

# Developing An It Based Safety Performance Index Measurement Tool for Measuring Safety Culture of a Company - A Case Study Tata Steel

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**Abstract**—Safety culture is increasingly acknowledged as a pivotal determinant of organisational performance and sustainability, particularly within high-risk industries such as steel manufacturing. Traditional methods for measuring safety culture often rely on manual observations, periodic audits, and subjective assessments, which may not fully reflect real-time performance or underlying behavioural drivers. This research article explores the design and development of an IT-based Safety Performance Index (SPI) measurement tool tailored for steel manufacturing environments, using Tata Steel as a case study. The study proposes a comprehensive framework that integrates digital data collection, analytics, visualization, and predictive scoring to monitor, assess, and improve safety culture. By leveraging real-time data streams and advanced analytics, the proposed tool enhances decision-making, drives continuous safety improvement, and aligns organizational behaviors with strategic safety goals. Key findings demonstrate that the IT-based tool enables more accurate, dynamic, and actionable insights compared to conventional safety measurement approaches. The research contributes a practical model for industries aiming to advance safety culture through digital transformation.

**Index Terms**—Safety Culture, IT-based measurement tool, Safety Performance Index, Tata Steel, digital analytics, occupational safety.

## I. INTRODUCTION

Tata Steel is an Integrated Steel Plant and it has started implementing Safety Excellence Journey from 2004 and since then it has undergone different phases to excel in Safety Maturity Curve over time. Last few years of the Safety Excellence Journey, have been

around managing safety at the shop floor level by understanding the various concerns from the workforce and addressing them through a method of 'Find It- Own It- Fix It' hazard approach. This approach was instrumental in improving our safety performance results.

To effectively drive into the next leg of the safety excellence journey, these individual experiences are required to be supplemented with data driven decision making. Collecting, analysing, and interpreting data to identify patterns, correlations, and trends that can guide decision-making processes at the shop floor and help assess the culture of safety for various units of the organization, has become the need of the hour. It is also imperative for the senior leadership to get a comprehensive view of the safety culture of the organization, which has more than 150+ units across India. Safety Line walks (Safety visit) need specific focus areas to be addressed and meetings need crucial agendas to be discussed.

It may also be noted that a Safety workshop with senior leadership was organised where it was suggested to focus more on lead indicators for improving our safety culture. Hence, to further refine our approach towards managing safety across the organization, the 'Safety Performance Index' (SPI) was formulated. This has given a push to develop a safety culture in the organisation.

The Safety Performance Index (SPI) is a fully automated and comprehensive scoring system designed to measure and improve safety performance of the organization. It is applied across various organizational levels, starting from the CEO & MD to various Vice Presidents, to departmental Chiefs, and

has a dual focus on lead and lag safety performance indicators.

The index is a single-version of truth derived from various data platforms such as Ensafe (safety management system); Contractor Labour Management system, SAP-HR, Generic Document Control System, Video Analytics portal, Generative AI reports etc.

Below Bradley curve (A tool used by Dupont to measure safety culture maturity) explains how an independent and interdependent safety culture helps reduce the injury rate in an organization. SPI has become a tool to drive this safety culture and by integrating a quality index, we are trying to reach to the optimum level of Interdependent safety culture.

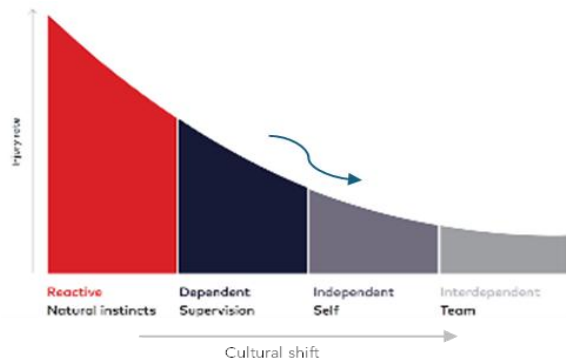


Table 1 Bradley Curve - Injury Rate v/s Cultural Shift (Reference taken from Dupont safety system)

The lead indicators measure compliance of proactive safety practices, while lag indicators reflect the frequency of safety incidents. The total SPI score, ranging from 0 to 350, provides a holistic view of a department's safety performance.

