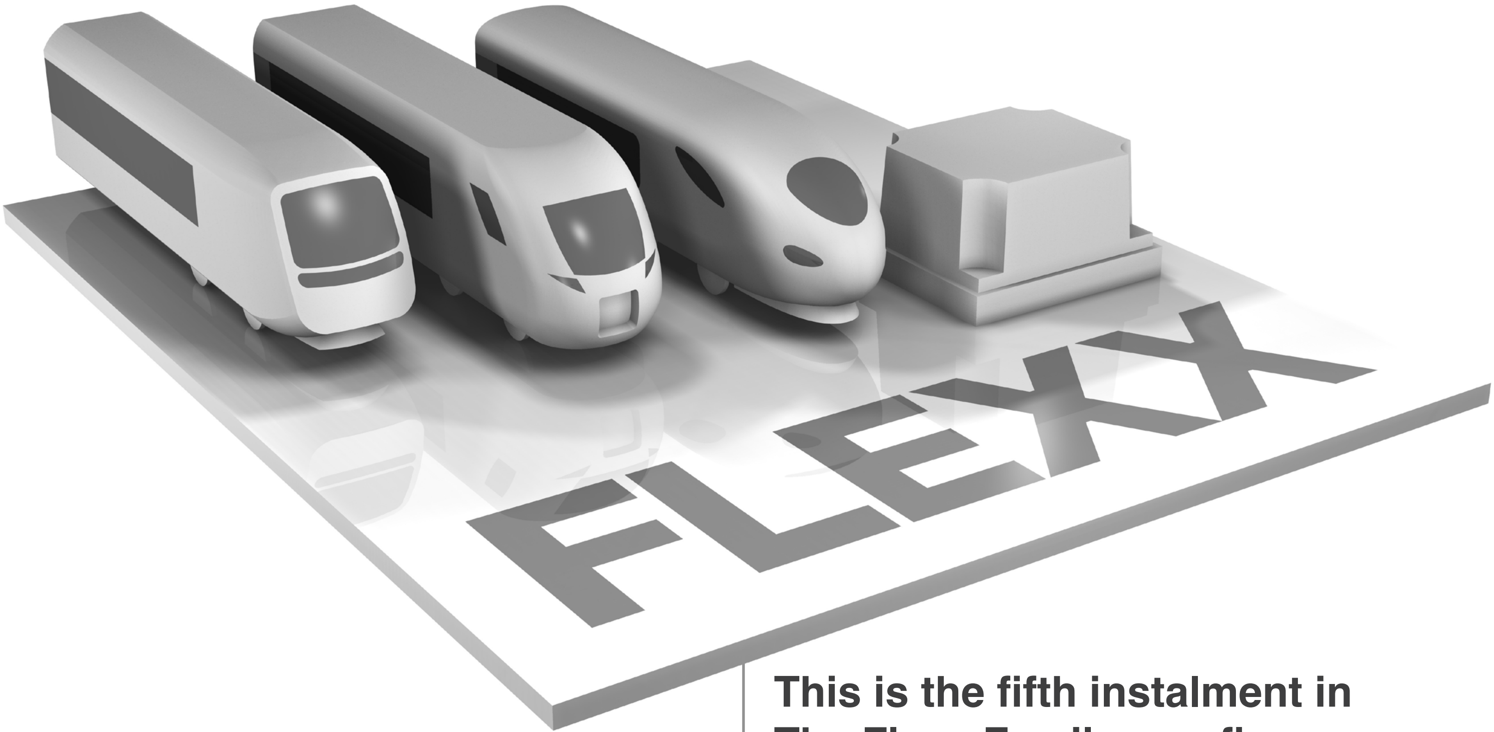
The Flexx Family: Converging on the future of brake architecture



This is the fifth instalment in The Flexx Family, our five-part series of white papers on our Metroflexx and Regio-flexx brake control solutions.

