytics capabilities, it is also possible that the ECM 3 function will merge with either ECM 2 to become a maintenance analytics and scheduling function or with ECM 4 towards automated tour planning, where maintenance scheduling and execution are considered simultaneously and thus optimized. This will lead to huge productivity gains and significantly shrink the employee base within these functions, especially within ECM 3. The specific efficiency gains depend, though, on the maintenance ecosystem's degree of automation.

An incremental shift from legacy equipment towards sensor-equipped new fleets as well as increased penetration of condition-based or predictive maintenance throughout the fleets call for an agile approach to incorporating insights from condition-based or predictive maintenance into decision rules and to monitoring the degree to which regulatory requirements are being met. With analytics tools continuously evolving throughout their rollout and deployment, surrounding processes and decision rules need to be adapted and incorporated into the maintenance processes. For example, today's low-frequency, periodic review of regulatory compliance needs to switch towards a continuous assessment of newly developed, condition-based maintenance decision rules. Internal processes, e.g., within ECM 2 or 3, also need to be continuously adapted based on fleet maturity and the penetration of condition-based or predictive maintenance.

In this changing landscape, two crucial questions remain: Which player in the rail operations ecosystem will take on which role? And: Will rail operators still mostly oversee the entire maintenance value chain or will control shift to rolling stock OEMs?

3. While rolling stock OEMs will focus on entering the (maintenance) service business, rail operators' future maintenance strategies depend on segment, market position, and region

Due to competitive pressure and over-capacity in production facilities, rolling stock OEMs seek growth in new service business models, e.g., offering train-as-a-service models

Rolling stock OEMs feel pressure on their margins with the main reason being overcapacity in production facilities across all geographies. With an estimated unused factory capacity of ~40% in Europe and North America and ~60% in Asia, consolidation is an expected activity. As a result, today's top ten rolling stock OEMs increased their market share from 53% in 2010 to 71% in 2015.² As the traditional value of new fleets flattens, rolling stock OEMs are keen to find additional sources of revenue. Also, in order not to lose customers to competitors, rolling stock OEMs need to develop a more in-depth understanding of rail operations and how to enhance the services they are able to offer their customers. Expectations, therefore, are that they will increasingly concentrate on cost efficiency and the identification of new business models, which can relieve some of the margin-squeezing pressure on the new vehicles business.

As the value that the equipment itself contributes begins to plateau, the main source of growth potential for rolling stock OEMs will lie in the service business. The development or acquisition of advanced maintenance and data analytics capabilities enables traditional rolling stock OEMs to tap into the service business with scalable and targeted solutions. This means that in addition to the sale of new vehicles, rolling stock OEMs' value will also come from service and maintenance over the vehicle's full lifecycle. Condition-based and predictive maintenance respectively facilitates this process as it allows rolling stock OEMs to deliver new service models, such as the committed provision of fleet availability with a greater reliability than previously possible. Alstom, for example, has launched the platform HealthHub, which allows the rolling stock OEM to monitor asset availability and provide decision-making assistance for advanced maintenance across the whole rail system.³

As customer structures will eventually shift towards more financial investors buying rolling stock, the opportunity for rolling stock OEMs to increase their grip on the aftersales business and offer "transport-as-a-service models" will grow. This is due to the fact that these players

² McKinsey (2016): Huge value pool shifts ahead – how rolling stock manufacturers can lay track for profitable growth

³ <http://www.alstom.com/press-centre/2014/646105/innotrans2014-alstom-launches-healthhub-an-innovative-tool-for-predictive-maintenance/>

have limited in-house capabilities in contrast to incumbent players with dedicated maintenance operations. Therefore, rolling stock OEMs will benefit from additional maintenance and service contracts being tendered by financial investors who lack in-house capabilities.

The perception and anticipation of how rail operators will react to increasing pressure from rolling stock OEMs varies fundamentally as our extensive discussions with rail operators revealed. Some believe that rail operators have the best chances of dominating the maintenance value chain – even in a context of advanced maintenance. Others think that the role of the rail operator will be reduced to pure operation, while the full maintenance value chain will become the domain of rolling stock OEMs. A third set of opinions is that it will be all about hybrid solutions in which rolling stock OEMs and rail operators cooperate with full data disclosure and operate the maintenance value chain collaboratively.

