

Rolling stock maintenance for the day after tomorrow

PROSE WHITE PAPER IN COLLABORATION WITH FUTUROLOGIST
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Where will vehicles be maintained in 2050?

How are automation, digitalisation, and ongoing urbanisation shaping maintenance?

How is the interaction between humans and robots changing?

How should the industry respond to the growing shortage of skilled workers?

Supported by Joël Luc Cachelin, PROSE has developed five theses on the future of rolling stock maintenance. They are intended to stimulate reflection and discussion, as well as to support strategic work. A structured approach and the analysis of expected influences are the first steps towards a successful future.

ROLLING STOCK MAINTENANCE OF THE DAY AFTER TOMORROW

- 1** Maintenance moves away from operations. Vehicle availability is leased externally from third parties.
- 2** Maintenance infrastructure is being displaced from attractive urban locations.
- 3** The intelligent rail vehicle organises its own maintenance.
- 4** Automation increases the requirements profile for maintenance staff. Fewer and fewer workers are available.
- 5** The increasing economic pressure to conserve resources reinforces sustainability.

INFLUENCE ON TODAY'S DECISIONS

ROLLING STOCK MAINTENANCE OF THE DAY AFTER TOMORROW

1 Maintenance moves away from operations. Vehicle availability is leased externally from third parties.

By 2050, ongoing densification and urbanisation have ensured that cities became even more important as living spaces and economic centres. Trains connect metropolitan areas quickly and in an environmentally friendly manner, while trams, metros and suburban railways, in conjunction with on-demand services, have replaced private cars in city centres. The inefficiency of privately owned cars in terms of usage, space requirements and emissions has led to a rethink in urban planning. New, green mobility and spatial design concepts are improving quality of life and reducing heating of urban spaces. Rail vehicles are the most important means of transport in this urban future due to their large transport capacities at maximum energy efficiency.

In 2050, the rail vehicle market will be characterized by: In the product portfolio, the consolidation of suppliers and the deindustrialisation of Europe, coupled with an increase in automation in production, has led to a reduction in the variety of products. This trend has been accelerated by increasing requirements for the approval of rail vehicles, which make adjustments to the railway-related parts of vehicles unprofitable for individual procurements.

On the operator side, competition, both intermodal and intramodal, has put pressure on the railways.

These developments have led to the vehicle fleets of various operators becoming increasingly similar in terms of their technical design. The only differences are in the visual design and the modular interior design, which is tailored to customer requirements and the intended use.

Operators' financial reserves for fleet investments are proving to be scarce, and financing conditions appear unattractive due to the economic situation of the companies. Operators are therefore being driven to lease vehicles instead of buying them.

The procurement and financing of assets is handled by large corporations (pension funds, investment companies, etc.), while rental companies organise management and marketing.

Higher numbers of similar rail vehicles operating within a region increase the market potential for providers of downstream services. The framework conditions create an attractive environment

for manufacturers, but also for third parties who are able and willing to take over the responsibility for vehicle maintenance. This makes it attractive for operators to source vehicles with full service or guaranteed availability.

The adapted business model ensures operators access to fully maintained vehicles at planned costs. This allows them to outsource the long-term risks of procurement, maintenance and technical operation over the entire lifecycle of the vehicles. Booking vehicles including maintenance is also practical because it allows them to focus on their core business of operating and marketing transport services. Vehicle performance is then monitored by simply comparing contractually agreed and actual availability.

Furthermore, the change in the business model to renting out availability represented the entry into the subscription economy. Like other industries (e.g. the entertainment or software industry), rental companies and maintenance providers benefit from regular income.

For maintenance providers, the new business models bring intensified competition. In order to increase their own profits and differentiate themselves from other market participants, there is an intrinsic motivation to continuously improve

Booking vehicles including maintenance is also practical because it allows transport companies to focus on their core business of operating and marketing transport services.



Vehicle data and its evaluation are the decisive lever for increasing availability.

maintenance through innovation and technical measures and to increase its efficiency. Vehicle data and its evaluation are becoming a decisive lever for increasing availability.

2 Maintenance infrastructure is being pushed out of attractive urban locations.

More pronounced than in other, less developed European regions, 85 percent of Switzerland's population will be living in urban areas by 2050. The short distances between urban areas and the close network mean that all their cities have increasingly grown together into a single entity: Helvetia. As urban space becomes increasingly scarce due to sealing, immigration and ageing, workshops, which for historical reasons are located close to train stations that serve as hubs for several lines, are also being displaced. Cities want to use the scarce land in these attractive locations differently and upgrade it from the residents' point of view. This displacement is reinforced by three other trends: The standardisation of fleets is leading to similar requirements for maintenance infrastructure across fleets.

