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Technology: Transforming Railway Transportation



Foreword



I am happy to share with you the FICCI–A.T. Kearney report *Technology: Transforming Railway Transportation* to be released at the second edition of the SMART Railways Conclave, organized by the Federation of Indian Chambers of Commerce and Industry (FICCI).

Indian Railways, the world's third-largest rail network, is undergoing a significant transformation led by large capital investments. Digitalization around asset management and network operations will accelerate this transformation—not only improving safety, on-time performance, network throughput, and asset performance but also enhancing the passenger experience and empowering the organization to move fast enough to meet the market's changing needs.

This FICCI–A.T. Kearney report focuses on the importance of embedding technology in Indian Railways, thereby creating a road map to become best in class in the world.

I hope you find this report useful. We welcome your suggestions and feedback.

Nalin Jain
Co-Chairman, FICCI National Committee on Infrastructure
President and Chief Executive Officer, Asia Pacific and China, GE Transportation



Indian Railways is the lifeline of India's economy and an integral part of the fabric of our country. The organization's importance to businesses and individuals cannot be overemphasized. However, the current infrastructure cannot sustain the expected economic growth or the public's expectations. Although the pace of change has been historically slow, technology provides an opportunity to transform Indian Railways' operations and contribute to the organization's mission of "being the engine for India's economic growth and development by being safe, financially viable, environment friendly, and caring for its customers and employees."

In this report, we identify the key technologies that can help Indian Railways redefine its image and improve operations. These technologies, which are in use in railway systems around the world, can act as benchmarks for Indian Railways to develop systems that suit the country's needs. We examine technologies and the best practices across five dimensions: safety enhancement, infrastructure upgrades, train operations effectiveness, passenger experience improvement, and organization capability enhancement. Because these are new technologies, the conventional procurement processes will not directly apply. Indian Railways will need to tailor a model that streamlines procurement for these technologies.

We would like to thank FICCI for the federation's support in creating this report to be presented at the SMART Railways Conclave in New Delhi.

Manish Mathur, partner
Head of Asia Pacific, Transportation and Infrastructure
A.T. Kearney

Executive Summary

This study aims to analyze the technology solutions and best practices used by global rail systems to understand how Indian Railways can improve the effectiveness of its operations. The solutions discussed in this report are structured across five dimensions. Following are some of the study's key insights and recommendations across these dimensions:

1. **Safety enhancement.** Four recommendations focus on achieving zero fatalities:
    a. For **track-related interventions**, introduce B-scan ultrasonic rail flaw detection (both non-stop and stop-and-verify systems) and track inspection with automated high-speed test trains.
    b. For signaling-related interventions, invest in **European Train Control System (ETCS) level 2** for high-density routes to increase network capacity and maintain the required safety standards.
    c. For rolling stock, fast-track the **switch of passenger rolling stock to Linke Hofmann Busch (LHB) coaches** to minimize fatalities.
    d. Increase surveillance of personnel with both interior and exterior **locomotive-mounted video surveillance** to improve monitoring.
2. **Infrastructure upgrades.** Three recommendations can lead to faster and more robust infrastructure upgrades:
    a. Invest in **track-laying machines** for mechanization of construction.
    b. Increase the **rate of electrification** through machines such as the self-propelled overhead electrification laying train (SPOLT).
    c. Proliferate use of **prefabrication** for construction elements.
3. **Train operations effectiveness.** Four recommendations are designed to increase asset availability and utilization:
    a. Invest in technologies such as complete train scanners for **improved diagnostics and maintenance.**
    b. Use **operations optimization tools** for better management and performance of trains, rakes, locomotives, and crews.
    c. **Digitize processes** to enhance work quality and lower costs, thereby reducing reliance on labor-intensive processes.
    d. Use **distributed power** to improve the efficiency of train operations with coordinated acceleration and deceleration.

4. **Passenger experience improvement.** To retain the passengers that Indian Railways carries, enhancing the passenger experience will be crucial.
    a. Establish **smart railway stations** by implementing access control at entry points, provide accurate real-time information, and put interactive solutions in place.
    b. Upgrade the **ticketing experience** with seamless integration across platforms and open-loop smart cards.
    c. Enhance the **train experience** with services such as infotainment and app-based systems.
5. **Organizational capability enhancement.** Two recommendations aim to enhance the capability and improve management reporting:
    a. Use training simulators and virtual reality training systems to **improve personnel capabilities.**
    b. Enhance decision-making by improving information management with **management reporting dashboards.**

Implementing these technology solutions will be essential for Indian Railways to get closer to the world-class standard for train operations. However, selecting and implementing technology as well as obtaining the optimum economic benefits will require adopting innovative procurement models.



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1. Introduction

With its roots in the 19th century and nearly 190 years of history since the opening of the passenger railway between Liverpool and Manchester, railway transportation has a long history. Although the basic concept of low-friction wheels on rails remains the same, the implementation has undergone significant changes, buoyed by multiple technological interventions. Now, two centuries later, technological innovations are expanding the capabilities of railway systems and helping to achieve faster speeds, greater capacity, and better safety to compete with other forms of transportation. Technology has transformed the way the industry works—fueled by railway operators' eagerness to reap benefits by making their operations more efficient, safe, and profitable.

Technology has the potential to impact five key dimensions of rail transportation (see figure 1).

Figure 1
Technology has the power to improve five dimensions of rail transportation



Source: A.T. Kearney analysis

- **Safety enhancement.** Technology can make train operations safer by detecting flaws in the tracks, remote monitoring the tracks, digitizing and automating maintenance, and improving basic processes such as welding and grinding. Improvements in signaling and telecommunication, crash safety of rolling stock, and surveillance of human operations can reduce errors and lessen the impact of accidents.
- **Infrastructure upgrades.** Mechanized construction can enhance the speed for infrastructure upgrades—track laying and electrification—while improving cost-effectiveness.
- **Train operations effectiveness.** The effectiveness of train operations is best measured through asset reliability, utilization, and employee productivity. Technology can help improve asset reliability through sensor-based condition monitoring and data-driven predictive maintenance. Decision support systems can play a strong role in enhancing asset utilization and employee productivity.
- **Passenger experience improvement.** The passenger experience is formed at each step of the journey—from planning a trip and booking a ticket to traveling to the railway station, arriving at the station, and traveling on the train. Technology can affect each stage of the experience. Seamless availability of information for planning, omnichannel ticket booking, smart railway stations, value-added services such as Wi-Fi and infotainment, and accurate train tracking based on GPS are just a few examples of ways that technology can enhance the passenger experience.
- **Organizational capability enhancement.** Technology can have a powerful impact on an organization's capability through effective trainings and assisting in decision-making. With the introduction of virtual reality (VR) and gamification that can simulate real-life scenarios, training has been revolutionized. IT dashboards and management information systems have been used extensively across industries to enable data-driven decision-making.

In the subsequent sections, we discuss innovative ways to use technology across all five dimensions. These recommendations have been developed with Indian Railways' current state of operations in mind, along with the technologies' maturity and the impact they are

having in railway systems around the world. Once implemented, these technologies will transform Indian Railways' operations and help the organization achieve its mission of "being the engine for India's economic growth and development by being safe, financially viable, environment friendly, and caring for its customers and employees."

