Chapter 1 - Introduction

1.1 Track and its components

Indian Railway (IR) has 92,084 running track kilometers[1] (as on 1 April 2016). Track or Permanent Way (P-way) is the rail-road on which the trains run. Track structure includes two parallel rails at a specified distance, fastened to sleepers, which are embedded in a layer of ballast of defined thickness spread over the formation.

Figure 1: Railway Track

The track on a railway also known as the P-way is the structure consisting of the rails, fasteners, sleepers and ballast plus the underlying sub-grade[2]. Track enables trains to move by providing a dependable surface for their wheels to roll upon.

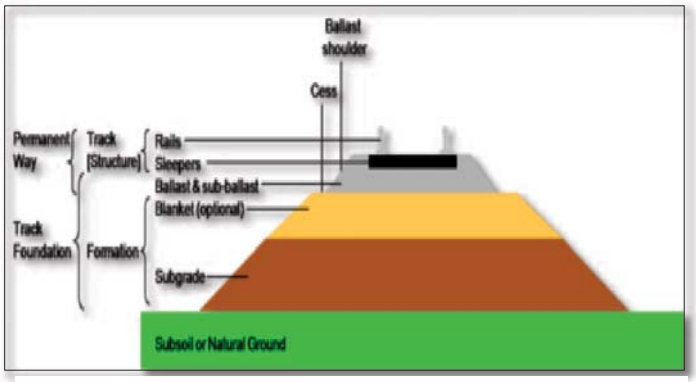

Figure 2: Components of track

Rail: Modern track typically uses hot rolled steel with a profile of an asymmetrical rounded **'I'** shaped cross-sectional beam. Unlike some other uses of iron and steel, railway rails are subject to very high stresses and are made of very high quality steel alloy. The stronger the rails and the rest of the track, the heavier and faster trains it can carry. Rail is graded by weight over a standard length. Heavier rails can support greater axle loads[3] and higher train speeds without sustaining damage than lighter rails.

Rails are produced in fixed lengths and need to be joined end to end to make a continuous surface on which trains run. The traditional method of joining the rails is to bolt them together using metal fishplates[4], producing jointed track. Because of the small gaps left between the rails, when trains pass over jointed tracks they

[1] The length of all running tracks excluding tracks in sidings, yards and crossings.
[2] *Sub – grade* is layer of small crushed stones, which gives a solid support for the top ballast, and reduces the seepage of water from the underlying ground.
[3] The *axle load* of a wheeled vehicle is the total weight felt by the Permanent way for all wheels connected to a given axle.
[4] Metal fishplates is a metal bar attached by means of bolts to the rails on either side of the joint

make a clack sound. Unless it is well-maintained, jointed track does not have the ride quality of welded rails and is less desirable for high speed trains. However, jointed track is still used in railways on lower speed lines and sidings[5] due to the lower cost for its installation and maintenance.

Where higher speeds are required, the lengths of rail are welded together to form Long Welded Rail[6] (LWR) or a Continuous Welded Rail[7] (CWR) that may be 250 meter to several kilometers long. Because there are few joints, this form of track is strong, gives a smooth ride and needs less maintenance; trains can travel on it at higher speeds and with less friction. Welded rails (presently used methodology of laying of rails) are more expensive to lay than jointed tracks, but have much lower maintenance costs.

Alumino Thermite (AT)[8] welding is used to repair or splice[9] together existing CWR segments. This is a manual process which uses molten iron to weld the gap between rails. AT bonded joints are less reliable and more prone to fracture. The preferred process of Flash Butt (FB) welding involves an automated track laying machine running a strong electrical current through the touching ends of two un-joined pieces of rail. The ends become white hot due to electrical resistance and are then pressed together to form a strong weld.

Sleepers: Sleepers are the transverse ties that are laid to fix and support the rails. The sleeper has two main roles, viz. to transfer the loads from the rails to the track, ballast and the ground underneath and to hold the rails to the correct width apart.

Several types of sleepers are in use on Indian Railways which includes wooden sleepers, cast iron sleepers, steel channel sleepers and concrete sleepers. Sleeper density is the number of sleepers per rail length and is determined based on various factors such as axle load and speed, type and section of rails, type and strength of the sleepers, type of ballast and ballast cushion and nature of formation. The spacing of sleepers is fixed depending upon the sleeper density. Spacing is not kept uniform throughout the rail length. It is closer near the joints because of the weakness of the joints and impact of moving loads on them.