- Pushing boundaries with integrated solutions
- Achieving more through unrivaled modularity
- A maintenance break-through
- Unlocking new functionali-ties with a SIL4 based archi-tecture
- Converging on the future of brake architecture

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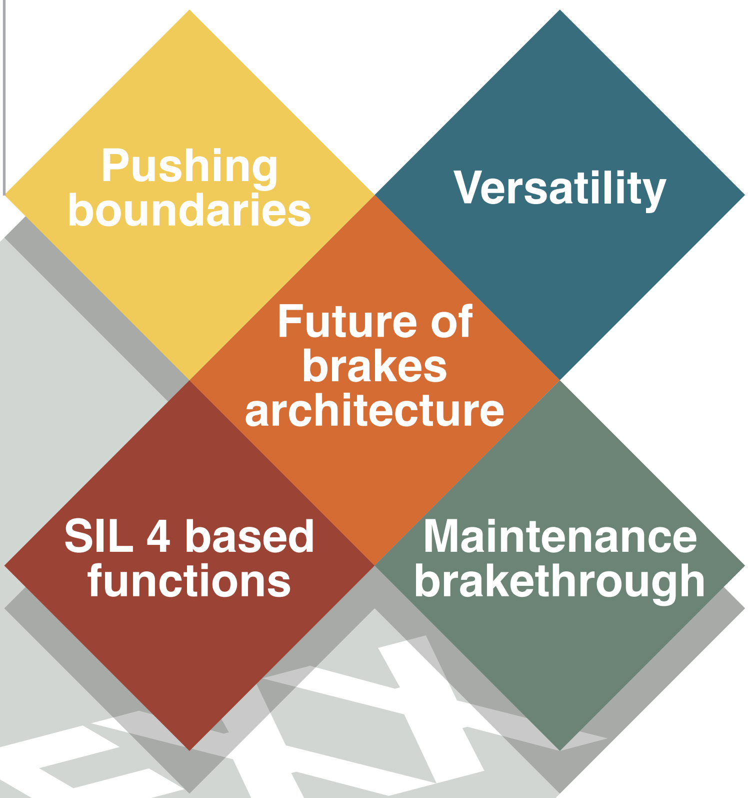
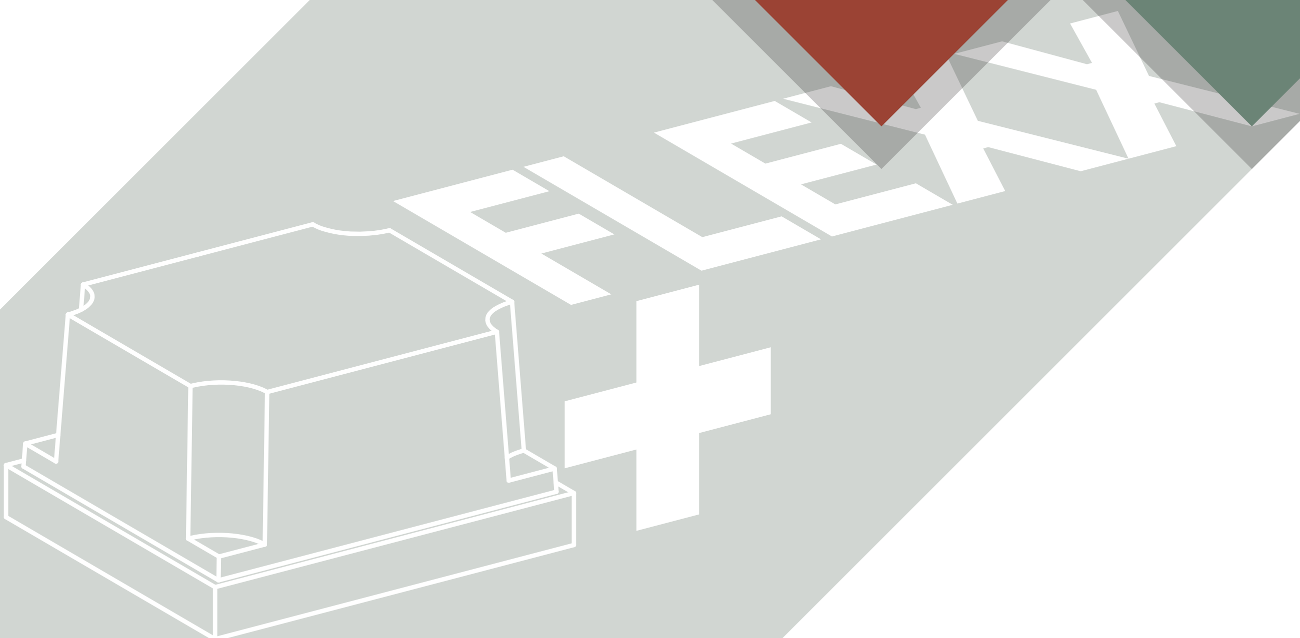
In the first four installments of our article series about the Flexx brake control family, we set the scene. We covered design philosophy and certification, the installation benefits for car builders, and the solution's versatility regarding brake control architecture. We also explored the benefits in terms of train availability as well as easy and cost-effective maintenance, plus the many new functions that SIL4-based architecture offers at negligible or even zero additional cost.