2. Safety Enhancement

Safety is the most important aspect of rail operations, and Indian Railways envisions running at near-zero fatalities in the near future. Many global railway systems have successfully implemented technological innovations in four areas to enhance the safety of operations:

- **Tracks.** Identifying broken rails and rail flaws, gaps in track geometry, and missing fittings and enabling remote track monitoring
- **Signaling and telecommunication.** Improving train control through better communication
- **Rolling stock.** Better crash-worthiness to ensure minimal casualties in mishaps
- **Personnel.** Better supervision of train operators and to aid post facto analysis of accidents

2.1 Tracks

Track failures and defects cause about 15 percent of all accidents on Indian Railways.[1] Various track-related technologies are in use across the globe—from those that identify flaws to those that help with predictive maintenance. Some can be mounted on regular train services while some require special vehicles. The prominent innovations being used in railway systems around the world, which have applicability for Indian Railways, are described below.

2.1.1 Broken rail detection

Track circuits are the only commercially deployed method for detecting broken rails. However, the primary function of such track circuits is signaling and not broken rail detection. Track circuits are used in North American railways (Canadian National and BNSF) and Japanese railways.

Multiple new technologies are in various stages of development for detecting broken rails, including ultrasonic track-lined broken rail detection, distributed acoustic sensing, and magnetic flux leakage detection systems. However, none of these are deployed commercially in a large network in any advanced railway system. For mature global railway operators, the focus is always on early identification of defects and prevention of broken rails.

Although Indian Railways is doing a trial of ultrasonic track-lined broken rail detection over a two-year period on two 25-kilometer stretches, the organization could consider focusing on enhancing the effectiveness of rail flaw detection through technology, rather than investing in broken rail detection enablement.[2]

2.1.2 Ultrasonic rail flaw detection

Ultrasonic flaw detection (USFD) units can enable early identification of rail flaws. Although used extensively at Indian Railways, the efficiency of the process can be significantly improved through adoption of innovative USFD technology.

[1] Ministry of Railways High-Level Safety Review Committee, Chairman Anil Kakodkar

[2] RailSonic

Rail flaw detection units can be either standalone (requiring track block for testing) or mounted onto locomotives (and hence can be put on commercial trains and not require specific blocks for testing):

- Standalone units can be operated either on a non-stop self-powered rail car or on stop-and-verify vehicles. The efficiency of non-stop units is greater than the stop-and-verify vehicles, but accuracy is lower with far more instances of false positives.[3] Canadian National has used stop-and-verify vehicles with great success.
- Locomotive-mounted rail flaw detection technologies, such as the ones developed by General Electric (GE) and Siemens, enable real-time testing of track integrity, and have been successfully piloted in North America and Australia (see sidebar: Rail Integrity Monitor by General Electric: Locomotive-based Rail Flaw Detection).

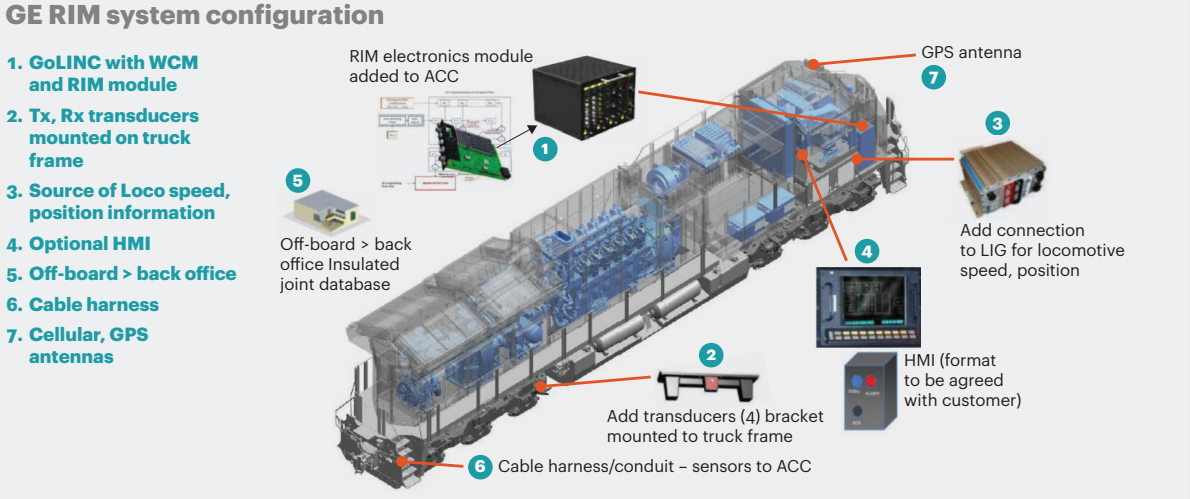
Rail Integrity Monitor by General Electric: Locomotive-based Rail Flaw Detection

Rail Integrity Monitor by General Electric (GE) is one of the few rail flaw detection technologies that have been piloted at a large scale. The technology enables real-time detection of track integrity by injecting two magnetically coupled signals through locomotives. It can inspect 500 kilometers of track each day with a single system, equivalent to daily locomotive productivity. It sends an alert to crew within seconds of detecting a rail flaw with a pinpointed location, with an average response time of around 10 seconds. The cost of the technology is about INR 10 lakh per locomotive.

GE has tested the technology on more than 17,500 locomotives around the world, including North America (about 80 percent); Europe, the Middle East, and Africa; Australia and New Zealand; and China and Southeast Asia. The company reported zero false positives in pilots.

BNSF has successfully implemented the technology, testing around 144,900 kilometers of track and analyzing 68,000 events, including rail joints and fractures (see figure a).

Figure a
General Electric's Rail Integrity Monitor can detect rail flaws in real time



Sources: General Electric; A.T. Kearney analysis

[3] *Assessment of Rail Flaw Inspection Data*, Brandon G. Jeffery and M.L. Peterson, Colorado State University, May 2000

Indian Railways can consider using non-stop USFD mechanism to increase coverage of flaw detection while using stop-and-verify systems for focused testing. At the same time, the organization could continue to pilot locomotive-mounted flaw detection on specific sections to assess accuracy and effectiveness of the system.

The use of digitization (B-scan USFD technology) can further enable storage of track data and help in trend analysis of rail health to predict failures early and take corrective actions.

2.1.3 Track monitoring

Track monitoring systems help identify irregularities in the tracks and can be done through specially designed test trains or through technology-enabled physical inspection. The process can include monitoring of signal and telecommunication systems and overhead electrification lines. Track monitoring rail vehicles can be of two types: autonomous railcars and automated test trains.

Autonomous railcars are coaches attached to regular trains and equipped to collect data on the tracks at line speeds. These have been successfully implemented by SNCF in France and Renfe in Spain.[4] One major advantage is that they can be attached to multiple trains to allow monitoring without disturbing scheduled trains.

