



Research Unit
Press Information Bureau
Government of India

Kavach: The Shield of Safety

India's Cutting-Edge Automatic Train Protection System

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In the quest for safer and more efficient train journeys, Indian Railways has unveiled Kavach, a state-of-the-art **Automatic Train Protection (ATP)** system that represents a breakthrough in indigenous technology. Named after the Hindi word for "shield," Kavach is designed to provide an unyielding layer of protection, ensuring the highest safety standards for train operations. Certified with the prestigious **Safety Integrity Level 4 (SIL-4)**, Kavach is a testament to its exceptional reliability.

Automatic Train Protection (ATP) is a train safety system designed to ensure that a train's speed remains within the limits set by the signalling system. It continuously monitors the train's speed and automatically enforces compliance with permitted speed restrictions. If the train exceeds the allowed speed or fails to respond to specific signal aspects, ATP promptly activates the emergency brakes to bring the train to a stop.

For train drivers navigating India's vast and complex rail network, Kavach acts as a vigilant guardian. It monitors train speeds and steps in when human action is delayed or missed. If the loco pilot fails to respond in critical moments, Kavach automatically applies the brakes, preventing potential accidents. But Kavach is more than just a safety mechanism; it's built to tackle the challenges of India's diverse and unpredictable weather. Whether it's thick fog, heavy monsoons, or soaring temperatures, Kavach ensures trains operate smoothly, providing a crucial safety net. It's a blend of cutting-edge technology with local expertise.

Tolerable Hazard Rate (THR) and Safety Integrity Levels (SIL)

The Tolerable Hazard Rate (THR) is a target measure used to assess both systematic and random failures related to safety integrity within a system. The THR helps determine the level of safety needed by providing a quantitative basis for ensuring acceptable safety standards. A system's safety integrity is categorized into four distinct levels, each representing a specific degree of safety: **Level 4**, which represents the highest level of safety integrity, and **Level 0**, which indicates no safety requirements.

A Safety Integrity Level (SIL) is assigned to a system based on a qualitative evaluation of various factors, including quality and safety management, as well as technical safety conditions. Achieving the appropriate SIL is essential to ensure both systematic and random failure risks are addressed.

Achieving optimal safety performance requires a balance between measures to prevent systematic failures (safeguards) and those to control random failures. While systematic failures are challenging to quantify, random failures can be controlled using quantitative methods, with the balance between the two being reflected in a table.

This SIL table applies to safety-related functions or subsystems implementing such functions, helping to define the required SIL based on the Tolerable Hazard Rate (THR). When the THR for a specific function has been determined quantitatively, this table can identify the required SIL.¹

THR / hour /function	SIL
$10^{-9} \geq 10^{-8}$	4
$10^{-8} \geq 10^{-7}$	3
$10^{-7} \geq 10^{-6}$	2
$10^{-6} \geq 10^{-5}$	1

Development and Evolution of Kavach

The journey of Kavach's development started with the first field trials conducted on passenger trains in February 2016. These trials provided crucial insights into the system's practical deployment and operation, laying the groundwork for further improvements.

Phase 1:

Based on the valuable feedback from field trial started in February 2016, and an Independent Safety Assessment conducted by an Independent Safety Assessor (ISA), three firms were approved between 2018 and 2019 for the supply of Kavach version 3.2. This version was refined through testing and assessments to improve its reliability and functionality on Indian Railways.

National Adoption (2020):

In July 2020, after considerable field trials and successful evaluation, the Kavach system was officially adopted by Indian Railways as the National Automatic Train Protection (ATP) system. This marked a major step forward in enhancing railway safety across the entire network.

Kavach Version 4.0 (2024):

The system evolved significantly with the introduction of Kavach version 4.0, approved by the Research Design and Standards Organization (RDSO) on 16th July 2024. This version incorporated numerous improvements based on feedback from previous deployments and real-world operational challenges. Some key advancements in Version 4.0 include:

Increased Location Accuracy: This enhancement ensures that train positions are determined with higher precision, which is critical for safe train movements, especially in complex railway layouts.

¹ <https://iriset.railnet.gov.in/content/gyandeep/2017/6-article.pdf>

- ✚ **Improved Signal Aspect Information:** The system now provides more detailed information on signal aspects in larger yards, improving operational efficiency and safety in busy terminal stations and junctions.
- ✚ **Station-to-Station Kavach Interface on Optical Fibre Cable (OFC):** This feature ensures seamless station communication, enhancing coordination and safety over large distances.
- ✚ **Direct Interface with Electronic Interlocking Systems:** Integrating existing electronic interlocking systems allows for more efficient train control, reducing delays and improving overall system reliability.

With these enhancements, the system is now better equipped to handle the diverse operational conditions across India's extensive railway network. The scale and complexity of deploying such a system nationwide are monumental, but the success of Kavach version 4.0 signals that this milestone will significantly improve safety for both passengers and freight.

Implementation of Kavach System

The deployment of Kavach is a large-scale initiative that involves the installation of multiple infrastructure components across the railway network. These components include trackside equipment, stations, locomotives, and communication systems that work together to ensure real-time train protection.