In this fifth and final article, we put all the puzzle pieces together and review how Flexx+ revolutionizes brake control: a mainstay of any rail transportation system.





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What are the FLEXX+ expected outcomes

Enhanced Guaranteed Emergency Braking Rate (GEBR)

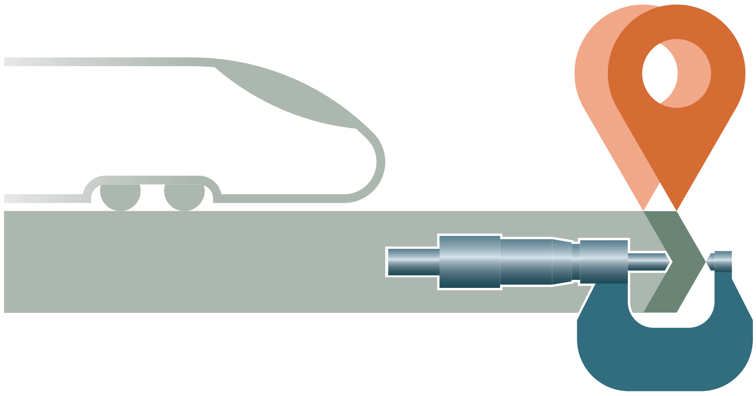
The system enables a higher and more consistent GEBR, which facilitates reduced train headways. This directly supports increased train frequency without the need for additional onboard hardware, contributing to more efficient use of existing infrastructure.

Improved Braking Accuracy and Repeatability

Accurate and repeatable braking distances offer multiple operational and safety advantages:

- Enhanced safety margins
- Optimized timetable planning and improved punctuality
- Seamless integration with automatic traffic management systems
- Reduced mechanical stress on both track and rolling stock
- Smoother passenger ride quality
- Lower energy consumption

These improvements collectively lead to reduced operational, maintenance, and asset management costs, while also supporting increased passenger throughput and revenue generation.



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Brake System Optimization and Cost Reduction

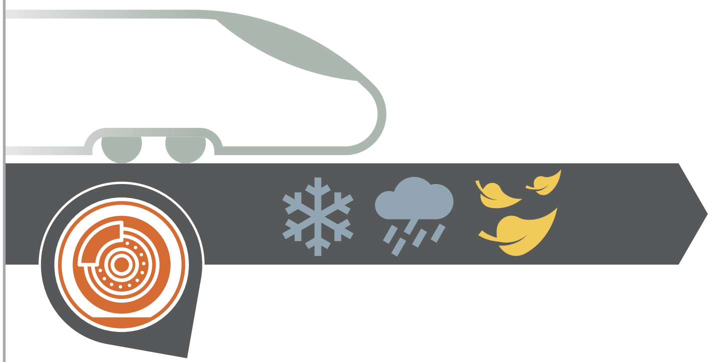
Reducing the number of friction brake components results in significant weight savings. This reduction:

- Improves energy efficiency
- Decreases infrastructure wear (lower rolling stock mass)
- Increases payload capacity
- Enhances revenue potential
- Lowers total cost of ownership through reduced acquisition and maintenance costs

The extent of weight reduction depends on train architecture (e.g., number and configuration of bogies, including motor bogies). In typical Regional or suburban train configurations, a 10% to 15% reduction in total brake system weight is achievable.