[5] Siding is a low speed track section distinct from a running line or through route such as a main line or branch line
[6] Long Welded Rail (LWR) is a welded rail, the central part of which does not undergo any longitudinal movement due to temperature variations. A length of greater than 250 meter on Broad Gauge (BG) will normally function as LWR. The maximum length of LWR under Indian conditions shall normally be restricted to one block section.
[7] Continuous Welded Rail (CWR) is a LWR which would continue through station yards including points and crossings.
[8] Alumino Thermite (AT) welding is a process involving exothermic reaction between aluminium and iron oxides which results in the production of molten steel which is poured into a mould around the gap to be welded. The superheated molten metal causes the rails to melt at the edges of the gap to be welded, and it is also the filler metal, so that the material from the rails coalesces with and joins the added molten steel as it solidifies to form a weld.
[9] Join or connect by interweaving the strands at the end

Bed and foundation: Ballast forms major component of track sub-structure and plays a dominant role in the track performance and its maintainability. Track ballast forms the track bed upon which railway sleepers are laid. It is packed between, below and around the sleepers. It also keeps down vegetation that might interfere with the track structure. It is typically made of crushed stone. The thickness of a layer of track ballast depends on the size and spacing of the sleepers, the amount of traffic expected on the line, speed of the trains to be run on the track, etc. It is essential for ballast to be piled as high as the sleepers, and for a substantial 'shoulder' to be placed at their ends, the latter being important, since this ballast shoulder is, for the most part, the only thing restraining lateral movement of the track. Ballast acts as a shock absorber and provides lateral resistance against longitudinal movement of sleepers. While providing lateral stability to track it facilitates distribution of weight of rolling stock[10], it also serves as a drainage system for the formation. Better riding comfort and safe passage of trains are achieved through provision of adequate quantity of quality ballast.

1.2 Track maintenance

The railway track should be maintained properly in order to enable trains to run safely at the highest permissible speeds and to provide passengers a reasonable level of comfort during the ride. Due to the constant movement of trains, the packing under the sleepers and track geometry[11] gets disturbed, the fittings of the track get undone, there is heavy wear and tear of the track and its components and the gauge[12] and alignment of the track gets affected adversely. The track and its components also get worn out as a result of the weathering effect of rain, sun, and sand. Thus, track undergoes vertical stresses (due to locomotive, wagons, coaches being run on the track) and longitudinal stresses (due to environmental factors such as temperature, floods, rain, sun, sand, etc.). If the track is not maintained properly, it will cause discomfort to the passengers and in extreme cases may even give rise to hazardous conditions that can lead to derailments and a consequential loss of life and property. Inadequate maintenance may also lead to 'speed restrictions'. Proper track maintenance ensures that such situations are avoided. It also ensures that the life of the track as well as that of the rolling stock gets enhanced and leads to reduction in operating costs and fuel consumption. High speed and heavy axle load operations on IR has also necessitated up-

[10] Locomotives, carriages, wagons, or other vehicle used on a railway are called *rolling stock*

[11] *Track geometry* is three-dimensional geometry of track layouts and associated measurements used in design, construction and maintenance of rail road tracks

[12] The *Gauge* of a railway track is defined as the clear minimum perpendicular distance between the inner faces of the two rails

gradation of the track structure and increased requirement for maintenance and monitoring.

Track maintenance ensures availability of track of desired standard for smooth running of trains. It was at one time, hard manual labour, requiring teams of labourers or trackmen, who used lining bars to correct irregularities in horizontal alignment of the track and tamping[13] and jacks[14] to correct vertical irregularities (surface). The track structure has become sturdier and less amenable for manual maintenance due to continuous developments in various track components namely rails, sleepers, fastenings[15], points[16], crossings[17], etc. This has led to gradual proliferation of use of track machines for mechanized maintenance of track. Over the years, mechanized maintenance has gained importance for reliable track maintenance with high degree of precision and quality with lesser dependence on manual labour. Inspections are also carried out by officers of various levels to detect flaws requiring preventive maintenance in track, either through manual inspection or using specialized machines.