There is no clearly defined target state for rail operators: all depends on segment, region, and context

Which scenario is the most probable for the rail sector? Again, we believe the answer is not simple and that there will be different target states by segment, region, and unique context in the medium term. Which target state will be most likely to materialize depends on the “fitness” and market position of the rail operator as well as the customer structure of the rolling stock OEMs. Competition in the segment and region and the infrastructural context are also important.

In bits and pieces we are already seeing the emergence of new maintenance ecosystems – and they are as diverse as expected. Let us give a few examples:

Cooperation between rail operators and rolling stock OEMs. In 2016, SNCF and Alstom, for example, launched their first innovation partnership to design and produce the next generation of the French high-speed train TGV. ⁴

Outsourcing of maintenance from rail operators to rolling stock OEM. While National Express and Abellio will operate the new fleet of regional trains called “Rhein-Ruhr-Express” in the metropolitan area of Nordrhein-Westfalen, Siemens has won the contract to build and maintain the fleet of 82 trains over the next 32 years (starting in 2018). Siemens profits from the maintenance agreement – which includes a fleet reliability guarantee that lowers operating costs – by earning an additional EUR 1.1 billion over the lifetime of the equipment. ⁵ Siemens has also won the 14-year contract to provide and maintain the 26 Velaro E high-speed trains for service between Barcelona and Madrid, offering very high train availability with the help of state-of-the-art predictive maintenance.

Cooperation between rail operators and software companies. German cargo rail operator DB Cargo, for example, is now collaborating with GE to equip 250 of DB Cargo’s locomotives with digital solutions from GE following a successful three-month trial period, during which the number of train failures was reduced by 25% using the GE-Predix-based solution “RailConnect 360.” ⁶ Cooperation is also key for Italian rail operator Trenitalia which now cooperates with SAP to support its digital transformation journey and operations goals. As early as 2014, Trenitalia had begun developing an advanced maintenance model, deploying and customizing a ready-

4 <http://www.alstom.com/press-centre/2016/9/sncf-and-alstom-launch-their-first-innovation-partnership-to-create-the-next-generation-of-the-tgv/>

5 <http://www.handelsblatt.com/my/unternehmen/handel-konsumgueter/rhein-ruhr-express-der-neue-zug-fuer-nrw/20053454.html>

6 <http://www.silicon.de/41642157/ge-bekommt-grossauftrag-der-deutschen-bahn/>

made solution from SAP and the SAP HANA platform to analyze sensor data and monitor equipment behavior remotely.⁷

Many different players want to claim their shares of the new maintenance scheme. Among these players are the rail operators themselves (e.g., Trenitalia, Deutsche Bahn), the rolling stock OEMs (e.g., Siemens, Bombardier, Alstom), component suppliers (e.g., Knorr-Bremse), IT platform providers (e.g., Microsoft, SAP, IBM, GE), and analytics or sensor technology start-ups (e.g., Konux, Predikto, C3IoT). However, when taking a closer look at these players it becomes clear that it is rail operators and rolling stock OEMs that are in the position to define the game. They own a significant share of the data generated by the fleet – be it operations data, track data, or data generated by sensors on the trains – and this gives them an advantage over other players. Rolling stock OEMs also have valuable experience they can leverage from other industries. All other players are more limited in what they bring to the table (e.g., only IT or analytics knowledge) or have a very narrow view regarding the full value chain (i.e., an understanding of only one specific component). Thus, IT platform providers, analytics start-ups, and system suppliers will – in most cases – only play a supporting role for either the rolling stock OEM or the rail operator or both as technology leadership in predictive maintenance erodes much faster today than it did just a couple of years ago.

4. The fiercest competition for maintenance value is currently happening within the large, urban/regional passenger rail and cargo rail segments in liberalized markets

For large rail operators, staying in control of the whole rail operations value chain is key to a sustainable business model

As rolling stock OEMs are already responsible to produce trains and stand a good chance of winning over maintenance work, it is a very small step to completely taking over rail operations and putting rail operators under pressure also on this part of the value chain and potentially out of business. Next to tapping the value pool of rail maintenance itself, staying in control of the entire rail operations value chain is thus key to making the business model of a rail operator sustainable.

Let us have a closer look at the individual rail operator segments in liberalized markets and discuss the underlying market forces and their implications for changes in the maintenance system.