Lower Maintenance Costs in Low Adhesion Conditions

The system's ability to effectively manage low adhesion scenarios significantly reduces the occurrence of wheel flats—a common cause of increased maintenance costs and rolling stock immobilization. This results in improved fleet availability and lower lifecycle maintenance expenditures.



How does FLEXX+ achieve these targets ?

Leveraging the use of electro-dynamic brakes—even during emergency braking

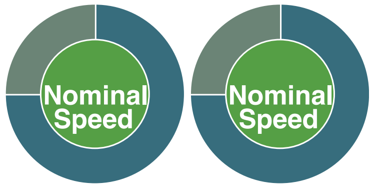
As previously discussed, Regioflexx's SIL4-certified architecture enables safe and precise measurement of train deceleration. This capability allows the system to prioritize the use of the electro-dynamic (ED) brake in both service and emergency braking modes. In cases where the ED brake cannot deliver the required braking performance, Regioflexx backup it with the friction brake to ensure compliance with safety requirements.
This core functionality unlocks significant opportunities for innovation—particularly in the design and sizing of friction braking systems. By relying more on the ED brake, the mechanical load on the friction brake can be substantially reduced, opening the door to alternative materials and configurations.

In both mainline and metro networks, energy recovery through ED braking is widely available.

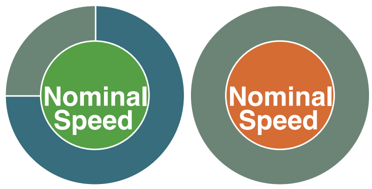
Therefore, the ED brake is considered an integral part of the train's braking system. The regulatory requirements for the braking system in normal operating mode—designed to handle the dissipation of braking energy, including scenarios involving two successive emergency brake applications from maximum speed—apply to the entire braking system (both mechanical and ED brakes).

Degraded operating conditions resulting from the unavailability of the ED brake, which is monitored by Regioflexx, are addressed in the following three scenarios:

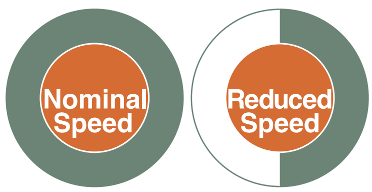
- **Scenario 1**: ED Brake Active in Both Applications. When the ED brake functions correctly during both emergency brake applications, the majority of the deceleration energy is converted into electrical energy. As a result, the friction brake is minimally engaged.

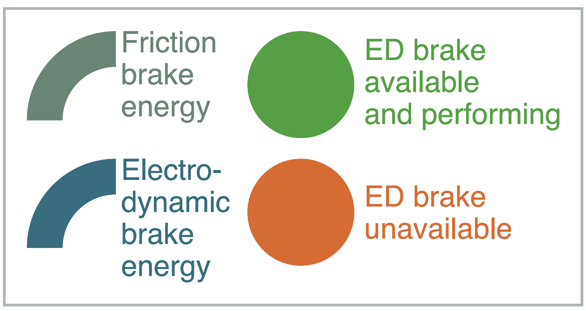


- **Scenario 2**: ED Brake Active in First Application Only. If the ED brake operates during the first application but fails during the second, the friction brake is required to absorb the full deceleration energy only once.



- **Scenario 3**: ED Brake Inactive in First Application. If the ED brake fails or cannot work as expected during the first emergency brake application, this typically indicates a major traction system unavailability. When such case is detected, the train is likely to be operated in degraded mode, either immobilized or subject to speed restrictions. Industry feedback suggests that approximately 70% of ED brake failures are linked to significant traction issues. Consequently, the friction brake is again only fully utilized once.





Increasing guaranteed brake performance and reducing dispersion

To ensure safe operation, trains are governed by signaling systems that define movement authority within physical or virtual blocks. A train may only enter a block once it has been vacated by the preceding train.

