# *Research and development*

Vossloh is a technological leader in the rail infrastructure segments in which it operates. Innovation plays a decisive role in ensuring that the company remains competitive from a technological standpoint. In the interest of safety, Vossloh's products and services are subject to detailed technical specifications and standards that must be met. By the time products and services for rail infrastructure are ready for the market, they have usually been through years of (further) development and test phases, as well as complex approval procedures by independent testing organizations. Research and development projects at Vossloh are, therefore, usually scheduled to run for several years.

In order to permanently meet the specific expectations of customers in the individual market regions and to further strengthen its own competitive position, Vossloh is constantly investing in the further development and optimization of its products and services with structured innovation management. The group-wide innovation guidelines (Innovation Playbook) adopted in 2021 define principles and procedures. Vossloh intends to increase collaboration across business units to develop new products, services and business models and ensure that customers and suppliers – with their specific expertise – are involved more closely in research and development processes. After reviewing its production processes over recent years, the company is now implementing a range of measures which will provide ongoing efficiency gains, including modernization, increased automation and specialization.

One focus of innovation at Vossloh is digitalization as the link between hardware and services. The company uses specialized sensor systems to collect data about load levels and track condition and, since 2023, data on the condition of rail vehicles. Among other things, this data can be used to gain knowledge about the degree of wear and damage to track components. With this knowledge, disclosures can be made about which maintenance strategies should be applied and when. This can reduce the risk of component failure – and thus the unavailability of routes and infrastructure – during ongoing operations. The use of artificial intelligence also plays an important role in this context. It makes wear patterns recognizable, allowing failures of track components to be predicted and avoided through planned maintenance measures. Vossloh uses its systemic understanding of the track to meet the central customer need – increasing the availability of the rail track – and develops holistic solutions in cooperation with all business units. Under the guiding principle of "enabling green mobility", these ensure that the rail infrastructure is more robust and resilient and that track availability is increased, even though the demands on the rail network are constantly increasing.

At the same time, sustainability criteria such as low material usage and energy consumption, the use of secondary raw materials and recycling or the avoidance of emissions play an important role in Vossloh's research and development activities. Vossloh is increasingly developing energy-efficient, recyclable products that reduce the environmental impact and promote a sustainable circular economy. Based on life cycle analyses, all business units are working on solutions that reduce the ecological footprint of Vossloh products and services. Detailed information on this can be found in the Group Sustainability Statement on pages 68 et seqq.

A significant proportion of Vossloh's research and development efforts relate to specific customer contracts. Accordingly, these expenses are reported under cost of sales in the income statement and not under research and development (R&D). Expenses for the development of market-ready products are only capitalized if they satisfy the relevant criteria defined in IAS 38. Development costs that cannot be capitalized are shown as research and development costs if they are not reported under cost of sales.

In 2024, research and development expenses – including capitalized own work – totaled €16.6 million (previous year: €12.0 million). This corresponds to a share of around 1.4 % of Group sales (previous year: 1.0 %). At €4.4 million (previous year: €4.0 million), R&D expenses in the Core Components division were largely attributable to the Fastening Systems business unit. In the Customized Modules division, R&D expenses amounted to €7.0 million (previous year: €4.6 million). €4.0 million (previous year: €3.0 million) was attributable to the Lifecycle Solutions division, while €1.2 million (previous year: €0.4 million) was attributable to Vossloh AG and Vossloh RailWatch GmbH.

The capitalized additions from own work and from third-party deliveries or services in the 2024 fiscal year in the amount of €2.3 million (previous year: €1.6 million) mainly related to the Lifecycle Solutions division.

Vossloh Group – Research and development costs

| € mill. | 2024 | 2023 |
|---|---|---|
| Research and development costs | 16.6 | 12.0 |
| of which capitalized | 2.3 | 1.6 |
| **Research and development expenses (income statement)** | **14.3** | **10.4** |
| Amortization (of capitalized development costs) | 0.9 | 0.6 |

Maximize track availability, reduce life cycle costs

Vossloh's research and development efforts in 2024 focused on creating new products and services that provide solutions to the major challenges currently facing the rail sector. This includes increasing the availability of rail tracks and developing solutions to deal with the consequences resulting from the increased load on tracks, such as wear and noise emissions. Vossloh also conducts research with a focus on extending the service life of infrastructure and infrastructure components in order to reduce lifecycle costs. Vossloh possesses comprehensive expertise on rail as a complex mode of transportation. The company is able to leverage this expertise to significantly improve the efficiency of rail network maintenance processes. Digitalization plays a key role in this. The focus is on intelligent rail systems and digital track monitoring. This promotes trouble-free operation and creates the conditions for more rail traffic. In this way, Vossloh is contributing to a more efficient rail infrastructure, which in turn is a necessary prerequisite for the environmentally friendly mobility of people and goods.