### 1.1 Problem Statement

Despite considerable investments in safety programs, many organizations, including Tata Steel, face challenges in accurately measuring safety culture. Existing methods frequently depend on qualitative audits, self-reported surveys, or lagging indicators such as injury rates. These approaches provide limited insights into the dynamic and multifaceted nature of safety culture.

To address these limitations, there is a need for an IT-based Safety Performance Index (SPI) measurement tool that can integrate multiple data sources, provide real-time monitoring, and generate actionable insights that reflect true safety performance and cultural attributes.

## II. LITERATURE REVIEW

### 2.1 Understanding Safety Culture

Safety culture emerged as a concept following major industrial disasters in the late 20th century, such as the Chernobyl accident, which highlighted the role of organizational values and human behaviour in safety outcomes (Reason, 1997). A strong safety culture is characterized by open communication about risks, shared commitment to safety across all levels, proactive hazard identification, and trust between employees and management.

### 2.2 Traditional Safety Measurement Approaches

- (i) Conventional safety measurement tools include:
- (ii) Lagging Indicators: Metrics such as lost time injury frequency rate (LTIFR) or total recordable incident rate (TRIR). These are retrospective and reflect outcomes rather than underlying safety culture.
- (iii) Safety Audits: Periodic evaluations of compliance with procedures and standards.
- (iv) Safety Climate Surveys: Questionnaire-based assessments of employee perceptions about safety.

While useful, these methods have limitations: they lack timeliness, may be influenced by respondent bias, and may not capture emerging risks or behavioural trends.

### 2.3 IT-Based Safety Performance Tools

Advances in information technology—IoT sensors, mobile platforms, data analytics, and dashboards—offer opportunities to develop dynamic and integrated safety measurement systems. Technology can capture real-time data relating to incidents, near misses, hazard reports, training compliance, and behavioral observations, enabling more robust safety management and predictive insights (Martínez-Criado et al., 2018).

However, the deployment of IT-based safety measurement remains nascent in heavy industries, particularly in developing contexts.

## III. RESEARCH METHODOLOGY

SPI is a composite score that reflects the safety performance of a department. It is divided into two components: lead indicators and lag indicators. The

lead indicators section, valued at 240 points (70% weightage), assesses compliance with key safety metrics. The lag indicator section, valued at 110 points (30% weightage), reflects the frequency of incidents, with fewer incidents yielding a higher score. The total SPI score, capped at 350, provides a comprehensive view of a department's safety performance.

### 3.1 Research Design

This study adopts a mixed-method research design combining qualitative and quantitative data collection with system development. The methodology encompasses:

- (i) Document Analysis: Examination of Tata Steel safety standards, reports, and audit records.
- (ii) Stakeholder Interviews: Discussions with safety officers, supervisors, and workers to identify key cultural attributes and data requirements.
- (iii) Indicator Selection: Development of a comprehensive set of safety performance indicators.
- (iv) System Development: Design and prototyping of the SPI measurement tool.
- (v) Pilot Testing: Implementation of the tool in selected plant areas for evaluation.

### 3.2 Objective of the Study

- (i) To design an IT-based Safety Performance Index (SPI) measurement framework.
- (ii) To integrate multiple safety indicators into a unified digital tool.
- (iii) To evaluate the applicability and effectiveness of the SPI tool in assessing safety culture at Tata Steel.

### 3.3 Hypothesis 1: Effectiveness of IT-Based SPI Framework

- (i) H01 (Null Hypothesis): The IT-based SPI framework does not significantly improve the accuracy and reliability of safety culture measurement compared to traditional safety measurement methods.
- (ii) H11 (Alternative Hypothesis): The IT-based SPI framework significantly improves the accuracy and reliability of safety culture measurement compared to traditional safety measurement methods.