Automated test trains have been deployed by major rail systems such as JR West's Doctor Yellow and SNCF's Iris 320 (see sidebar: SNCF's Iris 320: Automated High-Speed Test Train on page 5). These high-speed train sets are capable of monitoring tracks while running at speeds of up to 320 kilometers per hour. They have additional capabilities over the standalone railcars and are complete stand-alone laboratories for track monitoring. Although they require a separate window to run, the disruption is minimal because of the high speed of operation.

For Indian Railways, automated test trains will be preferable given their additional testing capabilities and may be gradually introduced to enhance safety of operations.

2.2 Signaling and telecommunication

Although the primary aim of signaling technologies is to ensure safety, modern technologies also help to maximize use of rails. Globally, two systems are used for automated train protection: the European Train Control System (ETCS) and communication-based train control (CBTC). While CBTC is largely useful only for suburban or metro rail, ETCS has utility for long-haul train networks.

ETCS is comprised of three levels and involves track-side or radio-based communication technology (see figure 2 on page 6).

ETCS Level 1 involves using line-side signals and an on-track device called a balise, which communicates with ETCS equipment on board to calculate the next braking point, thereby keeping over-speeding in check.

ETCS Level 2 involves continuous communication of the movement authority and permissible speed through a radio block center using a GSM-R radio channel. This information is displayed for the operator and negates the need for track-side signals. This helps increase track capacity as operations are more efficient. Although significant investment is required to upgrade all trains on the network to operate without track-side signals, the life-cycle costs of the technology are lower because of the reduced infrastructure requirement. Moreover, this system provides better reliability, maintainability, and safety. Major railway systems such as DB, SNCF, Renfe, and Chinese Railways have implemented ETCS Level 2.

[4] SNCF Melusine, Renfe Coche de Control

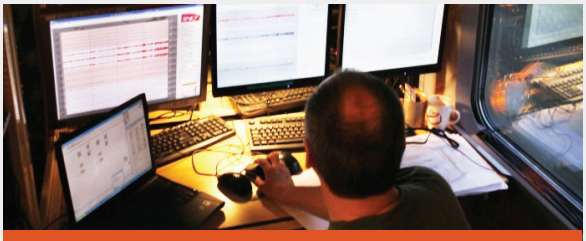
SNCF's Iris 320: Automated High-Speed Test Train

SNCF launched its automated high-speed test train Iris 320 in 2006, consisting of two power cars and eight trailer coaches. Providing a 160-meter-long laboratory, it runs at a speed of 320 kilometers per hour and inspects the entire French high-speed (LGV) network every 14 days based on a fixed schedule. It covered 111,198 kilometers of high-speed inspections in a year with a schedule of inspecting around 4,000 kilometers over six days along with maintenance every two weeks. The train is enabled with extensive inspection technologies to conduct a variety of measurements (see figure b):

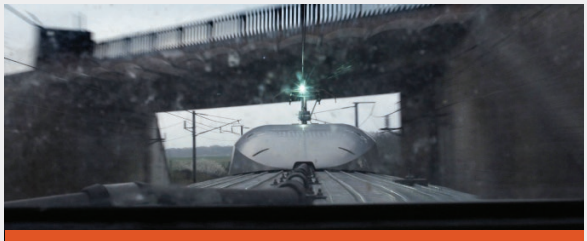
- **Tracks.** Geometry measurement and vehicle-track interactions
- **Signaling and overhead electrification.** Signaling, catenary, and continuity of supply current measurement with glass-roof (watch) for catenary observation
- **Trains.** Location, internal pressurization of train during crossings and tunnels, computer system and telecommunication measurement

Figure b

SNCF's Iris 320 automated high-speed test train checks the rail system



Feedback on signaling systems
Signaling data measured and analyzed in real time



Tracking catenaries
View from catenary watch while traveling at 320 kilometers per hour



Real-time inspection
Bogies outfitted with sensors to relay information



On-board sensors
Acceleration data monitored for passenger comfort

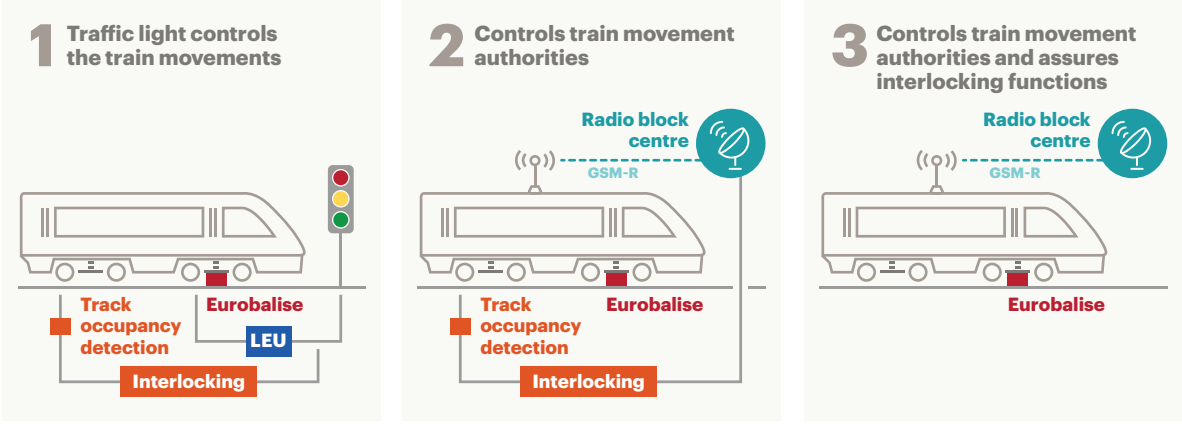
Sources: SNCF; A.T. Kearney analysis

ETCS Level 3 increases line capacity substantially and allows moving blocks by developing a safe envelope around the train.

Indian Railways is planning to upgrade its signaling systems to ETCS Level 1 (called the Train Warning and Protection Systems) across the high-density corridor. However, the organization could move directly to ETCS Level 2 to gain the added benefit of capacity enhancement while upgrading its signaling system from a safety perspective.

Figure 2

The European Train Control System has three configurations



Sources: European Rail Traffic Management System; A.T. Kearney analysis

2.3 Rolling stock

Modern Linke Hofmann Busch (LHB) coaches are much safer than the traditional Integral Coach Factory coaches. Several safety mechanisms are used on the LHB coaches, including the following:

- Center buffer couplers, which prevent coaches from climbing on top of each other during an accident
- Reduced tare weight because of lighter construction materials
- Efficient braking systems

With these features, the crash-worthiness of LHB coaches is much greater, thereby reducing the risk of fatalities in the event of an accident and improving passenger safety. While Indian Railways has been enhancing the share of LHB coaches in its fleet, the same needs to be fast-tracked to enhance passenger safety in case of accidents.

2.4 Personnel

Human error has been one of the biggest reasons for railway accidents across the world. Technological innovations allow for greater supervision and implementation of standard operating procedures to reduce errors and make railway systems safer.

One such innovation is locomotive-mounted video surveillance. These cameras provide continuous high-definition footage of both the interior and exterior of the locomotive, enabling the gauging of operator performance and identification of any inconsistencies on or alongside the track. This surveillance helps identify the root cause of any incidents and acts as a training tool for crew as well as a maintenance tool to pinpoint the exact location of track-related irregularities. Several companies have come up with such technology, including Railview by Klein Tech and LocoVISION by GE (see figure 3 on page 7). Key applications offered by these technologies include driver fatigue detection, trespasser alerts, and wayside monitoring. Indian Railways can consider piloting these applications to gauge their effectiveness in train running and safety.