Urban/regional passenger rail

In liberalized markets, separately tendered rail maintenance contracts fuel competition for efficiency in the urban/regional rail segment

In liberalized markets, competitive pressure from the consolidating rail OEM market and/or alternative transportation modes is most prominently felt in the urban/regional passenger and cargo rail segment. Among other things, this is due to public entities increasingly separating rail operations, ticketing, and rail maintenance in their rail tenders. Bidding on separate rail maintenance tenders yields a perfect opportunity for rolling stock OEMs to enter the rail maintenance market. Thus, with separately tendered rail maintenance, efficiency is key to staying competitive and the main lever to do so lies in the introduction of condition-based maintenance. As discussed before, its introduction leads to efficiency gains of up to 15% compared to conventional maintenance.

Regional and urban passenger rail operators are thus among the more vulnerable players and need to quickly build up their capabilities with respect to condition-based maintenance (leveraging their knowledge of operational contexts) and realize significant efficiencies in their maintenance. Furthermore, rolling stock OEMs will take on the maintenance for smaller regional and urban rail operators on a service basis, leveraging their currently superior analytical skills and knowledge of the assets and this way putting even more competitive pressure on larger regional and urban rail operators. As discussed above, rolling stock OEMs might even enter the rail operations market in the medium term.

⁷ <http://news.sap.com/trenitalia-showcases-railway-innovation-with-sap/>

Cargo rail

A similar story holds true for cargo rail operators. Financial investors increasingly invest in cargo leasing companies who tender the maintenance to the most cost-efficient bidder and thus offer an entry opportunity to rolling stock OEMs. Next to these players, competition increasingly stems from alternative transportation modes (due to cheap fuel prices and automation in trucking). This situation pushes cargo rail operators to make their maintenance as efficient as possible. The same argument as above holds true for controlling the rail operations value chain: large cargo rail operators need to quickly build up their capabilities with respect to condition-based maintenance (leveraging their knowledge of operational contexts) and realize significant efficiencies in their maintenance.

Long-distance passenger rail

In long-distance rail, the competitive pressure is significantly lower compared to urban/regional passenger and cargo rail segments. The transportation market (automobile, long-distance buses, airlines) is stable, and autonomous passenger cars are still a relatively far-off reality. Thus, there is currently no real competitive pressure on long-distance rail operators to overhaul their maintenance system. However, as customers more and more ask for a higher-quality transport experience, long-distance rail operators might be incentivized to reduce component failures through condition monitoring. This, next to a significant potential to increase margins, might yet make the case, albeit longer-term, for change in long-distance rail.

Pragmatic recommendations to capture value from the emerging maintenance ecosystem

From our extensive client experience in rail and other industries, we know that there are often big organizational and mental hurdles when it comes to transformation. What we recommend in digital manufacturing transformations in general, and in condition-based maintenance transformations in particular, is that organizations dream big, start small, and strive to achieve rapid impact.

Building a vision and identifying small incremental steps to achieve that vision can help companies overcome the initial hurdle to starting at all. Based on our experience and the insights derived from our interviews with rail COOs across Europe, we have formulated three pragmatic actions rail companies can initiate now to begin preparing for the condition-based/predictive maintenance ecosystem.

1. Define a strategically appropriate target state and structure “data partnerships” accordingly

Setting the strategic target

For rail operators, the setting of a strategic target begins with assessing their fitness for condition-based maintenance

As discussed above, most rail operators are not yet clear on where they want to be with respect to condition-based and predictive maintenance. Setting this target begins with a rail operator’s assessment of its current competitive position, i.e., its “fitness” for condition-based maintenance. The question of what is the overall goal regarding maintenance needs to be answered: keeping it in-house or outsourcing (parts) of the maintenance delivery and focusing on pure operations? Defining or enumerating a set of specific variables will help rail operators understand where they are today and set a practical strategy for the future:

- **Segment and competitive context.** As discussed above, competitive pressure and, thus, the need for action is highest for urban/regional or cargo rail operators in liberalized markets.
- **Fleet characteristics.** The more a fleet is dominated by legacy assets or a large heterogeneity, the harder it is for the rail operator to innovate itself or involve rolling stock OEMs in the process.
- **Number of assets.** Larger, more powerful rail operators with a multitude of assets will have a great incentive to conduct their maintenance in-house, while smaller rail operators might find it beneficial to outsource the maintenance – to either rolling stock OEMs or independent workshops.
- **Number of different operating contexts.** A heterogeneous set of operating contexts puts rail operators in the pole position for condition monitoring and predictive maintenance. This is because the operating context of a train determines the limits of functionality of its components. It makes a big difference whether a train is operated in an urban area with winding roads or, for example, in the mountains.
- **Current market share in rail maintenance.** Rail operators that are already heavily involved in rail maintenance will have significant reason to continue playing a part in the maintenance game and not hand it over to other players. For them, in-house maintenance might be more cost efficient than outsourcing.