### 3.4 Hypothesis 2: Integration of Multiple Safety Indicators

- (i) H02 (Null Hypothesis): Integration of multiple safety indicators into a unified digital tool does not significantly enhance predictive capability of safety performance.
- (ii) H12 (Alternative Hypothesis): Integration of multiple safety indicators into a unified digital tool significantly enhances predictive capability of safety performance.

### 3.5 Hypothesis 3: Applicability and Effectiveness of SPI Tool

- (i) H03 (Null Hypothesis): The IT-based SPI tool does not significantly improve safety culture outcomes within Tata Steel divisions.
- (ii) H13 (Alternative Hypothesis): The IT-based SPI tool significantly improves safety culture outcomes within Tata Steel division

### 3.6 Data Collection

Data sources include:

- (i) Incident and near miss reports (historical logs)
- (ii) Safety training records
- (iii) Employee safety perception surveys
- (iv) Behavioural observation records
- (v) Reports of corrective actions

### 3.7 Indicator Framework

Safety performance indicators were categorized into leading and lagging indicators:

- (i) Lagging Indicators: Injury rates, property damage incidents, regulatory violations.
- (ii) Leading Indicators: Training completion, hazard reports, corrective action implementation, predictive risk scores, and behavioural observations.

These indicators are weighted and aggregated into an overall Safety Performance Index.

### 3.8 KPIs of safety performance Index, representing elements of Independent & Interdependent safety culture:

- a. Individual engagement and Ownership
  - (i) Safety-Visit compliance (Nos.)
  - (ii) Safety Line-walk (IL3 & above)
  - (iii) Job Cycle Check (JCC) compliance
  - (iv) Reporting of Near Miss
  - (v) CSM Severity Audit (Contractor Site Severity Audit or CSS Audit)

(vi) Annexure# 9 Assessment of Vendors by respective Contract Owner.

b. Responsibility

- (i) Closure of safety Observation in time
- (ii) Closure of Incident Investigation in time
- (iii) Closure of FRCP in time
- (iv) Implementation compliance of Incident recommendations
- (v) Deployment of past Fatal recommendations.
- (vi) Deployment of Management of Change
- (vii) Compliance of red risk recommendation with time
- (viii) Compliance of Multisource recommendations with time

c. Accountability

- (i) Fatalities (Nos.)
- (ii) LTIs – Lost Time Injury (Nos.)
- (iii) First Aid Cases (Nos.)
- (iv) Red Risk Incidents (Nos.)
- (v) Road Safety Violation (Nos.)

(vi) Violations captured through CCTV & Image Analytics

d. Low Risk Tolerance amongst Team members

- (i) Process Safety Audit/ 5S & Visual Workplace Management (VWM) Assessment score
- (ii) Consequence management applied on Life Saving Rule violation. (Captured through command center)
- (iii) Contractor worker found in hazardous Zone without E-Permit.

e. Competency

- (i) Platinum/ Gold skilled worker in the department for contract workers.
- (ii) Compliance of Safety Standard E-Learning modules for employees.

IV. DATA ANALYSIS

Scoring Criteria-

Compliance below 80% = 0

Compliance above 80% = Absolute score

The screenshots from the SPI Dashboard are attached below: This is IT based system and generated using generative AI.

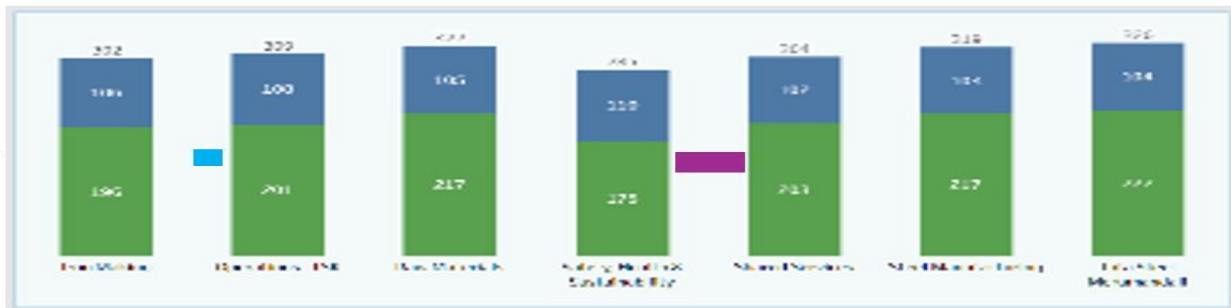


Figure 4.1 The above is the dynamic SPI score for all the divisions.