3. Infrastructure Upgrades

Multiple technologies exist that can improve the rate of construction, enhance structural integrity, and improve the cost-effectiveness of projects, thereby contributing to faster infrastructure upgrades.

3.1 Mechanization of track construction

Track laying forms a large part of all infrastructure projects that rail systems undertake. The key technologies available to improve the track-laying process are outlined below.

3.1.1 Track linking or laying plain track machines

Track-laying work includes laying of new track and capacity enhancement through doubling.

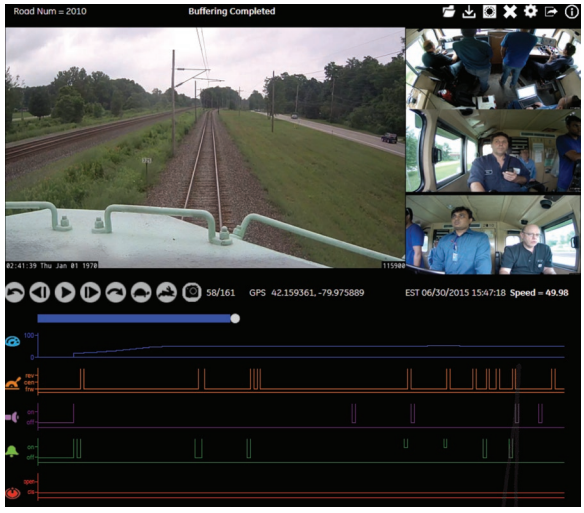
- **New track laying.** A new track construction machine can improve construction speeds with a truss-beam method of rail linking. The front end lays down the sleepers on the ground (see figure 4). These sleepers are carried on the rear end and brought to the drop point through conveyors. Deploying these machines requires availability of long stretches as well as sufficient availability of land.
- **Doubling.** Machines called portals can be used for this purpose (see figure 5). Wagons carry sleepers from depots to the construction sites where the portals are used to lift the sleepers and put them in place. The portals then lay the rails over the sleepers. The portals may also be used for new track laying over short stretches.

Similar to track-laying machines, there are specialized machines for laying turnouts.

3.1.2 Multipurpose track-laying machines

The recent industry trend is to move toward integrated solutions rather than specialized ones. Multipurpose track-laying machines

Figure 3
General Electric's LocoVISION provides clear images of any incidents or defects



Sources: General Electric; A.T. Kearney analysis

Figure 4
New track construction machines allow tracks to be built faster



Sources: Harsco Rail; A.T. Kearney analysis

Figure 5
Portals lift and place sleepers and rails



Sources: Colmar Rail; A.T. Kearney analysis

operate on a patented technique and are suitable for handling large panels (see figure 6). A big advantage of these machines is that they operate head-on, which means that any hold-up on the adjacent line can be avoided.

Indian Railways has seen limited adoption of such track-laying machines, which if used on a large scale could enhance the speed of creating infrastructure. Going forward, Indian Railways could use such machines at zonal levels.

Figure 6
Multipurpose tracklaying machines can handle large panels



Sources: InnoTrans; A.T. Kearney analysis

3.2 Mechanization of electrification

As Indian Railways progresses toward large-scale electrification, it will be crucial to induct innovative technologies for enhancing the rate of electrification. Several machines can be used:

- A **self-propelled overhead electrification laying train (SPOLT)** is used for putting in place the contact and catenary wires required for electrification of rail systems. This train has automatic tensioning arrangements, guide masts, and instrumentation for ensuring proper tension and uniform rotation of wiring drums.
- An **eight-wheeler self-propelled multi-utility vehicle (SPMUV)** has a cab at one end and a swiveling platform and crane at the other end, which support maintenance, adjustment of overhead equipment, and mast erection operations.

3.3 Usage of prefabrication

Another widely used practice in construction of road and railways infrastructure is prefabrication. This practice is used with standardized designs, where most of the construction elements are pre-cast separately at a central location. These items are then stored in a temporary depot near the construction site and transferred according to the installation requirement. Prefabrication has numerous advantages over on-site construction, including less construction time and lower manpower costs, improved structural integrity as a result of specialized construction equipment, and streamlined operations at the construction site, which reduces hazards.

Most of Indian Railways' construction is outsourced to third-party contractors, which manufacture elements on the construction site itself, potentially leading to substandard construction. Metro line construction, however, has been swift to adopt this practice because of a constraint on construction spaces as most of it takes place on traffic-ridden roads in India's metropolitan cities. Indian Railways has taken some steps to adopt prefabrication, but this practice could be included as a standard operating procedure for all construction works.

4. Train Operations Effectiveness

The key objective of train operations effectiveness is increasing asset availability and utilization. Multiple existing and new technologies are in play that can help Indian Railways achieve this. Key technologies are highlighted below.

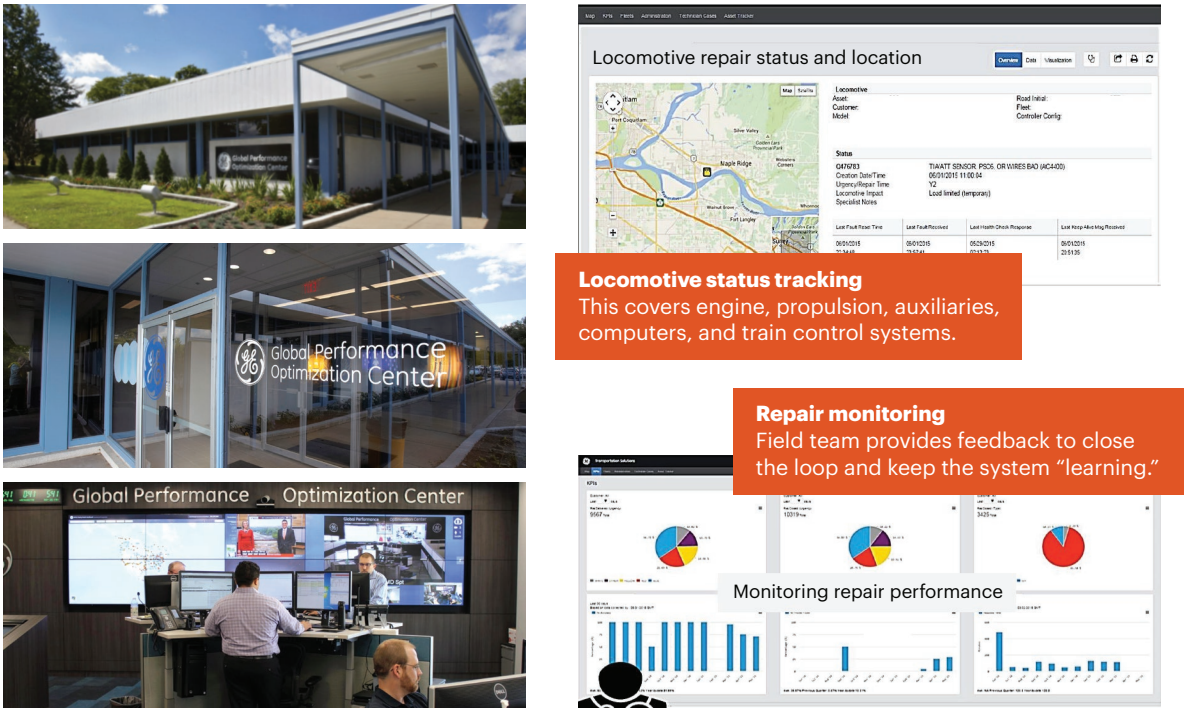
4.1 Overall asset performance management