- **Infrastructure context.** It is important to have a look at a country's infrastructure conditions, as they are a proxy for the speed of change in the rail sector as a whole in that country. In countries such as France, Germany, or the UK, which have a lot of legacy assets and very few track extension projects, it is easier for the incumbent maintenance players to remain dominant, as the rail operators will also remain steady. In regions such as the Middle East or Southeast Asia, where rail infrastructure is currently being built up, it is easier for new players (e.g., rolling stock OEMs) to enter the maintenance market if they deliver the best offer. Ease of entry also depends on the regulatory context of each country. In China, for example, where ~40 to 50% of all worldwide track extension projects are run, there is little opportunity for players other than the incumbent to enter the maintenance business due to regulatory restrictions.

Having assessed the current fitness for condition-based/predictive maintenance, rail operators should develop a desired target state regarding their maintenance and design the road map. Most likely, partnerships are necessary to realize the target state. The corresponding possibilities should be assessed along the entire tech stack, starting with sensor technology, transmission technology, and connectivity to data ingestion infrastructure and analytics.

Understanding data details and developing data-sharing partnerships

Success in the new digital maintenance ecosystem is often closely linked to which party owns which kind of data. Both sets of data – operations/maintenance data and component/sensor data – are needed for the switch towards condition-based and predictive maintenance. As data ownership is distributed across several players, all of them need to get in conversation and settle on agreements that suit their target state. Careful, up-front consideration of the following questions can help avoid getting locked into unfavorable terms for the duration of a fleet's life (or even longer in the case of strategic longer-term negotiations):

- What kind of data is being or should be generated to implement condition monitoring or predictive schemes, and how can this data be extracted from the trains in real time or at least in near time?
- Who owns which data and what data rights should other parties in potential cooperation models have?
- Is data shared between the parties and, if so, how?
- What IT solution is used as a platform? Is exclusivity desired, or is the aspiration a solution that benefits the sector as a whole?
- Should data be shared with other parties (e.g., analytics start-ups, system suppliers) who are potentially involved and, if so, how?
- What measures should be taken to prevent data breaches and asset manipulation, and how can cybersecurity be enforced?

Success in the new digital maintenance ecosystem is closely linked to who owns which data

Pure analytics often do not produce reliable prediction models for advanced maintenance

If neither rolling stock OEMs nor rail operators are willing to hand over or sell the data generated to the other party, both will find it beneficial to at least cooperate with each other to have access to the full picture and capture the entire potential of condition-based or predictive maintenance. Tons of data will be generated and extracted from trains in real time at some not-so-distant point in the future, and the danger of data being manipulated or used as a gateway to intrude into the train's operating system will increase. Therefore, incorporating principles of cybersecurity will become one of the most crucial efforts in setting up the predictive maintenance ecosystem – and getting permission to do so by regulatory bodies will be equally critical.

2. Create a physical space to bundle engineering and analytics know-how

A recent survey on Industry 4.0 conducted with ~400 executives from various industries in the US, Germany, Japan, and China shows that ~30% of companies in the logistics industry have been engaging in predictive maintenance pilots.

One dominating experience during these pilots is that pure analytics does not deliver the desired results, falling short in a few key ways:

- Poor data quality. Existing data and data history are not rich enough to predict the failure of specific subcomponents of more complex systems.
- Unreliable correlations. Prediction models reveal seeming correlations between sensor data and failure codes that ultimately prove to be wrong. Interpretation of the results and adaptation of the models is needed – which can only be made successful in close cooperation with engineering and analytics experts.
- Insufficient lead time. The findings of the prediction models often cannot be incorporated into the maintenance processes because the time between failure alert and component failure is often insufficient.