Physical Block Systems

In fixed-block systems, block length is predefined during the design phase. It is based on the maximum expected train speed and the guaranteed emergency stopping distance of the rolling stock intended for the route. The stopping distance must always be shorter than the distance between the warning and stop signals. While a train equipped with a braking system capable of shorter emergency stopping distances may be authorized to operate at higher speeds, actual operating speed is also constrained by route characteristics such as curvature and gradient. However, since train frequency is determined by block length and planned operating speed, increasing speed alone does not necessarily lead to higher throughput—especially when the number of trains on the line is a limiting factor.

Virtual Block Systems

In moving block or virtual block systems, block length and warning distances are dynamically calculated in real time by the signaling system. These calculations take into account:

- Train performance (including speed and Guaranteed Emergency Braking Rate, or GEBR)
- Route profile (e.g., gradients)

In such systems, improving the GEBR can directly enhance train frequency by reducing the required separation between trains, thereby increasing line capacity.
Given the high cost of railway infrastructure, block length has a direct and significant impact on operational efficiency and cost-effectiveness for train operators.

Guaranteeing Braking Performance in Degraded Conditions

To ensure compliance with safety requirements, braking system designers must evaluate performance under degraded conditions, as defined by operators, standards, and safety analyses. Two methods have been developed: one for the traditional variable consist trains where the brake performance is defined by a brake weight percentage, the other for the fixed consist trains where the brake performance is defined by a deceleration and a response time.
For this latter, the guaranteed deceleration performance is determined by applying to the nominal deceleration two correction factors:

- **Kdry_rst**

This factor accounts for the dispersion of emergency braking performance under dry rail conditions. It considers potential equipment failures and variability in braking component performance—particularly variations in friction coefficients. Kdry_rst is typically calculated offline using probabilistic methods such as Monte Carlo simulations.

- **Kwet_rst**

This factor quantifies the reduction in braking performance under reduced wheel/rail adhesion conditions, relative to dry rail performance. It is derived from field tests conducted to validate the Wheel Slide Protection (WSP) system, in accordance with EN 15595.

These correction factors are further adjusted by national parameters defined by the relevant infrastructure managers:

- Emergency Brake Confidence Level
- Available Adhesion Weighting Factor

FLEXX system optimize both factors.

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Resilience to Single Failures: Enhancing GEBR with Regioflexx

In conventional braking systems, a single failure affecting either the service or emergency brake typically results in the loss of braking capability on an entire bogie or car. This directly impacts the Guaranteed Emergency Braking Rate (GEBR).

Regioflexx fundamentally redefines this paradigm.

Thanks to its innovative architecture—featuring two fully independent electro-pneumatic (EP) control units—Regioflexx offers exceptional resilience to single-point failures.

- **Service Brake Isolation Without Compromising Emergency Braking**

In the event of a service brake failure, Regioflexx enables remote isolation of the affected subsystem, ensuring continued train operation without service disruption. Crucially, the emergency brake remains fully operational, preserving the GEBR.

- **Limited Impact of Emergency Brake Failures**

Any single failure affecting the emergency brake is confined to a maximum of 50% of the local braking effort (at the bogie or vehicle level, depending on the train architecture). This design effectively halves the impact on GEBR compared to conventional systems.

- **Full Channel Independence for High GEBR Targets**

For applications requiring stringent GEBR performance, each of the two independent EP unit embedded in Regioflexx can be supplied by a dedicated brake reservoir. This configuration—achieved at minimal additional cost (two small reservoirs instead of one large one)—ensures complete channel independence without the need for extra brake control equipment, reducing both system weight and cost.

