IMPACT OF RAIL GRINDING ON INDIA'S LARGEST BROAD & STANDARD GAUGE MASS RAPID TRANSIT NETWORK

दिल्ली मेट्रो रेल कॉरपोरेशन लिमिटेड
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Map – India & Delhi

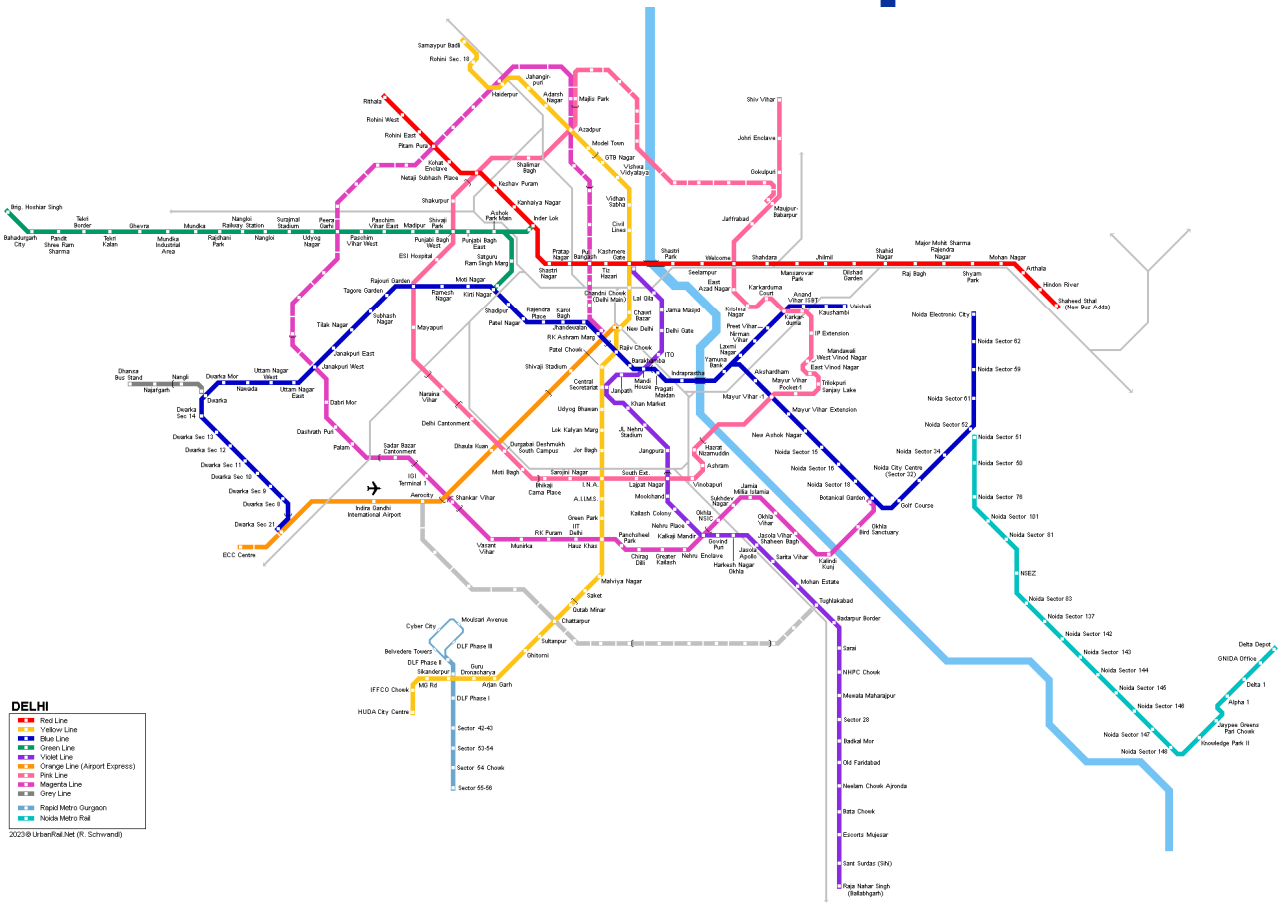
Introduction – DMRC

- Delhi Metro Rail Corporation (DMRC) is headquartered in New Delhi and was founded in 1995 as a joint venture with equal equity participation of the Government of India and Government of the National Capital Territory of Delhi.
- DMRC started construction of its first line in 1998 and opened its gate for commercial operation in 2002.
- DMRC's network have both standard gauge (SG) and broad gauge (BG) lines connecting 286 stations on 12 lines with a total route length of 390 Kms.

Introduction – DMRC

- DMRC operates commercially from 0500 to 2330 Hrs. carrying over 6.5 million passengers in 4,400 trips on a daily basis.
- DMRC connects Delhi and nearby satellite cities of Gurgaon, Noida, Ghaziabad, Faridabad, Bahadurgarh and Ballabhgarh in the Nation Capital Region of India.
- DMRC network busiest lines carry 44 MGT on annual basis.
- DMRC is the largest metro network in India and is unique as part of the network is Broad Gauge (1676mm) and Standard Gauge (1435mm)

Delhi Metro - Map



Operational Network		
Line	**Length**	**Stations**
1-Red	35 Kms	29
2-Yellow	49 Kms	37
3/4-Blue	65 Kms	58
5-Green	29 Kms	23
6-Violet	46 Kms	34
7-Pink	59 Kms	38
8-Magenta	37 Kms	25
9-Grey	6 Kms	4
APL-Orange	23 Kms	6
Aqua	29 Kms	21
Rapid	12 Kms	11
Total	**390 Kms**	**286**

Population and Network - Worldwide

Country	State	Population (Million)	Metro Name	System Length (Km)	Annual Ridership (Millions)
China	Shanghai	29.2	Shanghai Metro	803	2835
China	Beijing	21.7	Beijing Subway	780	2293
Japan	Tokyo	37.1	Tokyo Metro	195	2757
India	**New Delhi**	**32.9**	**Delhi Metro**	**390**	**2372**
South Korea	Seoul	9.9	Seoul Metropolitan Subway	345	2127
Russia	Moscow	12.7	Moscow Metro	397	2062
USA	New York	18.9	New York City Subway	337	1793