Overall asset performance management systems are designed to enhance the reliability of operations and increase availability of assets. In such systems, deploying sensors along the entire network provides data that is fed into a predictive maintenance tool, which can provide an advanced warning of a potential failure and allow for planned maintenance. Such systems have been deployed by several railways across the globe, including the Russian Railways, Canadian National, and BNSF. Examples of such systems are provided below.

- **General Electric locomotive asset performance management.** GE has set up four global performance optimization centers, which cater to an around-the-clock monitoring requirement for about 50 customers and track more than 17,500 locomotives in 20 countries (see figure 7). These centers remotely track the location and health of the locomotives while predicting and diagnosing faults and recommending repairs. The system uses a predictive maintenance technology in the back end (Predix) to predict failures based on the sensor data. This technology has enabled planning of maintenance and has led to a 20 percent increase in the locomotive reliability and availability.

Figure 7

General Electric global performance optimization centers monitor locomotives in 20 countries



Sources: General Electric; A.T. Kearney analysis

- **Alstom HealthHub TrainScanner.** TrainScanner uses advanced machine-learning algorithms and artificial intelligence software to identify patterns from sensor data and predict action steps. It analyzes data gathered by lasers or 3-D camera measurement systems installed in a diagnostic portal through which the locomotive passes (see figure 8).

Figure 8
Alstom's TrainScanner provides on-board real-time condition monitoring



Sources: Rail Forum; A.T. Kearney analysis

TrainScanner has automated the process of checking the status of rolling stock, infrastructure, and signaling and identifying components that might require repair or replacement along with the repair or replacement date. First deployed in the United Kingdom, this system has collected asset data for more than 700 trains over 10,000 kilometers of infrastructure through 500 machines. It has resulted in a 25 percent increase in maintenance intervals, thus lengthening the typical distance a Pendolino travels before repairs from 20,000 kilometers to 25,000.

4.2 Operations optimization

Operations optimization tools help ensure maximum asset utilization by making sure the locomotives, rolling stock, and crew are available at the origin and changeover points when required and trains run efficiently across the network. Given the vast nature of rail networks, it is very difficult to optimize train movement manually. Rail companies can make use of a number of optimization tools for either planning or taking decisions on a real-time basis.

Operations optimization measures are required to cover four aspects:

- **Trains.** Optimizing train scheduling and tracking in real time to enhance capability in unscheduled services (DB, CN, and BNSF are using freight service optimization tools.[5])
- **Rakes.** Ensuring availability of rakes for scheduled services and using idle rakes for unscheduled services for maximum utilization
- **Locomotives.** Locomotive optimization is similar to that of rakes and has been successfully adopted by CSX Transportation, a North American Class-I freight railroad, through Optym's locomotive planning tool.[6]
- **Crew.** Optimizing roster preparation so all regulatory requirements are followed and personal preferences of crew are also considered (Biarri Rail's crew optimization tool has been adopted by Aurizon and Pacific National in Australia.[7])

Following are four examples of operations optimization tools:

- Optym's locomotive optimization tool, called **LocoMAX**, is a fully functional mathematical model that considers all business rules, operational constraints, and cost terms. The

[5] E-Motion, Deutsche Bahn, BNSF case study by Optym

[6] CSX Transportation case study by Optym

[7] Aurizon and Pacific National case studies by Biarri Rail

interactive system provides output in the form of tables, graphs, and charts and has shown a 3 to 5 percent reduction in locomotive operating costs.[8]

- Biarri Rail's crew optimization tool, **BOSS**, is a comprehensive cloud-based optimization tool. Its powerful algorithms and modern design enable integration within the complex TMS and ERP systems and allows for dynamic scheduling by providing real-time tracking.
- A freight transportation company in Greece, **TrainOSE**, has come up with an RFID-based solution for better freight scheduling. RFID tags are applied on each wagon, and scanners are placed at key locations along the tracks. These give the company greater visibility into wagons, including detecting any errors. These scanners can alert authorities if any wagon arrives at the wrong destination or there is a schedule change. This tool helps in optimization as the company is aware of the location of all its wagons at any given point of time, thereby ensuring better utilization.
- Siemens has developed a method to use analytics to improve operations of railways. The company has been able to reduce spare capacity in railways and aims to reach 100 percent train availability. Siemens records data points such as mileage, brake and compressor performance, and the load being carried by the train and then uses this data to optimize rail operations.[9]

Indian Railways has an opportunity to identify and choose the right set of optimization tools, which can enhance the efficiency of its network through optimal use of existing resources. The need for such optimization tools will become more essential as Indian Railways proliferates time-tabled freight services (scheduled railroading).

4.3 Process digitization

Digital is now a buzzword that has ubiquitous applications, especially in processes dominated by manual operations. For Indian Railways, digital can be used to significantly augment employee productivity, improve the quality of work output, and reduce the cost of execution. Process digitization is common across most industries and is a natural progression for Indian Railways.

Global railways have adopted process digitization in a big way. For example, Network Rail undertook a seven-year program called Offering Rail Better Information Services (ORBIS) to digitize and transform maintenance of the UK rail network infrastructure. The deployment was carried out in three stages:

- **Information capture.** Development and use of mobile applications such as My Work, Fault Code Lookup, and Close Call apps were undertaken to report information related to the asset and update status of work orders. Additionally, as a part of this stage, a LiDAR-based imagery survey was conducted in 2014 to capture images of track and terrain.
- **Data integration.** During this stage, tools were deployed to create a rail infrastructure network model, which provided an asset-wide picture of the entire network using the LiDAR input.
- **Decision support for asset management.** Proactive maintenance management was enabled using the linear asset decision support tool, which provided the maintenance engineers a view of and data about the 32,000 kilometers of the track.

[8] CSX Transportation case study by Optym

[9] "Internet of Things in Motion: Analytics and Transportation," *MIT Sloan Management Review*, 25 May 2016

The entire digitization exercise reaped significant benefits for network rail with more than 3.5 million work orders closed, a 40 percent reduction in administrative requirements, and improved operational efficiency.

Some other examples of process digitization are the implementation of the Indian Railways e-procurement system for catering to tendering and order placement as well as Indian Railways' integrated material management system for demand generation, receipt and acceptance, and inventory management of stock items.

Going forward, Indian Railways could identify labor-intensive processes that can benefit significantly from digital interventions, build digital prototypes, and iterate the solution on the go. The old philosophy of drawn-out requirement gathering and then long development cycles has been replaced with quick fixes that improve iteratively.