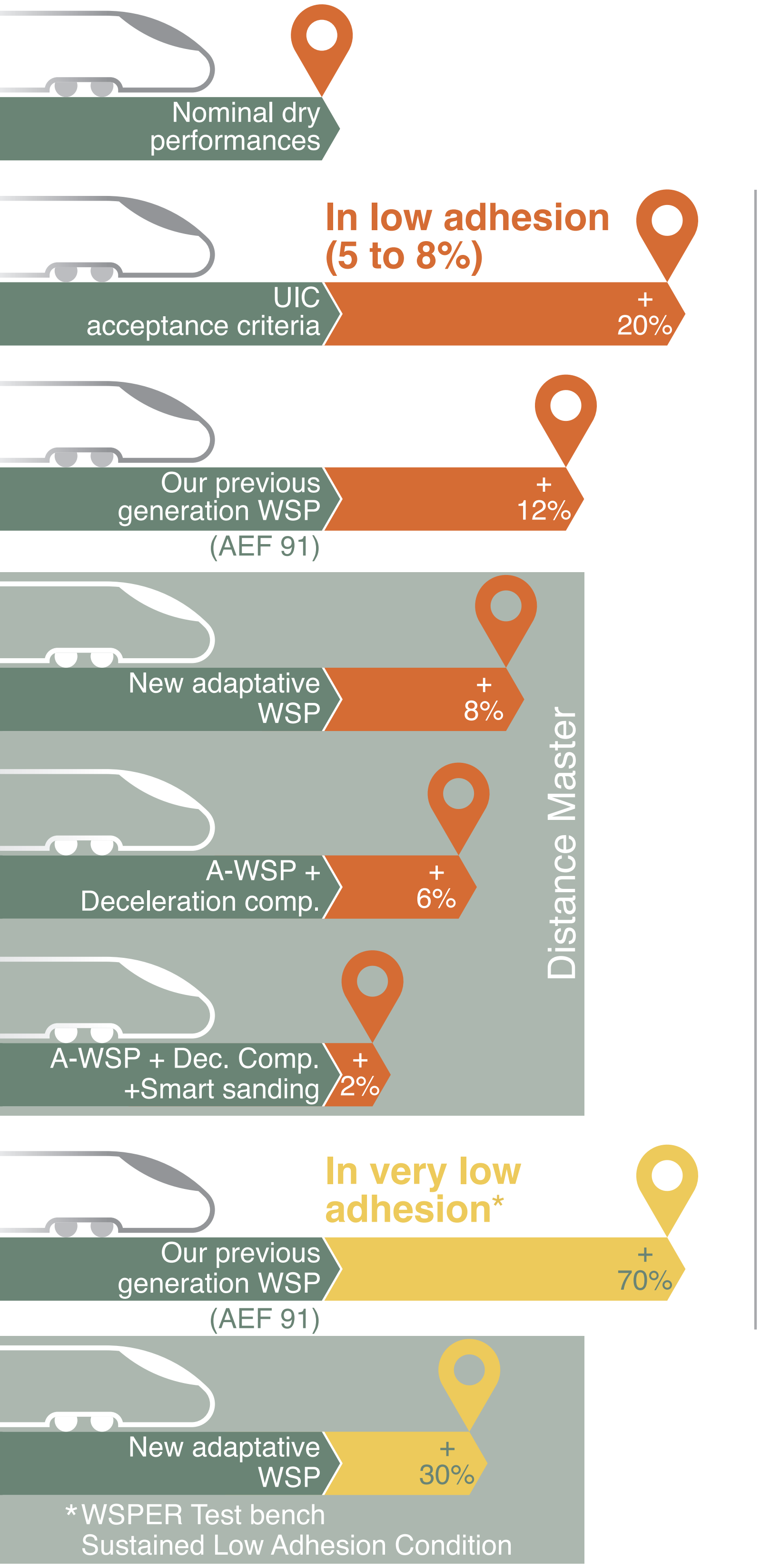
- **Redundancy on Motored Axles**

Regioflexx safely supervises the use of the electro-dynamic (ED) brake during emergency braking. In the event of ED brake unavailability, the friction brake automatically takes over. This redundancy enables the braking system to achieve exceptional reliability, with a Mean Time Between Service-Impacting Failures (MTBSF) exceeding 1 billion hours at the train level (value for typical reference train consist 2 cars / 4 bogies / 8 axles).

- **Support for Probabilistic Brake System Design**

The system's inherent fault tolerance simplifies overall brake system architecture and enhances GEBR performance when using probabilistic design methods, such as Monte Carlo simulations.