Key activities involved in the implementation of Kavach include:

- ✚ **Installation of Station Kavach:** Kavach is being installed at each and every station and block section along the tracks. These installations allow the system to monitor and manage train movements, ensuring safe operations.
- ✚ **RFID Tag Installation: Radio Frequency Identification (RFID) tags** are placed throughout the entire track length to enable the Kavach system to track train positions and detect any potential safety issues along the route.
- ✚ **Telecom Towers:** A network of telecom towers is being set up across the sections to facilitate continuous and reliable communication between the train and the control centres. These towers help in transmitting data between track-side equipment and the trains.
- ✚ **Optical Fibre Cable (OFC):** Optical Fibre Cable is laid along the tracks to ensure fast and efficient data transmission. This is crucial for communication between the station, trackside equipment, and locomotives.
- ✚ **Loco Kavach Installation** Every locomotive operating on Indian Railways is being equipped with Kavach technology to ensure that safety is maintained at the point of operation. These devices continuously monitor and control the speed of the trains.

KAVACH AUTOMATIC TRAIN PROTECTION



PREVENTION OF COLLISION BETWEEN TWO LOCOMOTIVES EQUIPPED WITH FUNCTIONAL KAVACH



CONTINUOUS UPDATE OF MOVEMENT AUTHORITY WITH DISPLAY OF SIGNAL ASPECTS IN DRIVER MACHINE INTERFACE (DMI) / LOCO PILOT OPERATION CUM INDICATION PANEL (LPOCIP)



CENTRALIZED LIVE MONITORING OF TRAIN MOVEMENTS THROUGH NETWORK MONITOR SYSTEM

AUTOMATIC BRAKING FOR PREVENTION OF OVER SPEEDING



PREVENTION OF SIGNAL PASSING AT DANGER (SPAD)



AUTO WHISTLING WHILE APPROACHING LEVEL CROSSING GATES



SOS MESSAGES DURING EMERGENCY SITUATIONS

Progress and Deployment Timeline

Kavach has been deployed on significant portions of the railway network, with steady progress being made across key railway zones and corridors. As of October 2024, the following progress has been made:

South Central Railway (SCR) and North Central Railway (NCR):

Kavach has already been deployed over 1548 Route Kilometers (RKm) of track in these regions. These deployments have provided valuable insights, enabling further refinements in the system.

Delhi-Mumbai and Delhi-Howrah Corridors:

Work is actively progressing on the major corridors connecting Delhi to Mumbai and Delhi to Howrah, which cover approximately 3000 RKm. The track-side works on these routes have been completed over 1081 RKm, with 705 RKm on the Delhi-Mumbai section and 376 RKm on the Delhi-Howrah section. Regular trials are being conducted to ensure the system's readiness for full deployment.

Detailed Progress of Key Items (As of October 2024)

Here is an overview of the major milestones achieved so far in the deployment of Kavach:

Laying of Optical Fibre Cable: 4960 Km

Installation of Telecom Towers: 378 Towers

Provision of Kavach at Stations: 381 Stations

Provision of Kavach in Locomotives: 482 Locomotives

Installation of Track-Side Equipment: 1948 RKm

These statistics reflect the scale and complexity of the Kavach implementation, and the progress made is a testament to the dedication and effort of Indian Railways.

Training and Capacity Building

A crucial element of Kavach's successful implementation is the training of railway personnel. Indian Railways has initiated specialized training programs at its centralized training institutes, such as IRISSET (Indian Railways Institute of Signal Engineering and Telecommunications). These programs are designed to ensure that technicians, operators, and engineers are fully equipped with the skills necessary to operate and maintain the Kavach system effectively. As of now, over 9,000 personnel have been trained on Kavach technology, ensuring that the workforce is ready for large-scale deployment and operation.

Cost and Funding for Kavach Implementation

The Kavach system is a substantial investment in the safety and future of Indian Railways. The costs involved are significant, but the benefits of improved safety and reduced accidents far outweigh these expenses.

Cost Estimates:

Track-Side Equipment (including Station Equipment): The estimated cost for providing track-side equipment, including station equipment, is approximately Rs. 50 Lakhs per kilometre.

Locomotive Equipment: The cost of providing Kavach equipment on locomotives is approximately Rs. 80 Lakhs per locomotive.

Funds:

A total of ₹1,547 crore has been utilized for Kavach-related works so far, an allocation of ₹1,112.57 crore has been allocated for the fiscal year 2024-25.

Conclusion

Implementing Kavach represents a transformative step forward in ensuring the safety of Indian Railways. With continuous improvements and a clear roadmap for nationwide deployment, the Kavach system is poised to enhance the safety of train operations across India significantly. From its initial trials in 2016 to the full-scale deployment underway in 2024, Kavach's journey reflects the commitment of Indian Railways to provide a safer and more efficient transportation network. As the project progresses, integrating advanced technology and infrastructure will make Indian Railways one of the safest rail networks in the world.

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