Figure 4.2 The above is the departmental SPI score of one of the departments

The practice involves several user categories: Reviewers: CEO & Managing Director, as well as Vice Presidents, who evaluate overall safety performance at the highest level- reviewed every month. Scorers: VPs of the divisions, Chiefs of Departments, and all their subordinates, including officers, non-officers, and contractors, who are responsible for

compliance and proactive safety measures- real time scoring and reviews. All 150+ units are ranked; top & bottom performers are reviewed for what went well & what could have been better, in CEO & MD’s monthly reviews and eventually in various Safety Review meetings across levels of the organisation.

4.1 Section: System Design Models, Figures & Data Architecture  
Table 4.3: Safety Culture Dimensions and Measurable Indicators

Dimension	Indicator Type	Measurement Variable	Data Source	Frequency
Leadership Commitment	Leading	Safety Walkthroughs Conducted	Digital Audit Logs	Monthly
Employee Behaviour	Leading	Near Miss Reporting Rate	Mobile App	Weekly
Compliance	Lagging	PPE Non-Compliance Cases	Inspection Records	Weekly
Risk Management	Leading	Hazard Identification Reports	Safety Portal	Real-Time
Training & Competency	Leading	Training Completion %	HR LMS System	Monthly
Incident Outcomes	Lagging	LTIFR, TRIR	Incident Database	Quarterly
Corrective Actions	Leading	Closure Rate (%)	CAPA System	Weekly

Table 4.4: Example Weight Allocation Model (Expert-Based MCDA)

Indicator Category	Weight (%)
Leadership & Governance	15
Behavioural Reporting	20
Training & Competency	10
Risk Identification	15
Compliance Monitoring	10
Incident Rates	20
Corrective Action Closure	10
Total	100%

Rationale: Higher weight is given to behavioural reporting and incident rates due to their strong influence on safety culture maturity.

Table 4.5: SPI Score Interpretation Model	
SPI Score Range Interpretation Level	
90 – 100	Excellent Safety Culture
75 – 89	Strong / Proactive
60 – 74	Moderate / Reactive
40 – 59	Weak / Compliance-
Driven Below 40	High Risk / Critical

Table 4.6: Sample SPI Output – Tata Steel Pilot Division

Division	SPI Score	Trend (3 Months)	Risk Category	Action Required
Production	82	↑ Improving	Strong	Continue monitoring
Maintenance	74	↓ Slight Drop	Moderate	Increase behavioural reporting
Raw Materials	68	Stable	Moderate	Conduct leadership safety training
Logistics	91	↑ Strong	Excellent	Benchmark model

V. FINDING

1. Impact on Safety Culture:

By requiring compliance with lead indicators above 80%, SPI encourages a proactive approach to safety. Departments must comply with each of the lead KPIs individually to earn full marks, fostering a sense of accountability and discipline. Additionally, achieving a high SPI score requires maintaining zero lag (incidents), creating a culture of vigilance and

preventive measures. The healthy competition among departments, driven by SPI scores, promotes a sense of pride and a commitment to continuous improvement. This dynamic has a ripple effect across the organization, encouraging all levels of staff to focus on safety and strive for excellence. The underline philosophy here is- ‘what gets measured, gets improved’- and SPI facilitates this in an easy yet comprehensive manner.

## 2. Improving Leadership Engagement

SPI also plays a crucial role in leadership accountability and engagement. The consolidated scores of all departments in a division determines the division's score, for which the Vice President is accountable for. This structured accountability encourages leaders to prioritize safety and take ownership of safety-related outcomes within their divisions. Leadership involvement is further enhanced through the SPI's systematic review approach. By using the SPI dashboard, leaders can track safety performance in real-time, identify areas for improvement, and act on early warning indicators. This empowers leaders to make informed decisions and to lead by example, reinforcing the safety culture within their teams.