Taking the sting out of degraded wheel / rail adhesion



Comparative / incremental test performed in Bilbao, Spain on Euskotren train (3 cars, 6 bogies)

The performance improvement

Regioflexx comes with DistanceMaster, a system that offers the following functions:

- Latest-generation Adaptative WSP, which reduces braking distance elongation in low-adhesion conditions (see chart below)
- Deceleration compensation, which enables the brake system to “reconfigure” in order to compensate for any degraded situation (such as low adhesion, isolated equipment, slope…)
- SmartSanding controlled by the WSP algorithm to generate adhesion before sliding occurs.

The following diagram shows the improvement in braking distance offered by DistanceMaster in a typical multiple-unit train:

- In low-adhesion situations (5% to 8% wheel / rail adhesion), braking distance elongation is improved by 34% with Adaptive WSP
- When adding deceleration compensation, in the same low-adhesion conditions, braking distance elongation is improved by 50% compared to previous-generation WSP systems
- Performant sudden slide detection leading to a significant wheel flat occurrence reduction (Proven operationally on a SNCF fleet of more than 50 trains).

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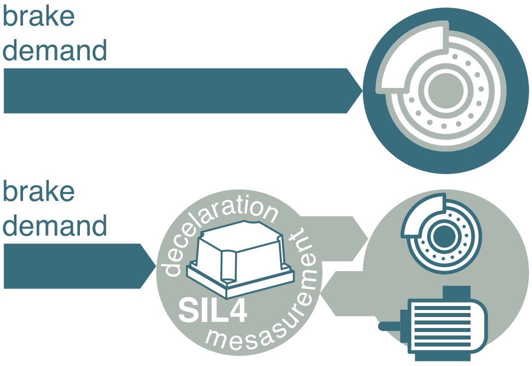
Key FLEXX+ benefits at a glance

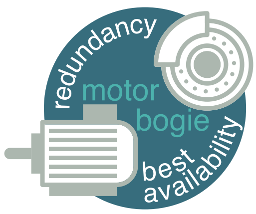


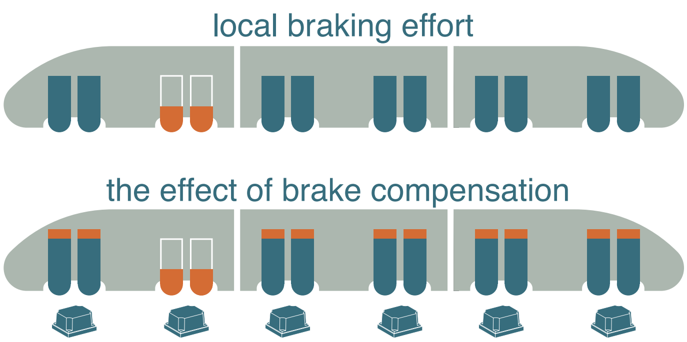
● **Enhanced Safety with SIL4 Compliance**

Regioflexx precisely measures the contribution of the ED brake to deceleration during emergency braking—meeting the highest safety integrity level (SIL4). This capability allows for optimized control, reducing the sizing demands on the friction brake system caused by the two consecutive emergency brake applications mandated by the TSI.

● **Exceptional Brake Redundancy**

Thanks to the ED/EP redundancy, brake performance loss on motor bogies during emergency braking is kept to an absolute minimum.



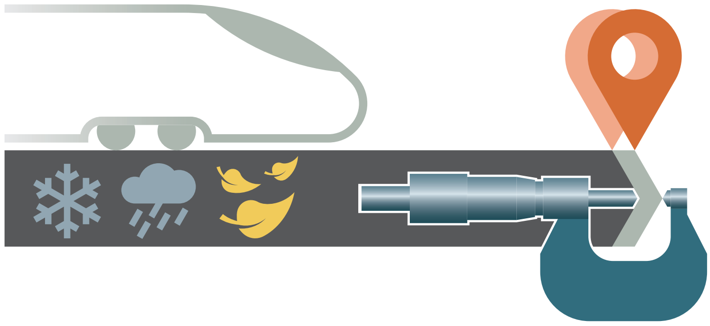


● **System-Wide Braking Compensation**

DistanceMaster mitigates the effects of any braking performance degradation by dynamically compensating braking effort across the entire train.