With Vossloh connect, the company is focusing on advanced digitalized applications in the rail infrastructure business. The cloud-based one-stop shop platform for customers from the entire rail network offers a range of state-of-the-art solutions that optimize the management and maintenance of rail infrastructure, thus contributing to greater safety, lower life cycle costs and improved overall performance. All digital solutions – mainly in-house developments from Vossloh, with additional complementary products from selected external partners – are integrated into a singular, user-friendly system. The platform provides a convenient, comprehensive overview of rail infrastructure and operations. In addition, the platform includes advanced analytics and alerting systems that reduce the risk of accidents and incidents. This is crucial for railbound traffic safety and helps to reduce the cost of emergency repairs and extend the service life of railroad systems.

Vossloh connect gives customers real-time access to data on the condition of their rail infrastructure. Measurement data and analyses that contribute to improving the maintenance of the rail network can be viewed in a protected area. By using advanced algorithms, the efficiency of maintenance work is increased and downtimes can be reduced.

### Condition data as the basis for predictive maintenance

The information about the condition of the rail infrastructure comes, among other things, from configurable IoT sensors directly in the track, which measure vibration conditions near turnouts to identify atypical track behavior. In addition, Vossloh rail processing machines, equipped with a series of sensors, as well as laser or eddy current instruments, serve as diagnostic vehicles. They measure the condition of the rails while the timetable is running. The collected data is transferred to an asset management system, for example, the in-house developed applications maple or MR.pro. In doing so, mapl-e can not only visualize the condition, but also assess it and derive maintenance measures from it, as well as carry out an economic evaluation of the necessary work. On this basis, the asset manager can create a plan and determine a budget for maintenance.

The condition of the track over time is also significantly influenced by the so-called wheel-rail contact. Vossloh RailWatch technology uses optical and acoustic sensors to identify the technical condition of freight and passenger cars, multiple units and locomotives as they pass by. A supplementary measuring system, which is installed in the track, enables further data to be recorded, including various parameters of the wheel profile, weight information and the distribution of axle loads. This collected information is also processed in the cloud using artificial intelligence. This means that wear or damage can be detected at an early stage and maintenance measures can be planned and implemented with pinpoint accuracy.

Turnouts are the most critical elements of the rail track, and also the components which require the most maintenance. Turnout disruptions are one of the main reasons for track unavailability and unplanned maintenance. Turnouts are also the ideal starting point for the continuous collection of condition data with sensors. In addition to tracks, a number of signaling and control systems cross each other at turnouts; as a result, the data collected at turnouts is particularly useful. Various digital solutions are now available for turnout management. In urban regional transportation, for example, Vossloh's compact electro-hydraulic Easydrive point machine can be equipped with smart sensor technology for remote monitoring. The PM-DiagBox can be added to conventional analog point machines to make them smart. Vossloh offers the innovative Easyswitch MIM-H point machine for mainline routes – a modular plug-and- play solution with excellent reliability. The proprietary development SMV (Motto: sense – see – solve) is already being used to avoid turnout failures and to proactively identify the need for tamping work on the ballast in the turnout area and to check its effectiveness. With the service provider France Aiguillages Service (FAS), Vossloh acquired further expertise in the maintenance of turnout systems and turnout signaling systems in July 2024.

Vossloh's AI-driven Wayside Monitoring is used in ports and on industrial sites, among other places. The pulsar installed in the track is equipped with high-resolution camera technology, among other things, and records process and status data such as UIC wagon numbers and brake block conditions. The continuous monitoring of incoming and outgoing trains helps to optimize operating processes and reduce downtimes.

### Digitalization accelerates development work

Digitalization also offers direct opportunities for Vossloh's R&D activities. Research and development work in all divisions is increasingly based on data processing technologies – a trend that continued in 2024. One example of successful development using digital means is Vossloh's new M-generation of tension clamps, for which the company required significantly less development time than for comparable products in the past. Thanks to a higher natural frequency and improved torsional rigidity, the tension clamps are more robust than their predecessors. At the same time, their compact design results in lower transportation costs and less potential for conflict on the track.