Track maintenance involves preventive maintenance (periodic maintenance activities) through deep screening of ballast, de-stressing of rail joints, condition monitoring of track structure through regular inspection/patrolling and repair of defects, tracking parameters to assess quality of track structure through use of Track Recording Cars, using Ultrasonic Flaw Detection (USFD) machines for assessing condition of rail (for detecting/identifying rails likely to be affected by buckling[18]and welds likely to fail), Wheel Impact Load Detector (WILD) for identifying wagons/coaches exerting higher vertical stresses on the rail (for detachment and repair of such wagon/coaches) and monitoring track maintenance activities using Track Management System (TMS).

Preventive maintenance also includes periodical changing of sleepers, lubricating and adjusting switches[19], tightening loose track components, and surfacing and lining[20] track to keep straight sections straight and curves within prescribed limits. Sleepers and rails are replaced where they have passed their life or on condition basis. Over time, ballast is crushed or moved by the weight of trains passing over

[13] Tamping means packing of (or tamp) the track ballast under the railway tracks to make the tracks more durable
[14] The hydraulic track jack (non–infringing type) is used for lifting of track in track maintenance/construction work
[15] Various types of nuts / bolts used to fasten rails to sleepers
[16] Point comprises of one pair of tongue rails and stock rails with necessary fittings to guide the train for change in direction. This works along with crossing element.
[17] *Crossings* is a device introduced at the junction where two rails cross each other to permit the wheel flange of a railway vehicle to pass from one track to another.
[18] *Buckling* is formation of large lateral misalignments in continuous welded rail (CWR) track. Buckles are typically caused by a combination of three major factors: high compressive forces, weakened track conditions, and vehicle loads.
[19] *Switch* or turnout is a mechanical installation which enables railway trains to be guided from one track to another.
[20] *Surfacing* (tamping) and *Lining* are track maintenance activities which restore the desired track geometry and smoothness of vehicle running.

it, periodically requiring re-leveling (tamping) and eventually to be cleaned (deep screening). If this is not done, the tracks may become uneven causing swaying, rough riding and possibly cause derailments. In the alternative, ballast can be reinserted beneath the rails and sleepers after lifting them. Maintenance activities are carried out using machines as well as manually through a group of railway personnel called 'gangs'.

Track maintenance activities (preventive and others) along with the responsibility centres are given below:

Table 1 – List of maintenance activities and their responsibility centres

S. no	Maintenance related activity	Detailed activities	Responsibility Centre
1	**Inspection of Track**	Patrolling by Track maintainers (Gang man, Track man, Key Man) Inspection by Junior Engineer Inspection by Senior Section Engineer(SSE) Inspection by Assistant Divisional Engineer(ADEN) Inspection by Divisional Engineer(DEN)	As per jurisdiction of sectional, sub-divisional and Divisional offices of Railways
		Daily inspection	Keyman, Senior Section Engineer
2	**USFD testing**	USFD testing of welds	Senior Section Engineer/ USFD team, Assistant Divisional Engineer and Divisional Engineer, Track
		USFD testing of Rails	
3	**Track monitoring**	Rail Profile Measurement by Track Recording Cars (TRC)	Track Machines and Monitoring Directorate of Research Design & Standards Organization for deployment of TRC. Assistant Divisional Engineer should accompany the TRC in his jurisdiction and take down notes regarding the spots needing attention
4	**Wheel Impact Load Detector**	Monitoring of impact of load on track by 'wayside detection system' through Wheel Impact Load Detector (WILD) system	Zonal Railway
5.	**Preventive and Periodic maintenance activities**	Deep Screening	Divisional and Sub – divisional offices
		De-stressing	Divisional and Sub – divisional offices
		Others	Senior Section Engineer (overall charge)
		Training	Principal Chief Engineer and Senior Divisional Engineer
		Co-ordination with other Departments	Assistant Divisional Engineer
		Track on Bridges	Assistant Divisional Engineer
		Ballast	Assistant Divisional Engineer

Detailed information regarding maintenance activities along with the prescribed periodicity are given in **Appendix I.**

1.3 Organisational Structure

At Railway Board, Member Engineering (ME), assisted by Additional Members (Works & Civil Engineering), Executive Directors (Works, Civil Engineering, Track Machines, General and Planning), Directors (Works, Civil Engineering Bridges & Structures and Planning) and Joint Directors (Works, Track Machines) are responsible for formulating policy relating to track and P-way.