● **Superior Performance in Low Adhesion Conditions**

DistanceMaster significantly improves braking in low adhesion scenarios—achieving up to a 50% reduction in braking distance when combined with A-WSP and deceleration compensation. Performance can be further enhanced with the integration of Smart Sanding.



Smarter Brake System Design

The combination of these technologies, along with a probabilistic brake calculation approach, open the door to a new paradigm in brake system sizing and optimization.

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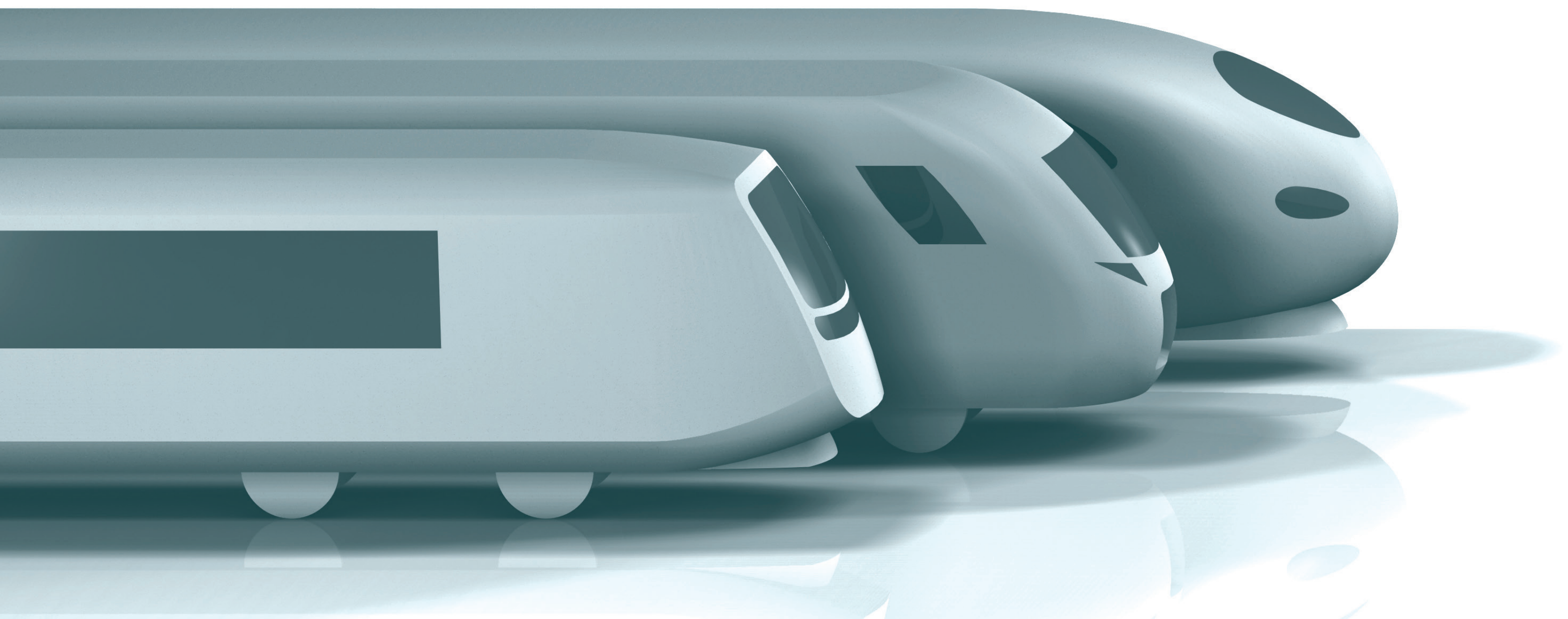
"The versatility of the Flexx Family brake control systems, and the possibility of dramatically improving GEBR performance at virtually no additional cost are powerful tools for building trains that meet tomorrow's requirements today"

Daniel Gradl
President,
Brakes & Couplers

Would you like to know more about how your trains could benefit from our solutions?

Contact us today at:
brakesandcouplers@wabtec.com



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