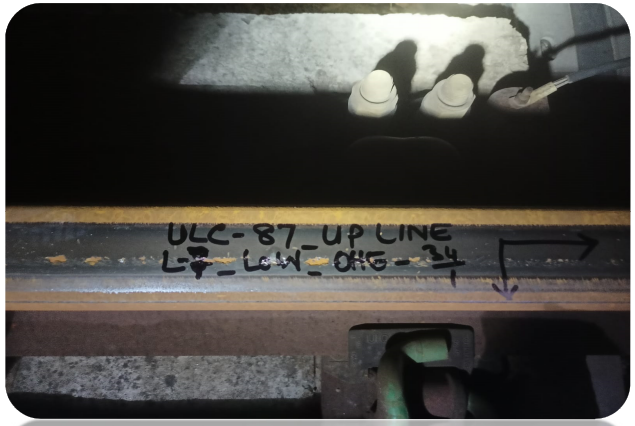
Track Details

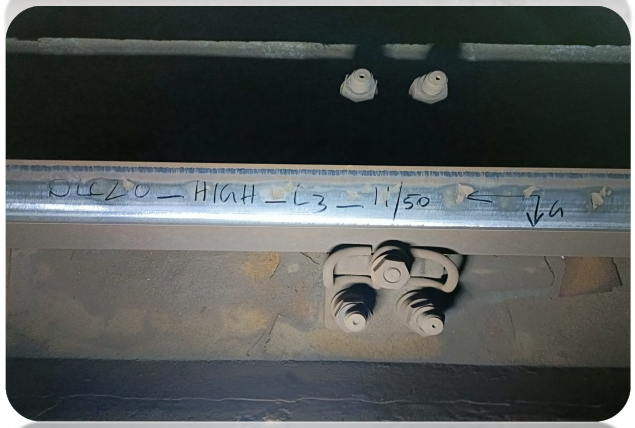
Red Line (BG) UP		Yellow Line (BG) UP		Blue Line (BG) UP		Green Line (SG) UP	
Track	Length (km)	Track	Length (km)	Track	Length (km)	Track	Length (km)
Mild Curve	1.35	Mild Curve	2.16	Mild Curve	4.52	Mild Curve	1.882
Sharp Curve	8.72	Sharp Curve	19.01	Sharp Curve	16.01	Sharp Curve	3.617
Tangent	14.32	Tangent	26.87	Tangent	35.83	Tangent	20.986
Red Line (BG) DN		**Yellow Line (BG) DN**		**Blue Line (BG) DN**		**Green Line (SG) DN**	
Mild Curve	1.68	Mild Curve	2.48	Mild Curve	4.8	Mild Curve	1.94
Sharp Curve	8.13	Sharp Curve	18.56	Sharp Curve	16.42	Sharp Curve	3.457
Tangent	14.56	Tangent	27.04	Tangent	35.42	Tangent	21.092
Total	**48.76**	**Total**	**96.12**	**Total**	**96.44**	**Total**	**52.974**

Track Details

Violet Line (SG) UP		Pink Line (SG) UP		Magenta Line (SG) UP		Orange Line (SG) UP	
Track	**Length (km)**	**Track**	**Length (km)**	**Track**	**Length (km)**	**Track**	**Length (km)**
Mild Curve	2.411	Mild Curve	2.629	Mild Curve	1.806	Mild Curve	0.901
Sharp Curve	18.3	Sharp Curve	25.466	Sharp Curve	17.501	Sharp Curve	12.604
Tangent	25.389	Tangent	36.049	Tangent	26.159	Tangent	9.413
Violet Line (SG) DN		**Pink Line (SG) DN**		**Magenta Line (SG) DN**		**Orange Line (SG) DN**	
Mild Curve	2.574	Mild Curve	2.105	Mild Curve	1.907	Mild Curve	0.933
Sharp Curve	18.274	Sharp Curve	25.659	Sharp Curve	17.164	Sharp Curve	12.565
Tangent	25.25	Tangent	36.537	Tangent	25.659	Tangent	9.42
Total	**92.198**	**Total**	**128.699**	**Total**	**90.196**	**Total**	**45.836**

Common Defects Observed on Rail





DMRC - Rail Related Concerns

- Head Hardened Rails has been used on the complete railway line.
- Visible surface defects including corrugation, RCF, pitting, spalling, etc. seen on track within first few years of operations.
- Stand alone issues of corrective rail maintenance.
- Desire to reduce rail wear.
- Small window for maintenance – 0000 Hrs. to 0430 Hrs. only.

Search for Solution(s)

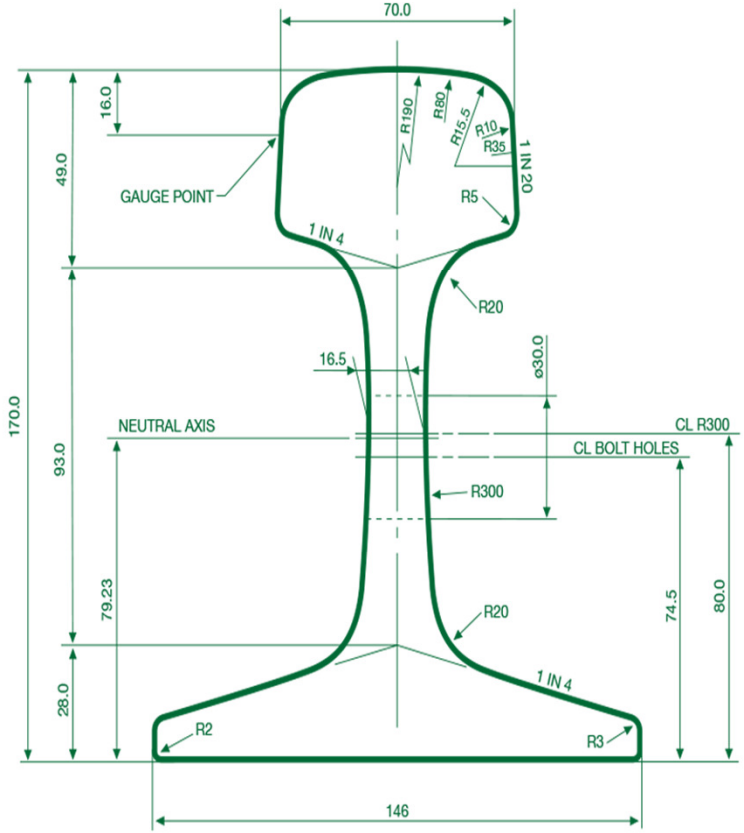
Three options were reviewed:

- **Rail Replacement**
  - **Replacement cost of Premium Head Hardened Rails is disproportionally high and extremely time consuming**
- **Rail Grinding**
  - **Could potentially address both preventive and corrective needs of DMRC**
- **Rail Milling**
  - **Slower process and predominantly for corrective maintenance and spot attention**

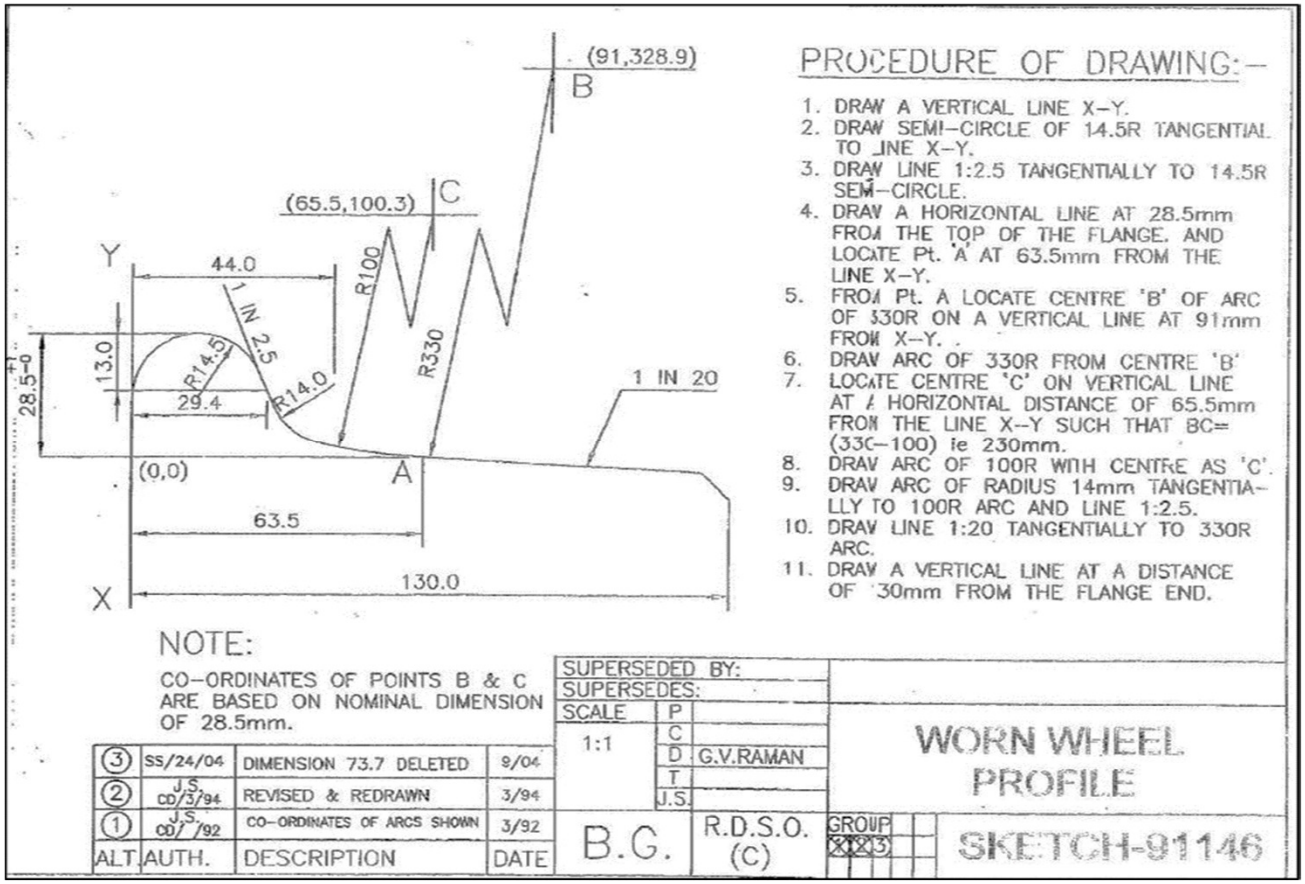
Other Deciding Factors

- **Gauge Type – Broad and Standard with:**
  - **Tangent Curves, Mild Curves and Sharp Curves**
  - **Different target rail profiles for different segments (High Rail / Low Rail)**
  - **Different MGTs across different lines requiring focused maintenance strategy**
- **Rail Type – UIC 60, 1080 Grade, Head Hardened Rail having:**
  - **Good ductility, high fatigue strength and moderate fracture toughness.**
  - **Good chemical property with enhanced head performance.**
- **Wheel Type – Custom Made for DMRC**

Head Hardened Rail used in DMRC



Wheel Profile used in DMRC



- **Wheel rail interaction was very important to understand while deciding on the preferred solution**

MGT of Broad Gauge Lines

Line	Section	Maximum MGT
Line 1 (East)	New Bus Adda to Dilshad Garden	15
Line 1 (West)	Dilshad Garden to Rithala	30
Line 2 (North)	Samaypur Badli to Vishwavidhyalaya	22
Line 2 (Mid)	Vishwavidhyalaya to Qutub Minar	44
Line 2 (South)	Qutub Minar to Huda City Centre	22
Line 3 (East)	Noida Electronic City to Yamuna Bank	40
Line 3 (Mid)	Yamuna Bank to Dwarka	40
Line 3 (West)	Dwarka to Dwarka Sector 21	22
Line 4	Yamuna Bank to Vaishali	22