This enables the centralisation of services across fleets, which allows unit costs to be reduced through economies of scale and efficiency gains. The remaining facilities are then optimised and designed to take advantage of the possibilities offered by automation for recurring activities. The maintenance of larger fleets allows the necessary larger investments to be amortised.

IoT applications on trains improve the predictability of maintenance. If unavailability can be postponed to periods of low demand and train runs to and from the maintenance can be taken into account in the planned vehicle circulation, their effects are negligible. The autonomous operation of vehicles supports flexible and, if necessary, extended transfers to and from a centralised workshop.

In addition, workshop owners can generate additional income by converting their workshops. They can either realise the value of their assets immediately by selling their space to pension funds or specialised property developers. Or they can opt for continuous income over the coming decades by developing, leasing and operating their sites themselves. This second option requires the development of appropriate skills in order to manage the vacated space in an economical and ecological manner.

According to debates on green urban development, the current maintenance sites are ripe for conversion into lofts with industrial charm or complete reorganisation with integrated residential, local retail and office space. It also makes sense to convert the often centrally located spaces into co-working offices, thereby symbolising the transformation of post-industrial society into a service society.

3 The intelligent rail vehicle organises its own maintenance.

The rail vehicle of the future is intelligent and deeply networked. It not only collects data about passengers and the weather, but also about its own status as well as providing valuable insights into the condition of the infrastructure it runs on. Diagnostics identify when repairs and maintenance are necessary and trigger the necessary preparatory work according to urgency.

Thanks to its new capabilities, the rail vehicle becomes a platform that coordinates its own maintenance.

«Knowledge immediately available at the point of use – augmented reality and trained voice assistants are becoming the digital tools of maintenance staff.»



Reto Grob

CEO
Augment IT AG



In addition to the workshop slot with the appropriate infrastructure, the rail vehicle initiates the organisation of the necessary tools and spare parts. Furthermore, employees with the appropriate skills are booked according to maintenance requirements. The downstream supply chain and logistics concept ensure that everything is provided in the right place and at the right time.

When their workshop slot is due, the trains in need of maintenance drive autonomously to the workshop in the correct order according to the schedule. In the event of short-term changes to the schedule, for example due to staff shortages, the schedule is automatically updated by the planning system with the aim of maintaining the highest possible vehicle availability.

Automation will make many maintenance tasks more efficient in the future. Machines will cooperate with skilled employees, who will be supported in their work by mobile robots, exoskeletons and digital assistants. The latter will help, for example, to reliably work through checklists and write reports. The ongoing digitalisation of workshops is also reflected in the widespread adoption of augmented reality (AR). Digital content supplements the field of vision, provides guidance and becomes the central interface with the maintenance system. Instead of using their fingers, workshop employees give instructions acoustically, similar to Siri and Alexa.

Translation bots facilitate work in Switzerland, which has four official languages, as well as in international teams, thereby simplifying the use of contractually agreed support from other specialists at subsystem suppliers worldwide.

Because maintenance is continuously digitally recorded and logged, the checklists become more dynamic. Instead of always performing the same steps for each vehicle type, vehicle diagnostics and checklists adapt to current wear, tear and damage. In addition, a vehicle's digital twin provides information on what specifically needs to be examined.

4 Automation increases the requirements profile for maintenance staff. Fewer and fewer workers are available.

New business models, smart vehicles, numerous robots and collaborative digital assistants are confronting workshop organisations with new questions: People remain at the centre, but do organisations understand how to attract and develop their employees in the future and how to optimally design the interaction between hu-

man-machine teams? The same personnel issues arise because Generations Z and Alpha represent a new work ethic. Additionally, skilled workers in particular, but also workforce in general, have become even scarcer due to the wave of retirements in previous decades.

To meet these challenges, the workshop of the future is organised as a cloud. Instead of fixed employment contracts, it increasingly relies on flexible contractual relationships with external parties. Rigid hierarchies are being replaced by more flexible forms of organisation that promote interdisciplinary, independent collaboration and networking. Employees are instructed according to the orders of the smart train, with their work steps supported by digital assistants and smart cameras.

Automation and digitalisation are promoting a division of the working world. On the one hand, the new complexity of rail vehicles and maintenance infrastructure requires new skills and approaches. The requirements profile for employees in strategic maintenance development and organisation is becoming more demanding. Interdisciplinarity is becoming much more important in procedures because technical complexity requires the integration of additional specialist skills. While the technical focus is shifting away from mechanical con-

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«The maintenance of tomorrow will require AI-based systems for servicing and maintenance in order to compensate for the decline in skilled personnel, facilitate processing and enable continuous learning.»



Stefan Klügl

CEO & Founder
teamhoch3



«Smart resource management in maintenance is becoming crucial for the economic management of vehicles.»