## 3. Improving workforce engagement

The implementation of SPI has resulted in tangible benefits, including a more engaged workforce, reduced safety incidents, and improved safety compliance. The increased use of ENSAFE, Organization's safety management system, further reflects the positive impact of SPI on safety culture. Additionally, the SPI framework has been expanded to include additional KPIs and bringing in absolute scoring above 80% compliance, allowing for a more nuanced assessment of safety performance. This expansion enables the organization to adapt to evolving safety challenges and align with the changing dynamics in the field of data, AI & reporting, thus maintaining its leadership position in the industry.

## 4. Proactive Risk mitigation

The Safety Performance Index (SPI) serves as a foundational pillar in the organization's safety journey towards a robust safety culture and effective leadership. By combining a comprehensive scoring system with proactive risk mitigation and leadership accountability, SPI has transformed safety practices within the organization. This project not only aligns with Organization's vision of corporate citizenship but also establishes a new standard for safety excellence in the steel industry.

### 5.1 Review by Senior Leadership:

Top management has played a pivotal role in leading and championing the SPI initiative. The CEO & MD set the tone for the entire organization, reviewing SPI

in the monthly meeting, emphasizing the importance of safety, and providing a clear vision for achieving a robust safety culture.

The leadership support cascades down the chain of command, with VPs and senior leaders actively engaging in reviewing safety scores and leading by example. The chain of management has embraced SPI, creating a culture of accountability and continuous improvement. Leaders at all levels participate in systematic reviews and actively engage with safety initiatives, reinforcing the company's commitment to safety excellence. This top-down support fosters a safety-centric mindset throughout the organization.

Key insights derived from the lead and lag indicators are formulated into action items, and eventually help in focusing on shop floor engagement.

Some of the shopfloor challenges which have started getting focus by use of SPI score include:

1. Identification of areas, where incident recommendations are pending for deployment on shopfloor.
2. Through use of Generative AI and linkage with lead indicators such as safety observation, people can identify potential incidents proactively.
3. In areas, where score of line-walks is low, usage of AI based analytics, helps identify blind spots, within the shopfloor.
4. Quality of compliance to lead indicators are being discussed, to move from compliance to commitment, visible in changes at the shopfloor.

We have reported a huge improvement in the lead KPIs (metrics) for last financial year after the inception of SPI. Moreover, after the reporting of the compliance improvement, we have added few more KPIs with inclusion of generative AI to evaluate the quality index for data logging KPIs.

5.2 Compliance of lead KPIs in April'23 (Example):  
In the first month of FY24, the overall SPI score of the organization was 186/350.

LEAD KPIs REQUIRING IMPROVEMENT	
Annexure# 9 Assessment of Vendors by re..	43
CSM Severity Audit	43
Closure of safety Observation in time	43
Reporting of Near Miss	46
Job Cycle Check (JCC) compliance	56
Safety-Visit compliance (Nos.)	65
Safety Linewalk (IL3 & above)	65
Closure of Incident Investigation in time	68
Closure of FRCP in time	82
Deployment of Management of Change	83
Implementation compliance of Incident re..	84
Deployment of past Fatal recommendations	89

All KPIs needed improvement across the organization with special focus on these.

5.3 Compliance of lead KPIs in March'24  
 In the last month of FY24, the overall SPI score of the organization was 300/350- Average score increased and large improvement was evident in leading metrics.

LEAD KPIs REQUIRING IMPROVEMENT	
Reporting of Near Miss	85
Closure of FRCP in time	85
CSM Severity Audit	85
Safety Linewalk (IL3 & above)	85
Job Cycle Check (JCC) compliance	89
Annexure# 9 Assessment of Vendors by re..	89
Deployment of Management of Change	90
Implementation compliance of Incident re..	91
Safety-Visit compliance (Nos.)	93
Closure of safety Observation in time	93
Closure of Incident Investigation in time	96
Deployment of past Fatal recommendations	100

Large improvement visible in all metrics- More than 100% improvement visible in many metrics.