4.4 Distributed power

Distributed power refers to distributing multiple locomotives across the length of the train with coordinated acceleration and deceleration to improve stopping time by 22 percent and reduce stopping distances by 30 percent. It also improves safety as there are fewer instances of train separation (break-in-two). Up to four radio-controlled locomotives per train can be controlled, enabling longer and heavier trains and improving the network throughput. This technology, which is owned by GE Transportation Systems under the name LOCOTROL, has been adopted by CN, BNSF, SNCF Freight, and Chinese Railways.[10]

4.5 Right powering through locomotive spec improvement

For efficient freight and passenger train movement, it is important to provide the right power to the trains according to the axle load. This helps achieve a good average speed, which in turn improves the use of the rail network by increasing throughput. In Russia and Finland, the horsepower-to-trailing-ton ratio can be as high as 3.2 for freight operations. While these are exceptionally high, the norm in major railway systems is to have a ratio of at least two for freight operations.[11]

One simple way to achieve this is to expand the number of locomotives powering a train to increase the horsepower. However, this lengthens the train and puts a strain on other infrastructure such as the loop lines, which may no longer be able to accommodate these trains, resulting in slower movement across the network. A better way to ensure the right power-to-load ratio is to use locomotives that have high power per axle. This will address the issue of right powering without impacting the length of the train, thereby substantially increasing network capacity.

In case of electric freight locomotives, Indian Railways' continuous power rating is only 0.75 MW/axle (1007 HP/axle) with WAG-9 and 1.16 MW/axle (1500 HP/axle) with WAG-12. The norm in Europe is 1.5 to 1.6 MW/axle (about 2000 HP/axle). Similarly, China has implemented configurations such as 2xBoBo (13,500 HP), 3xBoBo (20,000 HP), and CoCo (12,888 HP) in the past 15 years, achieving a continuous power rating of 1.25 MW/axle (1678 HP/axle) and 1.6 MW/axle (2148 HP/axle) within 22.5-ton to 25-ton axle load limits.

[10] Canadian National Leadership in Safety Report 2017, A.T. Kearney subject-matter experts, Railway Gazette 2014, "Technological Development of Chinese Railway Heavy Haul Freight Cars" by the Transportation Bureau of the Ministry of Railways 2009

[11] Company annual reports, IHS Jane's World Railways, A.T. Kearney reports

Similarly, for the electric passenger locomotive fleet, Indian Railways is severely underpowered compared with major rail corporations around the globe. While a continuous power rating of 1.5 to 1.6 MW/axle (about 2000 HP/axle) and starting tractive effort of 75 to 85 kN/axle is the norm globally, Indian Railways' continuous power figure is only 1 MW/axle (1340 HP/axle) with WAP-5 and 0.75 MW/axle (1007 HP/axle) with WAP-7, and starting tractive effort is not more than 55 kN/axle.

Therefore, Indian Railways could consider focusing on improving the specifications of its locomotives to ensure right powering of trains without reducing network capacity.

5. Passenger Experience

Railways are such an integral part of the common man's life that a small change in experience is easily recognized and appreciated. Also, to keep abreast with Indian consumers' rising expectations, Indian Railways must transition from a traditional railway station model to a smart railways system. The tenets of the smart railway stations include seamless connectivity and enhanced passenger experience.

5.1 Railway stations

5.1.1 Access control

Access control is an important addition to railway stations to ensure that unauthorized personnel are not permitted to use station facilities and to provide a better experience for passengers, who are the rightful users of these facilities. Access control can be established through manual or digital means. Manual access control involves deploying security personnel at the station gates to verify tickets of each person entering the station; digital involves a digital entry system that can only be accessed by using QR codes or contactless cards (see figure 9). Unique QR codes can be integrated into each ticket. Entry through contactless cards could be established using open loop smart cards (see section 5.2.2). These codes and cards unlock the automatic entry gates at stations. Countries such as China and Canada have successfully implemented access control on a large scale at mainline stations.[12]

Figure 9
High-entrance turnstiles and QR codes can help with access control



Sources: Wikipedia; A.T. Kearney analysis

For Indian Railways, full digital access control could be one of the major goals. However, it will be very challenging to establish right away given the changes in the ticketing system and the level of passenger know-how that are required. Access control can be implemented in a phased manner starting with a partly digital and partly manual solution wherein security personnel are deployed alongside automatic gates to educate passengers about the new technology.

[12] Evolis Chinese Railways solution partner, Go Transit

5.1.2 Real-time information systems

Many global rail systems use GPS positioning and footpath mapping to track trains in real time and relay the information to passengers. These systems can automatically and accurately measure any delays in operations. Using such systems goes a long way in enhancing the passenger experience and optimizing the use of resources. Even though some delays are unavoidable, it is important to keep passengers updated, thereby improving system reliability. GPS systems can provide data to a central control center that then relays the information to displays at the stations as well as to passengers' phones. Such systems are used by rail networks such as JR East, JR West, and SNCF. Indian Railways could consider fast-tracking the implementation of the Real Time Intelligent System project to support passenger convenience and provide inputs to analytical systems.

5.1.3 Interactive solutions

To make it easier for passengers to gather information and improve their mobility around the station, some rail systems in France, Britain, and Japan have installed interactive terminals at various points across the stations. These act as a good source of information for passengers and can provide revenue to the company through advertisements. The JR East rail company in Japan has also developed an app for users to access their tickets and get information about the services offered at the stations.

Indian Railways may consider taking initiatives in these regards to establish smart railway stations and enhance the passenger experience. In addition, Indian Railways can invest in other key areas of the passenger experience to establish itself as a conducive option for traveling within the country.

5.2 Ticketing

5.2.1 Omnichannel ticketing experience

With the growing popularity of the Internet and smartphones, it has become essential to make the ticketing experience hassle-free and available on all platforms. Passengers demand the freedom to book tickets through not only the traditional ticket counters at stations but also an app on their smartphones and a website on their laptops. The physical and digital channels should be seamlessly integrated to ensure an omnichannel ticketing experience. However, accessibility is not the only aspect passengers are looking for on these channels; many also seek assistance when planning a trip. Indian Railway Catering and Tourism Corporation has taken significant steps on this front and could consider enhancing the interface for customers and making it uniform across platforms.

5.2.2 Open loop smart card

Open loop smart cards are multipurpose cards that can be used at various access points. Because they can be integrated with the ticketing system, passengers may not be required to purchase a ticket and can use these prepaid cards for their train travel. These cards can be also used for intra-city travel—creating a hassle-free experience for passengers to get to and from the stations, and they can be used for access control purposes (see section 5.1.1). ScotRail has used similar smart cards.[13]

[13] "No more ticket queues. No more paper ticket." ScotRail

5.3 Train experience

5.3.1 Wi-Fi

Wi-Fi has become a necessity even when people are on the move. Most major rail systems, including DB and SNCF, have started providing Wi-Fi on trains to improve the passenger experience. This helps to attract business passengers who may prefer to be connected at all times to get work done while traveling. These train operators have installed devices called WLAN hotspot generators, which communicate with commercial mobile network towers to provide Wi-Fi onboard trains, depending on the contracts with the network providers. Because bandwidth is limited on trains, most rail operators have restricted the use of Wi-Fi to certain data limits. Some also restrict the use of onboard Wi-Fi for services such as video streaming, which consumes a large amount of data.