MGT of Standard Gauge Lines

Line	Section	Maximum MGT
Line 5 (East)	Inderlok/Kirti Nagar to Mundka	14
Line 5 (West)	Mundka To Bahadurgarh	10
Line 6 (North)	Kashmere Gate to Badarpur	30
Line 6 (South)	Badarpur to NCB Ballabhgarh	15
Line 7	Majlis Park to Shiv Vihar	17
Line 8	Botanical Garden to Janakpuri West	17
Line APL	New Delhi to Dwarka Sector 21	10

Preferred Solution

Rail Grinding

- Compatible with both preventive and corrective rail reprofiling strategies.
- Helps in achieving a specific designed target profile to improve the rail-wheel interaction.
- Improvement in steering by increasing rolling radius difference of wheelsets.
- Reduction in surface defects to a minimum level.
- Possible to switch between different grinding patterns easily.
- Reduces the wear between flange and inner side of rail; and
- Prolong the rail service life by means of asymmetrical rail grinding in sharp-radius curves.

Preferred Solution – Rail Grinding

- DMRC purchased a 16-stone Light Rail Grinder (LRG-18) Machine in 2009 from M/s Loram Maintenance of Way Inc. USA.
- The scope of supply included 04 years of comprehensive Operations and Maintenance support which was provided by M/s Vandhana International, India.
- The initial machine could work on both SG & BG lines.
- Realizing the benefits and effectiveness of a dedicated Rail Grinding Program, DMRC purchased another 16-stone Light Rail Grinder (LRG-30) in 2017 exclusively for SG lines.

DMRC – Loram's LRG Machines

LRG18 – for BG /SG

LRG30 – for SG

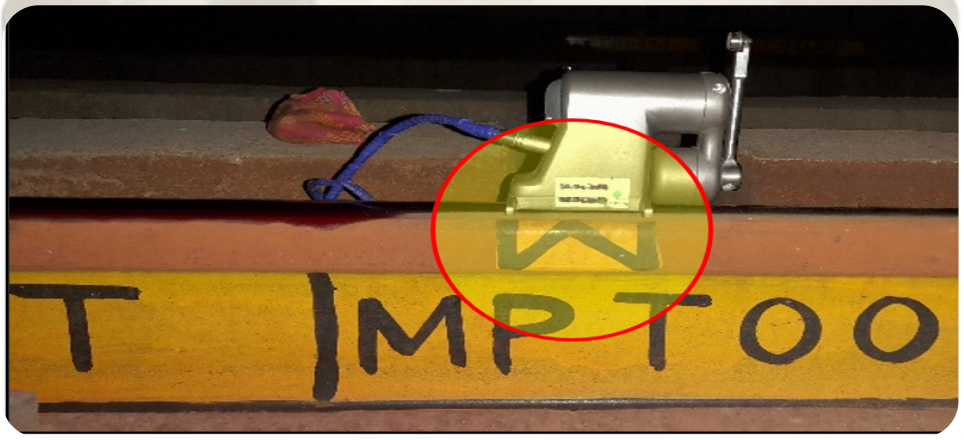
Pattern Sheet used in LRG

DMRC Grinding Frequency

- Team of Rail Quality Experts from LORAM, USA had visited DMRC and inspected their rail tracks for determination of grinding frequency. As an outcome of the study, LORAM proposed the following rail grinding frequency to attain maximum benefits from the deployed rail grinding machines.
- Detailed test site analysis (through inspections) was conducted to validate these aspects.

Track	Grinding Frequency (Months)	
	< 25 MGT Per Year	> 25 MGT Per Year
Tangent/Straight	27	18
Mild Curve	18	12
Sharp Curve	9	6