Thus, the main results of initial proofs of concepts were that pure analytics and prediction models are not precise, sufficient, or comprehensive enough to support a predictive maintenance scheme. With the data available today, descriptive analyses of failure data together with rail engineering expertise prove more promising than a purely analytical approach. Rail operators/rolling stock OEMs need to find a way to effectively couple rail engineering expert knowledge and analytics power because it will take rail experts and analytics scientists working in tandem to develop powerful models. To get there, they can either build up an in-house analytics function – which consists of rail and analytics experts working in tandem (or one of the two in a cooperation model) – or buy analytics as a service, where the provider works on-site together with rail experts.

Bringing rail knowledge and analytics expertise together is made especially challenging by the fact that rail engineering know-how is usually fragmented across different divisions of a rail operator. In order to make a fundamental change, it is important that all rail knowledge be collocated in a physical space with the analytics team. This means pulling together relevant rail experts from all of the siloed functions of procurement, fleet management, and maintenance planning.

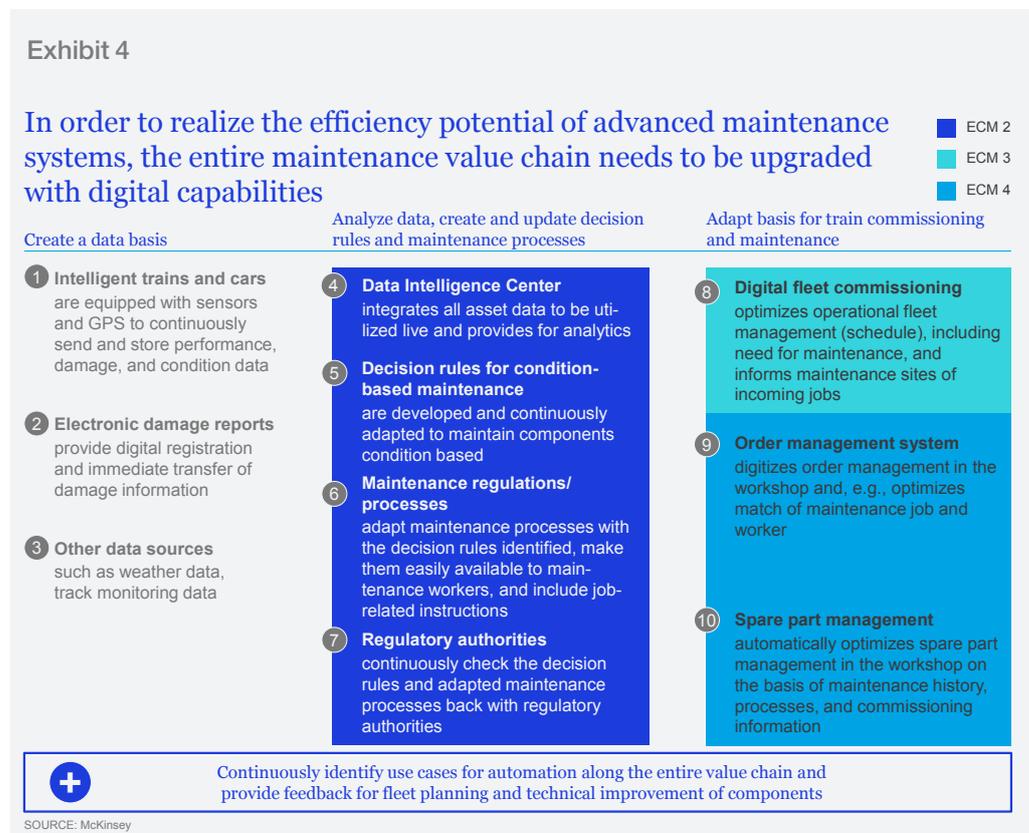
An example is the Siemens Mobility Data Services Centers in Atlanta, Munich-Allach, and Moscow, where Siemens strives for optimized train operation by intelligently using rail system data for condition-based and predictive maintenance. But Siemens does not only use virtual train data. Especially in Allach, where Siemens builds and maintains locomotives, the company combines the virtual and the real worlds to make sure its train experts do not lose sight of what matters – the physical trains.⁸

Beyond the technical elements, additional implementation challenges remain that should not be underestimated. Companies need to carefully consider organizational issues related to cross-department or cross-company collaboration, culture clashes between data analysts and rail engineering experts, or change management and transformation of maintenance processes across the organization. Sometimes even defining a business case upfront can be difficult.