5.3.2 Infotainment

Along with Wi-Fi, infotainment screens have become the norm to provide accurate information about train operations and for entertainment purposes. This helps passengers have a more relaxed travel experience as it is easier for them to pass time. These systems can also act as an additional source of revenue by displaying advertisements. Indian Railways has introduced LCD screens in the Tejas Express and select routes of the Shatabdi Express. However, long-term implementation is unclear with multiple instances of vandalism by passengers.[14]

Eurostar, a train in Europe that connects the United Kingdom and mainland Europe with an underwater channel tunnel, has gone one step further in the entertainment aspect.[15] The company offers free VR headsets for passengers to have an immersive experience while traveling—a first-of-its-kind innovation to provide VR-based entertainment onboard a train. The experience shows a simulation of what is happening outside the train as the train travels across the seabed.

Deutsche Bahn is trying to improve this experience by developing augmented reality windows on its future trains. This technology is in the research stage and would allow passengers to gain information about the landscapes they are crossing while on the train.

5.3.3 App-based systems

Other innovations include an app that allows passengers to point out any problems onboard and then track the status of their complaints in real time to know when they have been addressed.[16] Passengers can submit complaints along with photos of the problem through the app, and these get conveyed directly to authorities.

Also, a UK railway company is testing new technology that uses sensors to provide information to passengers about empty seats. These sensors detect that a seat is empty and convey the information to passengers through an app on their phones, negating the need for them to walk through the train looking for a seat.

In terms of enhancing the passenger experience across the trains, Indian Railways could tailor an approach with infotainment solutions for entertainment and app-based solutions for onboard services such as catering and route information.

[14] "No more movies on Tejas", Hindustan Times

[15] "Eurostar Odyssey: A Virtual Reality Adventure on Board," Eurostar

[16] "Transreport for a Better Journey," Transreport

6. Organizational Capability Enhancement

Technology can improve the organizational capability enhancement in railways, especially in personnel training and leadership decision-making.

Several technologies such as virtual reality and training simulators enable recreation of real-life scenarios, leading to hands-on training as opposed to basic classroom-based training. These technologies are particularly relevant for roles with significant manual intervention.

> Simulators and VR-enabled training help impart hands-on training by recreating lifelike scenarios.

Additionally, technology and digitization interventions such as management information systems and dashboards are widely used across industries to improve visibility of the organization's performance to the top management and enable sound decision-making. They also assist in centralized management of current projects and planning of new projects based on tracking of key performance indicators and availability of resources.

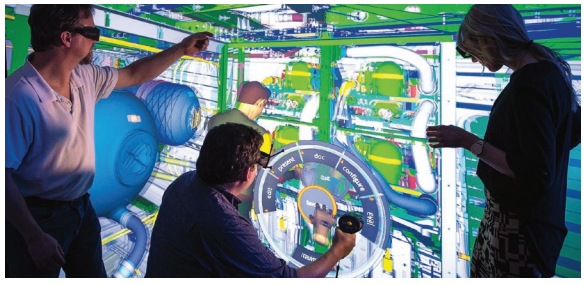
6.1 Training

Rail systems around the world have adopted technology to train personnel, including drivers and maintenance crew. Simulators and VR-enabled training help impart more hands-on training by recreating lifelike scenarios. For example, simulators can help familiarizing drivers with specific routes and emergency conditions. Also, VR can create awareness among the maintenance crew about required safety procedures while executing various tasks.

6.1.1 Virtual-reality enabled training

Virtual reality creates an interactive 3-D computer-simulated world that enables users to explore and experience various components. VR-assisted training has been used in variety of industries, including air transport and healthcare. Major rail systems across the world, including DB, BNSF, and SNCF, are also adopting VR training—allowing trainees to practice skill-intensive processes (see figure 10).

Figure 10
Railways around the world use virtual reality to train employees



Sources: Innovation & Recherche SNCF; A.T. Kearney analysis

For example, SNCF developed a game to raise awareness among new hires and less-experienced staff about health and safety risks related to maintenance of rolling stock. The training module is comprised of several scenarios with tasks such as performing a pantograph visit and refilling window washer fluid. The modules deliver important messages related to topics such as personal protective equipment, risk assessment, and electrical hazards.

Indian Railways could also explore using VR-enabled trainings and measure their effectiveness before launching a full-scale deployment.

6.1.2 Training simulators

Simulators are traditionally used for training locomotive drivers to experience real-life conditions and respond appropriately during an emergency. They are also used to familiarize trainees with route-specific nuances. The types of simulators used for locomotive pilots are software interfaces, partial task trainers, partial cab replicas, and full cab replicas.

Simulators can also be used to train engineers, specialists, and traffic controllers on tasks related to maintenance, infrastructure, track telecommunications, and information systems.

For example, ADIF in Spain uses simulators at three technology centers across Valencia and Madrid to train nearly 10,000 employees annually with at least 40 hours of training. Similarly, Russian Railways delivers both classroom and simulator-based training at 15 vocational training centers.

Although Indian Railways uses simulators to train locomotive drivers, these drivers spend less time on them than operators in other countries. For example, assistant locomotive pilots in India spend 4.5 to six hours on simulators during initial training, while rail operators around the world spend about 30 hours. Hence, Indian Railways could plan to use more simulators in locomotive driver training and initiate use of simulators for training other personnel, such as traffic controllers and engineers.

6.2 Management reporting dashboards

Management reporting dashboards are information management tools that help organizations capture, process, and visualize information across functions to support planning, decision-making, and transaction processing at various levels. The dashboards can be specialized to support different organizational functions such as manufacturing, logistics and supply chain, personnel, finance and accounting, marketing, sales, and customer relations.

Dashboards are useful not only to top management and decision-makers for enhanced visibility of the organization but also for middle and lower executives to track day-to-day activities and plan tasks. Additionally, they can be a key decision-making tool that provides insights across functions using the organization data. Dashboards allow management to view consolidated information from across the organization and from different software applications. They are useful in monitoring progress of key projects and undertake timely interventions to ensure fulfilment of organization goals. They also simplify the complexity of running organizations by prioritizing access to vital information.

Widely used across industries, dashboards have become an important tool for efficient management of organizations. For rail transport, basic dashboards can be used to view information related to elements such as train scheduling and dispatch, passenger and ticketing information, freight transit, and personnel deployment. Additionally, advanced analytics-powered dashboards can help with optimizing processes, resource allocation, and demand forecasting. With the advent of big data handling capabilities, dashboards can now ingest data from a variety of sources, such as sensors, GPS, and RFID systems, and provide nearly real-time information.

A key differentiator in the success of rail corporations across the world has been the quick adoption of technology. For example, BNSF has won awards for excellence in business intelligence, and the company's dashboard application has won the Transforming Data With

Intelligence (TDWI) Best Practices Award for performance management. The intuitive dashboard enabled BNSF to pull information from across its business systems into a single view for quick identification of problems before they impact service levels. The dashboard provided information needed BNSF decision-makers to quickly respond to customer needs and improve company performance.