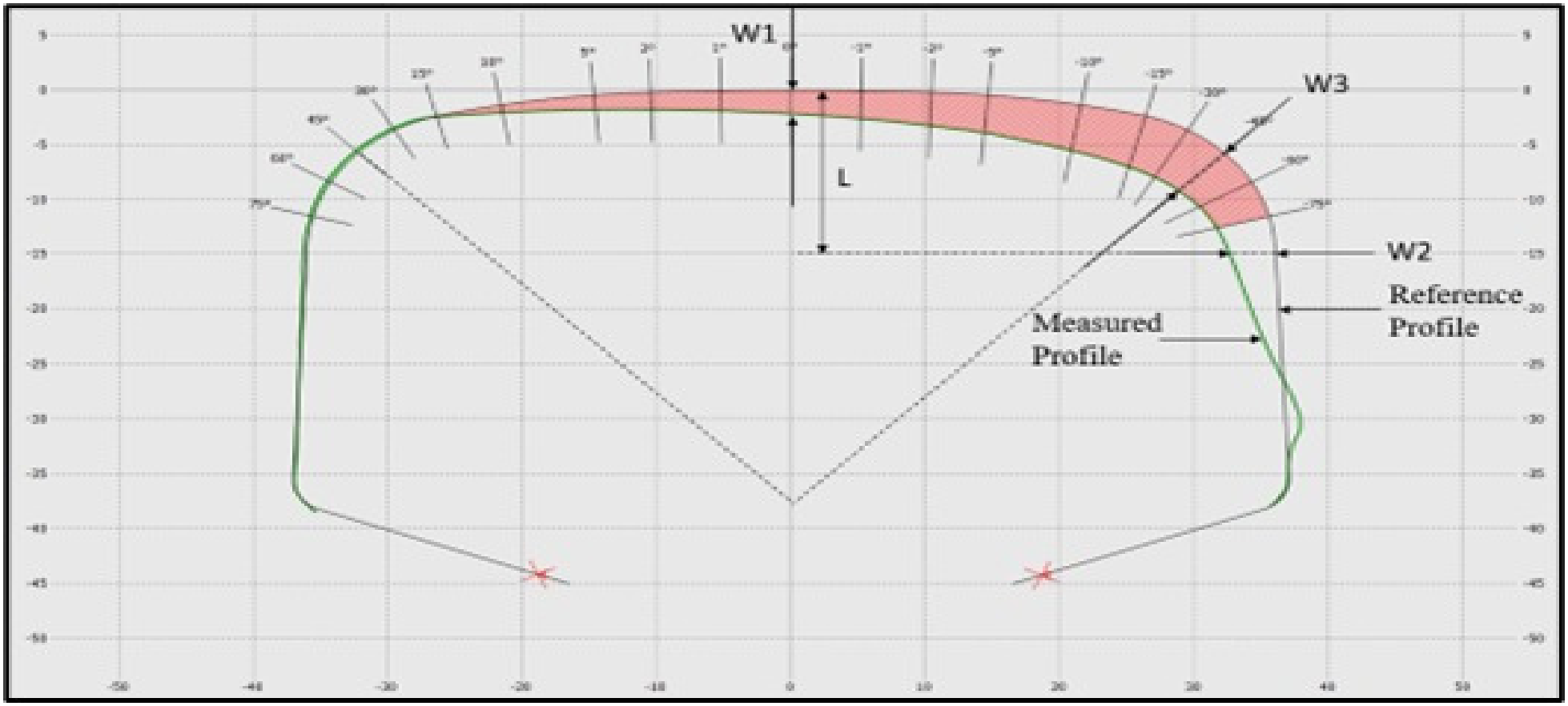
Inspection Procedure



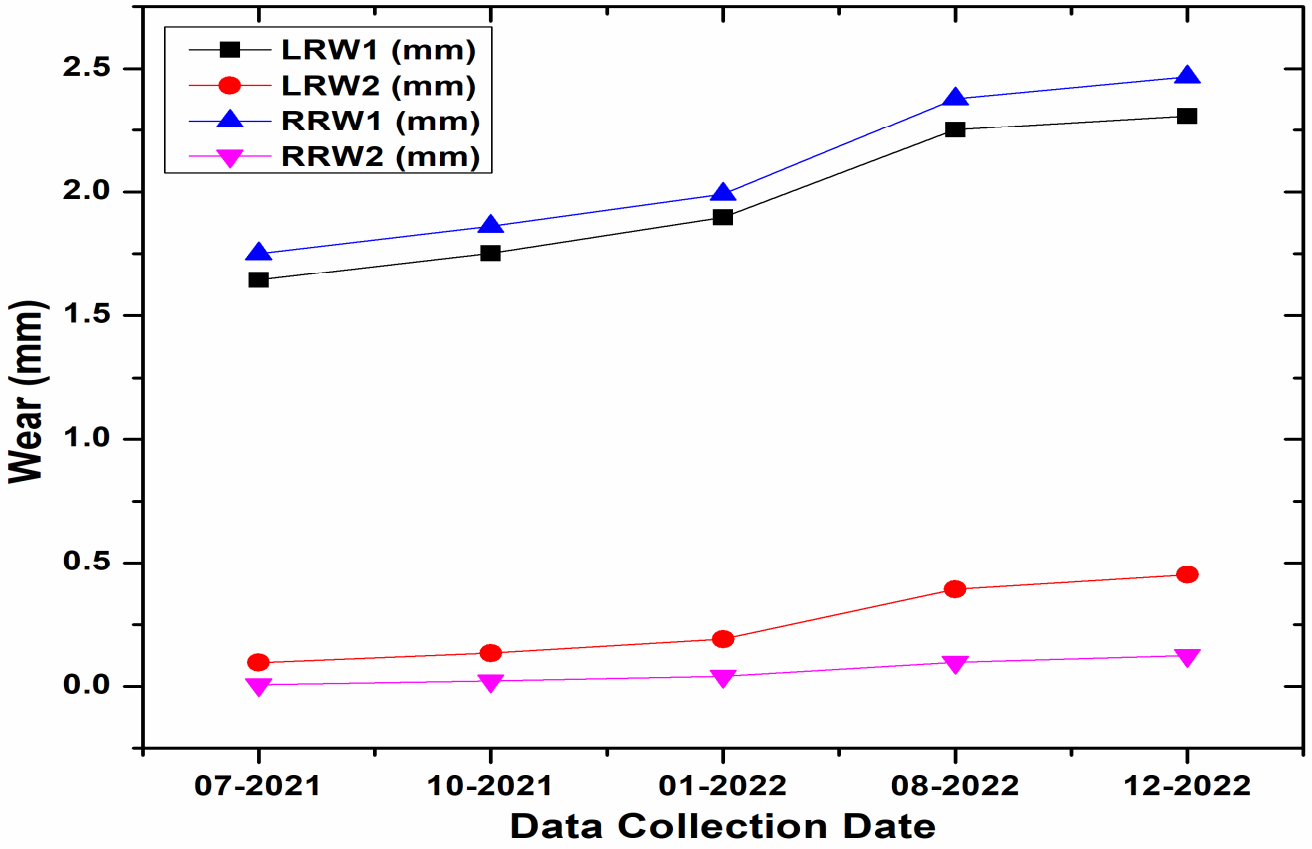
LRG – 18 Grinding on DMRC Network

- Video showing Rail Grinding on Blue Line by LRG-18 Machine during night block.