Roland Alder
Head of Service Centers
Maintenance Rolling Stock
SBB AG

Suppliers are moving closer to maintenance, ideally achieving strategic lock-in.

tent, the skills required in the fields of mechatronics, electrical engineering, computer science in conjunction with statistics and data science, and data management are increasing.

On the other hand, there are workshop tasks that do not require any special knowledge, but for which automation has not yet provided any solutions. As these tasks are divided into precisely defined steps, they carry the risk of monotony. The resulting conflict between the desire for economic efficiency and greater self-determination for employees can be countered by job enrichment and job rotation. Employees then specialise not only in a single work step, but also learn about various aspects of maintenance. This promotes an eye for the big picture and thus the purpose demanded by younger generations.

5 The increasing economic pressure to conserve resources reinforces sustainability.

Maintenance is, by its very nature, an activity dedicated to sustainability. It serves to preserve the longevity of goods through regular inspection, servicing and repair. Repairs involve removing defective components such as seats, floors, lights, heating and cooling systems, doors and electrical systems, replacing them with functioning parts. Defective units are usually

repaired afterwards.

This does not mean that there is no potential for ecological optimisation in the design of future workshops. Large photovoltaic systems are being installed on roofs. Biotores promote biodiversity, and aquaponics systems are used to produce local food in line with urban agriculture principles. 3D printers will replace cumbersome transport routes. The areas around the buildings of the facilities remaining in urban areas will be unsealed, and the newly designed fountains and parks will cool the cities and improve the quality of life for young and old alike. Workshops of the future will also contribute to ecological sustainability by adding offices and living spaces or by accommodating restaurants on their roofs through floor extensions.

In addition, the circular economy is becoming more firmly anchored in workshop management. Where possible, raw materials and built-in components are kept in the material cycle instead of being thrown away. Reuse is preferred over recycling, as recycling often implies downsizing of raw materials. Furthermore, melting down and reprocessing aluminium, plastic or glass is energy-intensive. With reuse washbasins or luggage racks are reused in a different location. Old seat cushions become carpets, old floor coverings become insulation material.

In order to realise this potential, the workshop is pursuing a recycling strategy that is motivated by both ecological and economic considerations. In previous decades, sustainability was at odds with the pressure for economic efficiency. The industry was more interested in short life cycles. However, the battle between sustainability and economic efficiency will inevitably tip in favour of economic sustainability: resources and energy are becoming scarcer and more expensive, while the global population continues to grow. This makes the return of materials, components and subsystems to suppliers financially attractive, as it enables cost-reduced sourcing by eliminating additional supplier qualifications and minimising the use of resources. This brings suppliers closer to maintenance and, in the best case scenario, gives them a strategic lock-in.

Modularisation and a reduction in the variety of rolling stock further reinforce the application of circular economy models.



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The following next steps for asset management and maintenance today can be derived from the scenarios described for vehicle maintenance in the future:

Vehicle tenders represent a special milestone for operators. The requirements specify the management and thus define a large part of the running costs for the coming decades. It is therefore advisable to define the corporate strategy with regard to procurement and management in advance in order to be able to take advantage of the opportunities offered by the changed framework conditions. This concept must be coordinated with the strategy for developing the maintenance infrastructure. Its optimised design can also be a relevant factor in availability.

The definition of the vehicle specifications pays attention to standardised vehicle design and flexible application options. Technical requirements are reduced and give way to functional criteria. At the same time, it is essential to define criteria regarding the sustainability of the vehicles, both because this can achieve long-term savings in maintenance and material procurement, and for the purpose of marketing them as a sustainable, green means of transport.

The development of skills in data management and utilisation is particularly important for the further development of maintenance. This guarantees the exploitation of potential in management and availability through data collection, analysis and exchange. A powerful IT infrastructure that provides interfaces to other internal and external systems and avoids data silos is a basic prerequisite for this.

The attractiveness of companies is already of central importance today and is becoming even more acute due to the increasing shortage of labour and skilled workers. Until automation in maintenance brings about significant improvements, development work and significant investments in systems and infrastructure are still necessary. For companies, the development of attractive employment models is particularly necessary in the area of maintenance.

We invite you to join us in discussing these theories and our conclusions. Furthermore, we would be delighted to support your company in the dedicated implementation of the next steps.

About PROSE

At PROSE, we combine expertise, innovation, and independence to deliver world-class solutions within the field of railway technology. As a trusted partner in rolling stock engineering and railway consulting, we help manufacturers, operators, and authorities tackle their challenges—wherever they are in the world.

We are a majority employee-owned company, which means we remain fully independent in our work, allowing us to focus entirely on creating value for our clients. With a team of over 150 dedicated professionals and a presence in Switzerland, Germany, Sweden, Italy, France, and Austria, we're committed to shaping tomorrow's mobility.

Established in 1982 and with 5'000+ successful projects, we have earned our place as a trusted partner in delivering cutting-edge mobility solutions worldwide.