At Indian Railways, multiple reports get published, but the data and formats are non-intuitive in the form of tables. The organization needs a strong management information system, which can aid its officers in visualizing data and making data-driven decisions.

7. Conclusion

The success of Indian Railways is an important objective not only for the Government of India, but also for the common man. Technology offers a unique opportunity to leapfrog the current state and move closer to best-in-class standards. However, the nature of the technology and product development and the complexity of the selection process make it imperative to look for new frameworks for identifying the relevant players to supply the technology.

Conventionally, the Indian Railways has used the request-for-proposal process to procure technologies. However, this has some limitations that make it difficult to acquire modern technology:

- **Not all technology is readily available** and may have to be designed in collaboration with the rail operator to ensure proper functionality. Some technology may be available but could require customization before deployment.
- **Some systems may need to be tested** before being implementing on a large scale to understand their true impact.
- **Commercial bids may not be an exact quote** but an agreement for a share in the gains from the implementation of the technology, such as those from increase in freight or passengers.

7.1 Alternate approach

An alternate process that addresses the above issues begins with defining the scope, after which a detailed pilot could be conducted, and finally, based on performance in the pilot, the final contract would be awarded (see figure 11). The contracting process is expected to be outcome based so Indian Railways reaps the maximum benefits from the technology implementation.

Figure 11
External procurement should follow a three-step process

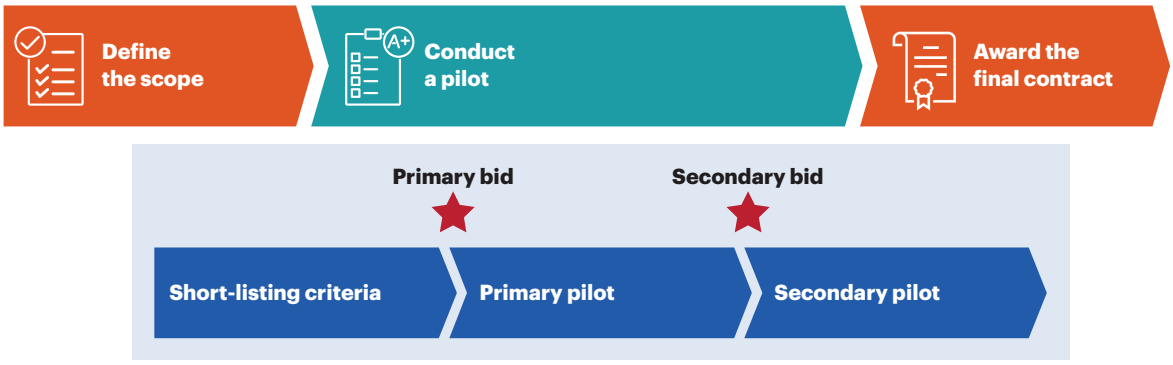


Source: A.T. Kearney analysis

7.1.1 Scope definition

The scope of the technology and the requirement should be clearly defined at the beginning of the process (see figure 12). This should detail out the purpose for which the technology is required and the utility that it will provide.

Figure 12
Three-stage pilot process



Source: A.T. Kearney analysis

At this stage, the scope should only cover the requirements at the pilot and first stage of the contract. These can be extended to cover more aspects when required through an agreement between the rail organization and the vendor.

7.1.2 Conduct a pilot

A phased elimination process could be conducted during the pilot stage, starting with a basic short-listing criteria-based elimination followed by two stages of technology implementation. At each stage, a certain number of vendors would be eliminated based on their performance on the specified metrics.

- **Short-listing criteria for pilot.** The purpose of the short-listing criteria would be to understand the technical capabilities of the vendors and eliminate those that are small or lack requisite know-how. Several criteria can help address these issues:
  - Total revenue of the bidder
  - Number of projects of similar nature in the past 10 years
  - Impact achieved in these projects
  - Testimonials and references of clientele
- **Primary pilot.** This pilot provides the opportunity to a relatively large number of short-listed vendors to implement their technological solution in the field and do a preliminary assessment of the strength of their solutions. This gives vendors an opportunity to showcase their product features and impact at a basic level. Based on the outcomes of the primary pilot, a short list of vendors will be invited for a secondary pilot.

- **Secondary pilot.** This pilot is more comprehensive, in terms that all required features will need to be implemented by the vendors to showcase the solution comprehensiveness and accuracy. This step will also give Indian Railways an opportunity to finetune specifications.

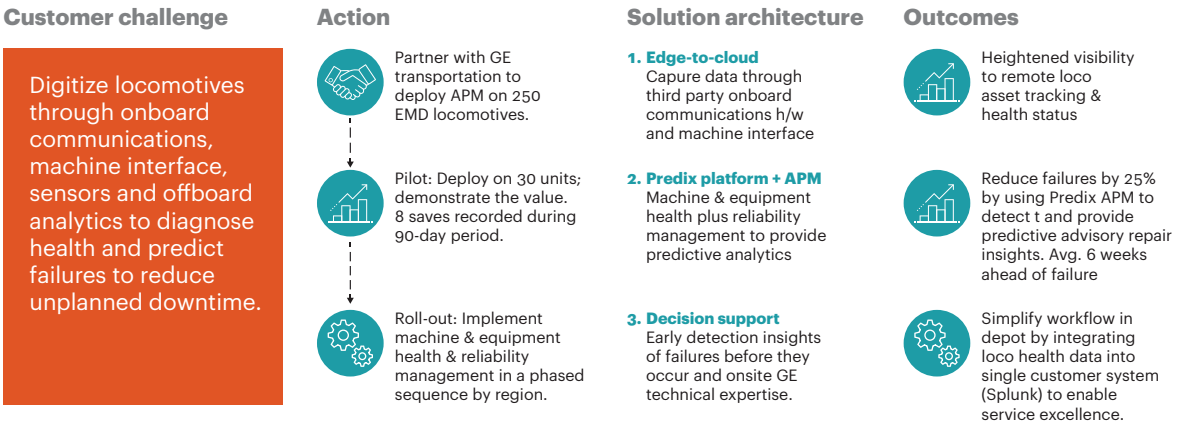
Both the primary and secondary pilot must be paid contracts (through a bidding mechanism), and these bids can be used to award the final contract.

7.1.3 Award the final contract

The final contract would be awarded based on a weighted average of three elements: primary bid, secondary bid, and performance score from the secondary pilot. The vendor with the highest score would be awarded the final contract.

Rail operators around the world have used such an outcome-based, pilot-driven technology procurement and implementation approach. For example, DB conducted a similar process before awarding a contract to GE for their asset performance management solution on 250 locomotives (see figure 13). A pilot was conducted on 30 locomotives for 90 days. During this time, the GE technology was able to correctly predict eight failures, so GE was awarded the contract.

Figure 13
DB Cargo partnered with General Electric for asset performance management



Sources: General Electric; A.T. Kearney analysis

Indian railways may need to consider a new approach to procurement for modern technology while ensuring optimum selection and implementation of the same.

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