Rail Wear Study



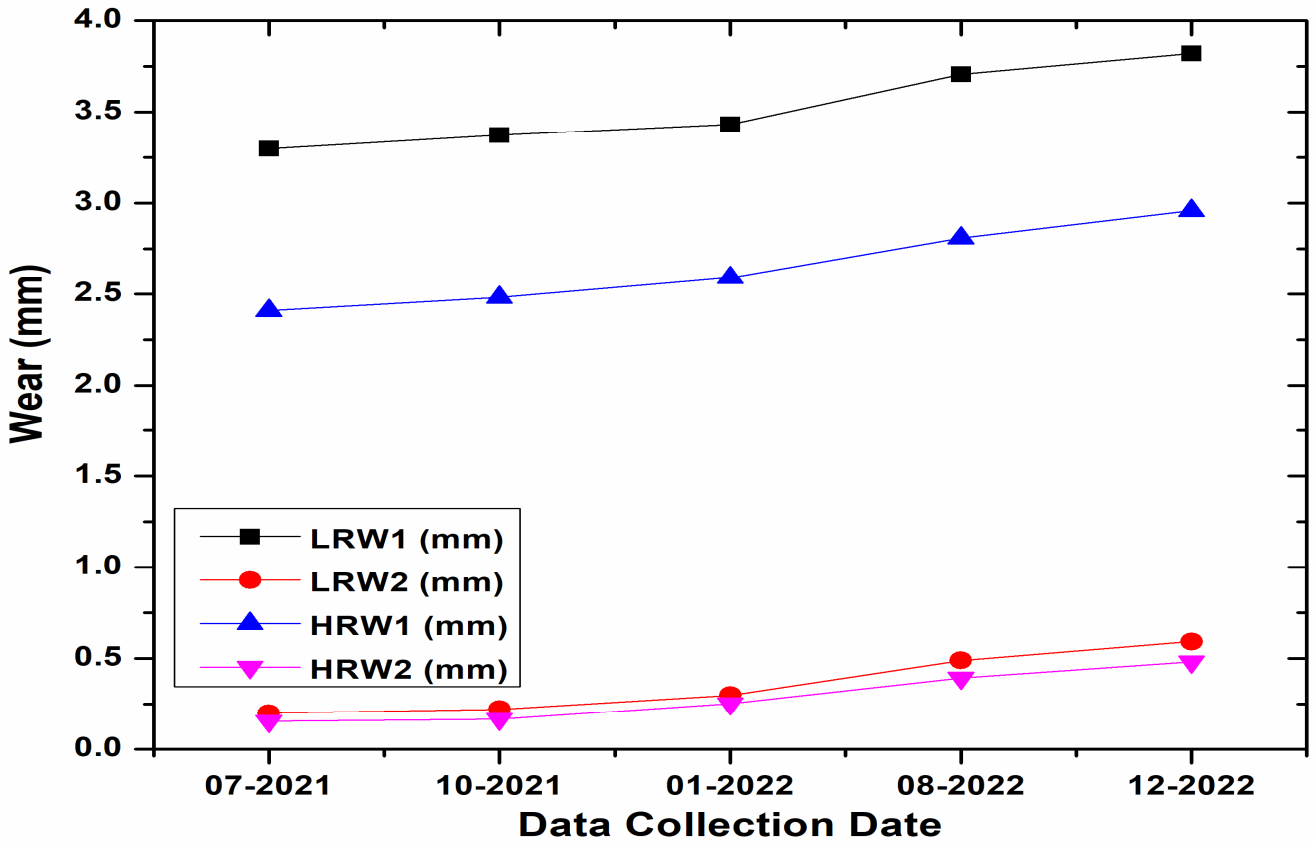
Wear Analysis for Tangent



Grinding carried out in: 08-2022

- Reduction in natural rail wear on tangent post-grinding
- Data revealed a shallower slope attained for tangents post-grinding which was beneficial.