3. Commit to “value-chain-wide” digitization

Sensor technology and analytical capabilities alone are not enough to realize the efficiency potential of condition-based maintenance systems. The entire maintenance process needs to be upgraded with digital capabilities – component by component and/or sub-fleet by sub-fleet – to ensure positive ROI (Exhibit 4).

Sensor technology and analytical capabilities are not enough: the entire maintenance value chain needs to be upgraded with digital capabilities



⁸ <https://www.siemens.com/innovation/en/home/pictures-of-the-future/digitalization-and-software/from-big-data-to-smart-data-heading-for-data-driven-rail-systems.html>

Creating and updating decision rules and implementing them in the maintenance processes will be at the heart of the new maintenance system

A rollout of advanced maintenance component by component spares the need of heavy up-front investments

The steps of the maintenance scheme transformation

Equipping locomotives and wagons with sensors for critical components is only the first step. Also, an efficient data transmission and integration system needs to be installed. This ensures that data can be continuously and automatically analyzed via smart analytics. Last but not least, fleet management and maintenance workshops need to be adapted in order to process the information suggested by the condition-monitoring algorithms.

Creating and updating decision rules

A layer in itself is the analytics behind the condition monitoring. Next to automatically evaluating data and suggesting maintenance jobs for fleet maintenance commissioning, the analytics layer needs to create and update decision rules, i.e., sensor thresholds for the surveilled components. These decision rules have to be implemented in the maintenance processes and checked for conformity with regulations. This element of the new analytics layer is at the heart of condition-based maintenance: the value of condition-based maintenance is created here. As discussed before, a physical space bundling engineering and analytics know-how can boost the overall results of this new function.

The continued surveillance of critical components with the help of sensor data will provide input for discussions with the regulatory authorities. Furthermore, the insights gained will also provide input to lifecycle cost assessments and thus help optimize fleet planning and suggest technical improvements of components.

Rolling out the new maintenance scheme

As discussed before, what is most important for a component-driven rollout is to start from the top and formulate a clear operations and maintenance strategy over the coming decades (as assets usually have a lifecycle of several decades). This provides more insights into what the specific needs for action will be. Following the development of the strategy, a thorough evaluation of each train component needs to take place to estimate the impact of shifting towards a condition-based or predictive maintenance scheme – including the investment costs for sensors, etc. and the estimated return on investment.

Only for business-case-positive components should a rollout of the new technology be anticipated; there is no need to equip the whole system at high cost. Thus, the fixed cost should be kept manageable, especially when sticking to a condition-based maintenance scheme at first. The components that come first in the transformation process should already contain sensors that data can be pulled from.

Further prioritizing components by customer relevance and the degree to which malfunction can lead to train failure is also helpful. For passenger trains, customer-relevant components could, for example, be air conditioning, doors, or toilets, while for cargo fleets it could be components that allow for automatic train preparation to speed up processes. Across segments, failure-relevant components might include brakes or the powertrain. For example, urban transport rail operator Transport for London started working with technology services contractor telent in 2014 to install sensors specifically in escalators, elevators, air-conditioning systems, and subway tunnels as well as PA and monitoring systems and closed-circuit television cameras.⁹

⁹ <https://www.psfk.com/2014/05/london-underground-internet-of-things.html>, among others

Getting started on your journey towards “value-chain-wide” digitization

Upfront to a transformation of the maintenance value towards a condition-based or even predictive maintenance scheme, rail operators usually fear high amounts of fixed cost: setting up a data management structure and system, equipping every component with sensors, and building up a fully-fledged analytics team – just to name a few.

The plan, however, does not need to be to implement the complete system solution from the start. Trains are already generating tons of data today, which can be used in an initial step for condition monitoring. This data needs to be collected, stored, and made usable. For a condition-based maintenance scheme, the only additional cost lies in ensuring that the maintenance records are being maintained, evaluated, and used for maintenance planning.

What are you waiting for?

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We would like to thank all contributors who invested time and effort in shaping the content of this report, especially all rail COOs who participated in extended interviews and/or provided feedback on the development of this report.

Also, we owe special thanks to the many McKinsey rail and predictive maintenance experts – including Arnt-Philipp Hein, Anselm Ott, Stuart Shilson, Chad Cisco, Dilip Bhattacharjee, and Malte Hippe – who supported us on the journey of writing this report.

Are you interested in learning more about how rail operators and rolling stock OEMs can benefit from digital maintenance opportunities? Please contact our authors and content leaders.

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