At the Zonal level, the Chief Track Engineer (CTE), working under the control of Principal Chief Engineer (PCE), is responsible for implementing the policy guidelines / orders of the Railway Board. The Track Machine Organisation (TMO) is headed by the Principal Chief Engineer (PCE) and assisted by the Chief Engineer (Track Machines), Deputy Chief Engineer (Machines) and Executive Engineer (Machines). At the divisional level, the Senior Divisional Engineers / Divisional Engineers (Sr. DEN / DEN), aided by Assistant Divisional Engineer / Assistant Engineers (ADEN/AEN) / Senior Section Engineers (SSE)/Section Engineers (SE) (P-way) take care of day to day operations, repair and maintenance of the track.

Track Machines and Monitoring Directorate of RDSO is responsible for Track Monitoring by Track Recording Cars and Rail Profile Measurement System[21], Testing of track components like Sleepers, Fastening, welds, etc. Entire length of track of Indian Railways is monitored by Track Recording Cars of RDSO.

1.4 Audit Objectives

The review was carried out with a view to assess:

1. Whether the maintenance of tracks was planned and undertaken following the laid down norms and keeping in view the instructions of Railway Board?
2. Whether the resources/infrastructure required for maintenance of tracks were available and used efficiently and effectively?

1.5 Audit Criteria

The provisions laid down in the following manuals/documents were adopted as Audit Criteria:

- Indian Railway Permanent Way Manual (IRPWM)
- Indian Railway Small Track Machine Manual (IRSTM)
- Indian Railway Track Machine Manual (IRTMM)

[21]Rail profile measurement is a system of inspection and monitoring of track by mechanical means in which laser based contactless track recording cars, portable accelerometers and optical rail profile measurement etc. are used.

- Indian Railway Code for the Engineering Department
- Vision 2020 Document of IR
- Manual of instructions on long welded rails (Long Welded Rails/ Continuous Welded Rails)
- Ultrasonic Flaw Detection (USFD) Manual
- Guidelines/ instructions issued by Railway Board / Zonal Railway relating to track maintenance

1.6 Audit scope, methodology and sample

The review covered the period from 01 April 2016 to 31 March 2017. Audit assignment was aimed at studying maintenance of track vis-à-vis provisions of different codes/ manuals, safety measures prescribed and other related orders and instructions issued by the Railway Board from time to time. The focus of the study was primarily on maintenance of tracks on selected 29 sections of High Density Network (HDN) Routes. Eight sections non-HDN routes were also selected for study and comparison.

Audit methodology consisted of examination of records at the Zonal / Divisional Headquarters and field offices relating to action for compliance to plan/ policies framed by the IR and their implementation at the field level, examination of records maintained in Assistant Divisional Engineer/Senior Section Engineer (P-way) offices of selected sections, Zonal and Divisional Engineering Department, Safety Department and at Research Designs & Standards Organisation (RDSO), Lucknow.

In Indian Railways, a common rail track is used for both passenger and freight traffic. With increase in passenger and freight traffic over the recent years, the rail network has experienced severe capacity constraints. The major hub of activity, namely the Golden Quadrilateral and its diagonals connecting the major metros – Mumbai, Delhi, Chennai and Kolkata constitute merely 25 *per cent* of the total network; but carry around 70 *per ce*nt of total freight resulting in consequent over-saturation in levels of capacity utilisation in a number of stretches. There are seven High Density Networks over Indian Railway:

1. Delhi-Howrah along with the alternative 'B' route on Northern Railway and its extension towards Shakurbasti-Bhatinda-Suratgarh and Andal Sainthia for the coal routes
2. Mumbai-Howrah along with the link route of Bilaspur-Anuppur-Katni-Bina-Kota and Jalgaon-Surat

3. Delhi-Mumbai via Kota-Ratlam including alternative route of Delhi-Rewari-Phulera-Ajmer-Chittorgarh and Gandhidham-Palanpur-Bhildi-Samdari-Jodhpur Bhatinda and Panvel JNPT
4. Delhi-Guwahati via Moradabad–Sitapur-Burhwal-Gonda Gorakhpur-Chhapra Barauni-Katihar
5. Delhi-Chennai via Jhansi-Bhopal-Itarsi-Nagpur-Ballarshah
6. Howrah-Chennai along with alternative route via Jharsuguda-Sambalpur-Titlagarh-Vizianagram including 3rd line between Vizianagram and Kotavalasa and 4th line between Kotavalasa and Simhachalam North
7. Mumbai-Chennai along with link route Guntakal – Hospet Hubli-Vasco (iron ore circuit)