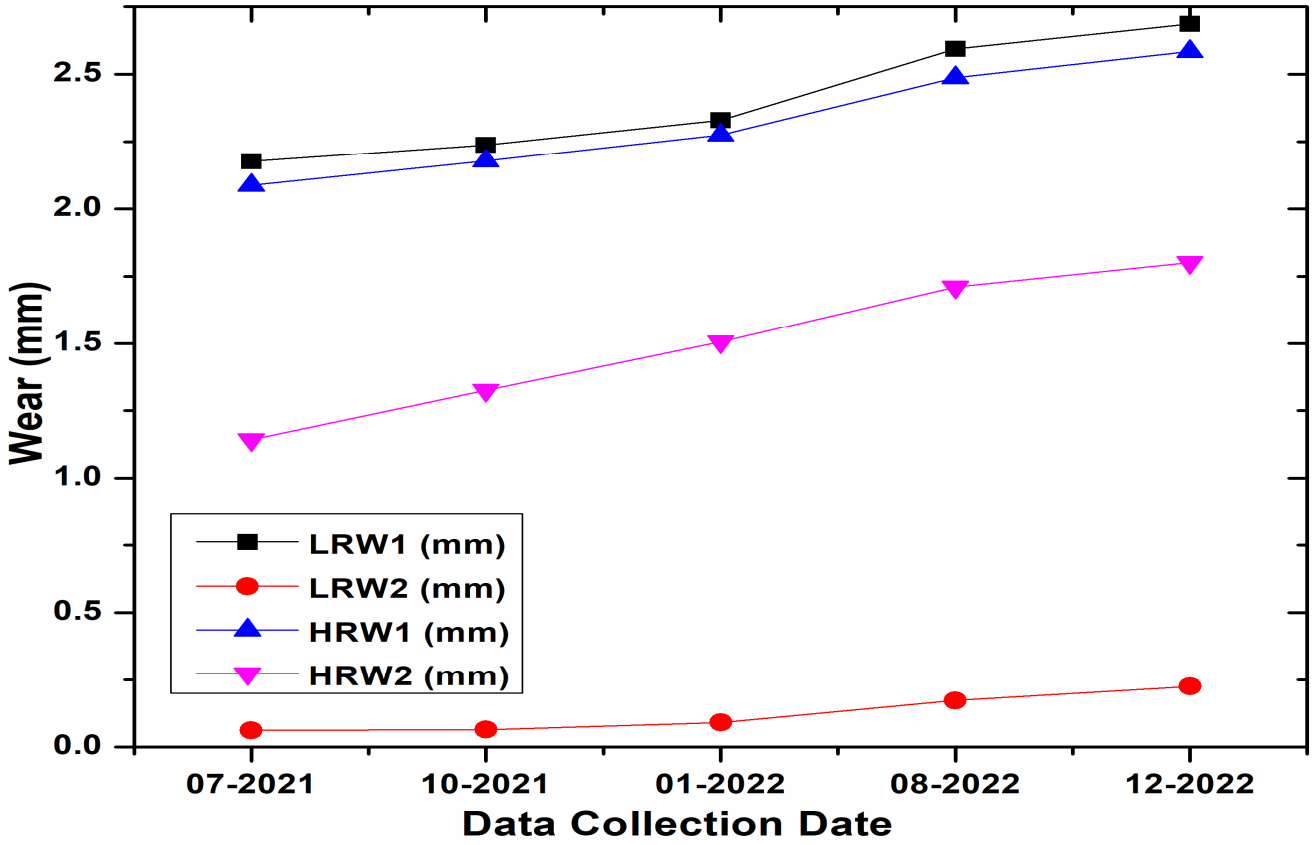
Wear Analysis for Mild Curve



Grinding carried out in: 08-2022

- Reduction in natural rail wear on mild curve post-grinding
- Data revealed a shallower slope attained for mild curves post-grinding which was beneficial.

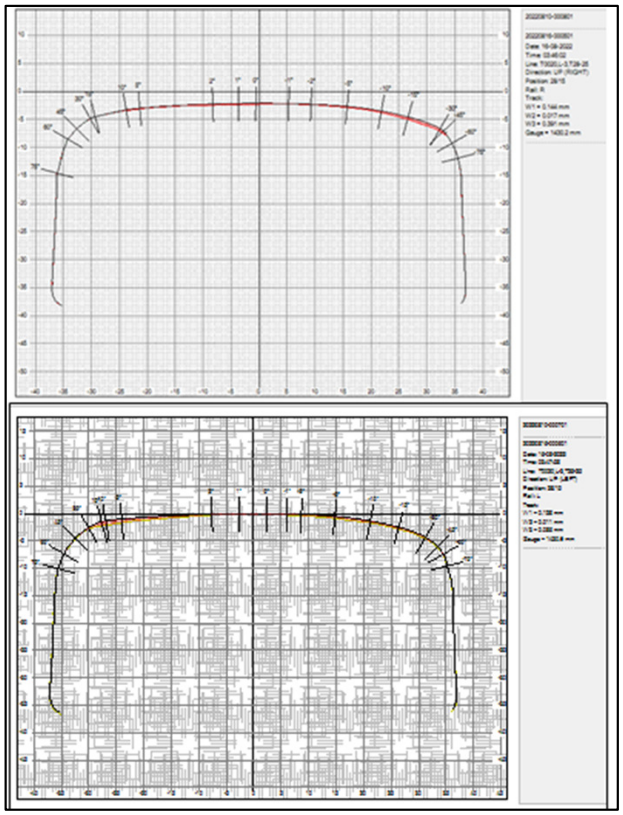
Wear Analysis for Sharp Curve



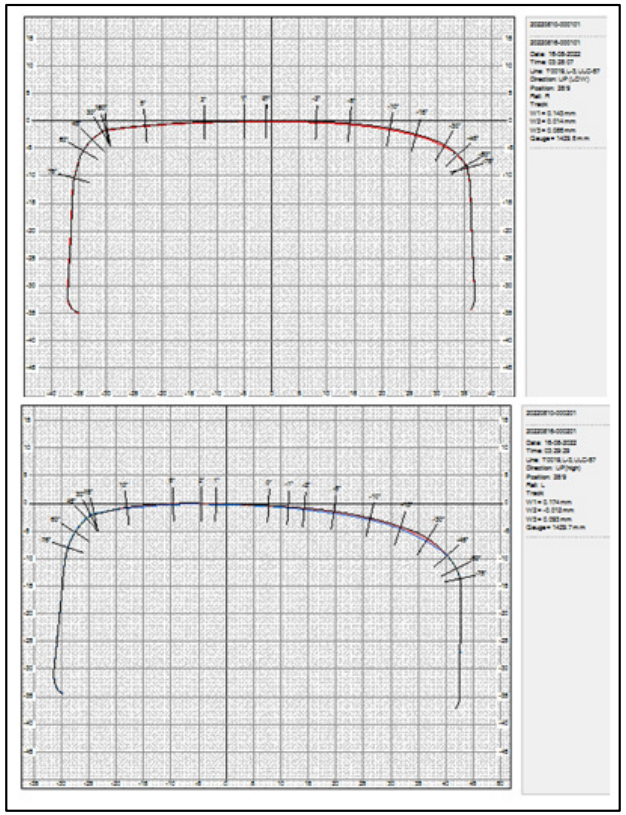
Grinding carried out in: 08-2022

- Reduction in natural rail wear on sharp curve post-grinding
- Data revealed a shallower slope attained for sharp curves post-grinding which was beneficial.