Contributions for a "quiet rail"

All of Vossloh's innovations also focus on quiet rails as noise and vibrations are a major inconvenience, particularly for people in dense urban areas. Vossloh helps to reduce noise emissions with damped rail fasteners, whisper turnouts, and acoustic grinding of tracks. A number of solutions in this area were improved in 2024. The company also provides maintenance measures that are proven to reduce noise emissions. Vossloh monitors noise using sensor technology and can keep the noise level of rail infrastructure permanently low through targeted track grinding. This is another example of how the company is using digitalization to improve the quality of life for people in urban areas by reducing noise.

Cooperation efforts and partnerships

Vossloh has long relied on the specific expertise of external specialists for some of its development work. The Group has access to an extensive network of experts. Vossloh works closely with well-known universities and research institutes around the world, for example, in Germany, France, Sweden, China, Australia and the USA, in the context of long-term partnerships at different levels and in various configurations. Vossloh focuses on partnerships with technology companies and startups working in digitalization and big data analysis. The joint venture established with Rhomberg Sersa represents a crucial partnership that offers a wide range of monitoring and maintenance services for turnouts and rails. The MR.pro software provides the joint venture with a set of open-system digital tools for evaluating and visualizing the condition and material of track infrastructure.

As part of a strategic partnership with the Swedish digitalization specialist Predge, work is being carried out on a prediction model that provides precise fault forecasts and valuable insights into impending failures, particularly of turnout drives. Vossloh developed the SoniQ Rail Explorer together with its specialist French partner UltraRS. The hand-guided ultrasonic inspection system can detect and localize irregularities inside the rail – even in a manganese cast iron crossing down to a depth of 60 millimeters below the running surface. A partnership between Vossloh and the British Cordel Group has been in place since the beginning of 2025. Its flagship platform uses artificial intelligence to provide automated analysis of transport corridors based on video and LiDAR (Light Detection and Ranging) data.

In addition to Vossloh, several selected partners also offer innovative digital solutions on the Vossloh connect platform. The Swedish company Strainlabs contributes its expertise in the field of intelligent screws. Cervello, a company based in Israel, specializes in cybersecurity solutions for the rail industry.

R&D in the divisions

In 2024, the R&D experts in the Fastening Systems business unit of the Core Components division focused, among other things, on further developing the tension clamps of the new M generation. One of the requirements was to increase the service life of the components in heavily used tracks. The potential of rail fastening systems with M clamps in ballasted track was also validated in complex measurement campaigns. Sustainability aspects were at the forefront of the development of new and improved plastic components. The combination of highly elastic rail fastening systems with highly elastic damping intermediate layers has resulted in a new solution for slab tracks. The Tie Technologies business unit again focused its R&D activities in the reporting year on material and energy-saving changes to the composition of concrete for railroad sleepers. The track tests were continued with a product whose cement mixture leads to a significantly improved $CO_2$ balance while maintaining the same properties.

In the Customized Modules division, the R&D experts focused on life cycle cost analyses, for example, for a complete streetcar network, as well as on the recycling and reuse of turnout elements. Vossloh can now offer manganese crossings that consist of up to around 90 % recycled material. This is linked to changes and adjustments to production processes, which are being geared more towards the circular economy. Several turnout solutions were also further developed in 2024 with a view to reducing $CO_2$ emissions during all phases of the vehicle's life cycle. The existing methods and models for inspecting and monitoring turnouts on the track have been improved with the help of new software. In general, advancing digitalization was an important R&D topic throughout the division. This is why Building Information Modeling (BIM) is playing an increasingly important role, both in internal processes and in collaboration with customers.

In the Lifecycle Solutions division, (further) development work focuses on machines for rail processing on the one hand, and onboard measuring systems for even more comprehensive condition monitoring of rail lines and software for evaluating and displaying the overall data (keywords "smart maintenance") on the other. In 2024, the control, sensor and measurement technology of various grinding and milling vehicles was also adapted to further customer requirements. An improved version of the successful high-speed grinding train is in preparation ("HSG-next"). The installation of a measuring system that measures and documents the quality of machined new rails began in the welding plant. The development of the RailTainer for efficient rail transportation to construction sites made further progress, as did the development of a loading and unloading system for transporting the VTM-c local milling machine with a RoMo wagon.

### Optimization of production and administration

Streamlined processes and digital data flows along the entire value chain are becoming an increasingly important part of Vossloh's internal processes. The cross-business-segment exchange of knowledge in the context of international development projects with the help of modern communication and collaboration solutions is growing. Accordingly, the IT structure was further expanded and standardized in 2024. In addition to the rollout of the group-wide standardized Enterprise Resource Planning (ERP) system, the focus was on cybersecurity. The information security management system was further refined in order to be armed against cyber threats of all kinds.