In respect of three HDN routes viz. HDN 1, 2 and 7, 100 *per cent* sections with more than 150 *per cent* capacity utilisation and 50 *per cent* of the sections with 100 to 150 *per cent* capacity utilisation were selected for a detailed review in audit. Besides, a few sections with utilization in excess of 90 *per cent* line capacity were also included. Eight non-HDN sections with more than 100 *per cent* line capacity utilisation were also selected. The following 37 sections were selected over five Zonal Railways:

Table 2– Details of sample selection

S.no	Zonal Railway	Name of the section	Route KM	Line Capacity in 2015-16
		HDN-1 Delhi-Howrah		
1.	NCR	Dadri-Dankaur	17.6	140
2.	NCR	Tundla-Shikohabad	36.4	156
3.	NCR	Shikohabad-Panki	183.4	154
4.	NCR	Panki-Juhi	7.4	154
5.	NCR	Juhi-Kanpur	1.4	158
6.	NCR	Juhi-Chandari	2	99
7.	NCR	Allahabad-Naini	7.48	125
8.	NCR	Naini-Cheoki	1.4	120
9.	NCR	Jeonathpur-Mughalsarai	7.8	128
10.	ECR	Mughalsarai-Dehri-on-Sone	117.1	106
11.	ECR	Dehri-on-Sone-Sonenagar	5.7	120
12.	ECR	Sonenagar-Gaya	79.4	93
13.	ECR	Gaya-Gomoh	169.1	103
		HDN-2 MUMBAI-HOWRAH		
14.	SER	Jharsuguda-Rourkela	101	106
15.	SER	Rourkela-Bondamunda	8.5	102
16.	SER	Tata-Kharagpur	134	96
17.	SER	Santragachi-Tikaipara	5.6	104
18.	SER	Tikiapara-Howrah	2	113
		HDN-7 MUMBAI-CHENNAI		
19.	SR	Arakkonam-Tiruvallur	26.83	111
20.	SR	Pattabiram-Avadi	3.91	103

Table 2– Details of sample selection				
S.no	Zonal Railway	Name of the section	Route KM	Line Capacity in 2015-16
21.	SR	Avadi-Villivakkam	11.61	119
22.	SR	Villivakkam-Vyasarpadi	5.8	123
23.	SR	Basin Bridge- Chennai Central	2.22	128
24.	SWR	Vellary-Hospet	64.84	126
25.	SWR	Hospet-Gadag	85.14	114
26.	SWR	Gadag-Hubli	58.08	139
27.	SWR	Hubli-Dharwar	20.09	119
28.	SWR	Dharwar-Londa	70.36	141
29.	SWR	Londa-Castle Rock	24.48	99
		NON-HDN ROUTES		
30.	ECR	Patna-Danapur	9.00	120
31.	ECR	Danapur-Ara	39	127
32.	ECR	Ara-Buxar	69	125
33.	ECR	Buxar-Mughalsarai	94	128
34.	SER	Nimpura – Gokulpur	6	137
35.	SER	Panskura – Haldia	70	148
36.	SER	Burnpur – Asansol	5.6	139
37.	SER	Muri – Barkakana	58	165

In addition, on these five Zonal Railways, sections where accidents/derailments, etc. have taken place for reasons attributable to track or where final investigation report and reason for accident was yet to be known, during the past three years (2014-15 to 2016-17) were also checked in detail. Data regarding reasons for accident, rail weld failure, etc. for one year i.e. 2016-17 was also collected and analysed. Audit findings and recommendations were discussed with the Ministry of Railways during an Exit Conference on 30 August 2017. Their responses have been duly incorporated in the Audit Report.

The audit was conducted in selected heavy traffic routes over five Zonal Railways (NCR, ECR, SER, SR and SWR), on which traffic much more their line capacity was being handled. Similar deficiencies and issues may be prevalent in other Zonal Railways as well. The basic purpose of this audit was to identify the weakness in track maintenance work and highlight systemic weakness, which are required to be addressed by Indian Railways.

1.7 Acknowledgement

Audit acknowledges the co-operation extended by the Railway Board and the Zonal Railway Administrations during the field audit.