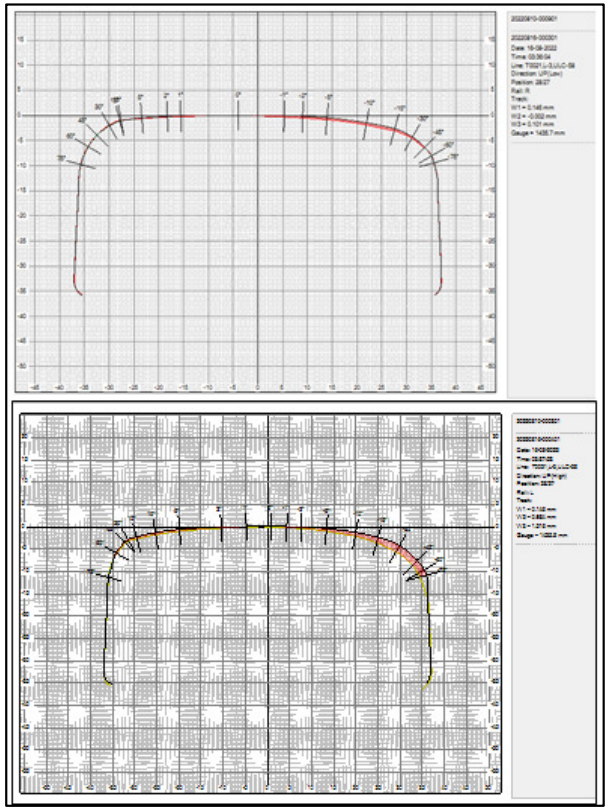
Wear Analysis by MiniProf



Tangent



Mild Curve



Sharp Curve

BG - Grind Quality Index

Track	Curve Name	Degree of Curve (DOC)	Pre Grind Data		Post Grind Data	
			High or Left Rail GQI	Low or Right Rail GQI	High or Left Rail GQI	Low or Right Rail GQI
UP	T-10_19	0.00	81	76	94 ▲	89 ▲
UP	EXT ULC-22	2.88	57	80	81 ▲	94 ▲
UP	T-10_73	0.00	89	74	97 ▲	88 ▲
UP	EXT ULC-21	0.68	59	83	83 ▲	91 ▲
UP	T-9_60	0.00	87	85	98 ▲	95 ▲
UP	Ext ULC-2	5.73	87	41	94 ▲	83 ▲
UP	ULC - 15	1.73	75	99	87 ▲	100 ▲
UP	T2_63	0.00	43	58	72 ▲	83 ▲
UP	ULC - 16	0.48	95	96	100 ▲	100 ▲
UP	T4_17	0.00	46	54	75 ▲	87 ▲

Data implying improvement of GQI in every grind cycle increased the achievement of asymmetric rail profile.

BG - Observations on RCF – Low Rail

Pre-Grind

Post-Grind

Mild Curves

Sharp Curves

BG - Observations on RCF – High Rail

Pre-Grind

Post-Grind

Mild Curves

Sharp Curves

SG - Grind Quality Index

Track	Curve Name	Degree of Curve (DOC)	Pre Grind Data		Post Grind Data	
			High or Left Rail GQI	Low or Right Rail GQI	High or Left Rail GQI	Low or Right Rail GQI
UP	ULC-133	7.95	97	44	100 ▲	79 ▲
UP	T55-57	0.00	93	56	98 ▲	77 ▲
UP	ULC-115	6.85	98	50	99 ▲	85 ▲
UP	T49_99	0.00	56	65	86 ▲	88 ▲
UP	T45_60	0.00	77	87	83 ▲	90 ▲
UP	ULC-105	5.62	98	52	100 ▲	89 ▲
UP	ULC-96	5.87	97	50	100 ▲	87 ▲
UP	ULC-89	3.45	95	51	100 ▲	90 ▲
UP	T36_47	0.00	82	82	99 ▲	86 ▲
UP	T32_81	0.00	95	69	100 ▲	82 ▲

Data implying improvement of GQI in every grind cycle increased the achievement of asymmetric rail profile.

SG - Observations on RCF

Pre-Grind

Post-Grind

Mild Curves

Sharp Curves

Conclusions

- Rail grinding has proven to be a right strategy for DMRC's rail maintenance program to control rail fatigue and improve rail-wheel interaction.
- DMRC has continued to outsource all technical support including Operations & Maintenance to M/s Loram USA and M/s Vandhana International Pvt. Ltd., India for last 13 years.
- This has resulted in increase in rail surface quality; reduction in RCF and achievement of asymmetric rail profile leading to better system dynamics including reduced wheel wear.

Conclusions

- It is also realized that due to limited block availability during maintenance shifts, more innovative efforts needs to be implemented for attaining maximum output from the rail grinding program.
- DMRC would increase effective monitoring of test sites in order to critically demonstrate the extension of rail life.
- The current presentation is a preamble to the outcomes of the preliminary data on rail wear and subsequent studies will be done to explore tangible increase in rail life.

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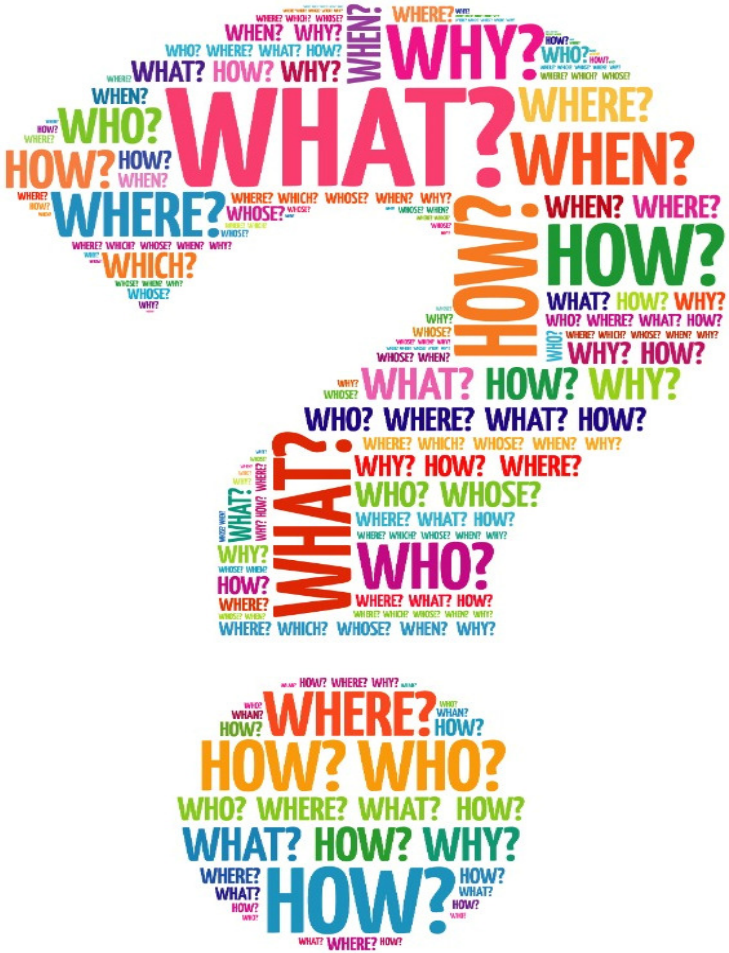
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