The above improvement was reported in the 1<sup>st</sup> phase of the initiative. Post phase 1 implementation and during the review sessions, chaired by CEO&MD, members suggested to include the qualitative index of the KPIs in scoring. The reviewers also suggested to include new KPIs to reduce the dependency on the

employees, especially in the reporting KPIs, such as number of safety visits/line walks by introducing the ongoing video analytics alerts (violations captured by CCTV and AI models) . They have also suggested to include the KPIs related to the skills of workers and employees and to introduce alerts by 'Suraksha Card' (LORA based tracking technology) to capture the unauthorized entries into the hazardous zones.

We worked on 2 tracks for phase 2:

1. Addition of new KPIs to enhance the scope of individuals and departments.
2. Integration of Quality Index

1. Addition of new KPIs:

- (i) Compliance of red risk recommendation with time
- (ii) Compliance of Multisource recommendations with time (Process Safety Applicable Departments)
- (iii) Contractor worker found in hazardous Zone without E-Permit.
- (iv) Platinum/ Gold skilled worker in the department for contract workers.
- (v) Compliance of Safety Standard E-Learning modules for employees.
- (vi) Consequence management applied on Violation of Life Saving Rule. (Captured through CCTV)
- (vii) Process Safety Audit/ 5S & VWM assessment score

2. Quality Index using Generative AI:

- (i) Quality Index for Safety Visit, Line Walks, ECAUP\*, CSS Audits\* & Near miss based on adequacy and accuracy of data logged by the users.
- (ii) Generative AI is being utilized to score the adequacy and accuracy of the data logged by the users. The model checks the specified hazard, potential result, and location to determine the quality of data logged.

3. Video Analytics & Connected Workforce:

The newly added KPIs have 2 forward looking KPIs, which are results of 2 past digital initiatives taken up in Safety:

- (i) Consequence management applied on Violation of Life Saving Rule. (Violations captured through CCTV.)

- (ii) Contractor worker found in hazardous Zone without E-Permit.
- 4. Workforce tracking system: Unauthorized entry in hazardous zone is the result of integration of Connected Workforce infrastructure (i.e., tracking of footprints of workers inside the plant) with E-permit system. Whereas CCTV capturing of unsafe activities are being monitored centrally by Safety Alert Command Centre. Inhouse developed and few outsourced AI models run on the CCTV feeds from prioritized cameras and generate alert for immediate action.
- 5. Safety Alert Command Centre prepares cases and monitors the alerts till the closure. Now these alerts are also connected with SPI to bring them to the view of management leadership and to streamline the closure. This initiative is also making the organization's infrastructure future ready to become interdependent and self-guiding system.

#### 5.4 Generative AI for Review & Reporting:

Along with the quality index inclusion, we are utilizing Generative AI in reporting following on a weekly basis:

- (i) High Risk Observations: Similarity of a newly logged observations with past/historical incident with high-risk score. These observations also get highlighted in EnsafeNxt screen to communicate the priority ask with the users.
- (ii) Gaps in Lag & Lead – gap in focus area of safety visits / line walks based on types of incidents getting logged.
- (iii) Blind Spots and Gray Areas: Areas with logged incidents or red SOPs, which have not been visited for past few weeks.

Inclusion of all the new KPIs along with integration of Generative AI shall help us improve the KPIs further and reduce the lag indicators and eliminate the workplace safety risk.

## VI. DISCUSSION

### 6.1 Advantages of IT-Based SPI

The digital tool provides several benefits over traditional methods:

- 1. Timeliness: Continuous data capture enables early warning of safety issues.

- 2. Objectivity: Reduces reliance on subjective audit assessments.
- 3. Integration: Consolidates disparate data sources into a unified view.
- 4. Actionability: Predictive analytics and dashboards support decision making.

### 6.2 Implications for Safety Culture

The SPI tool contributes to shaping safety culture by:

- 1. Encouraging proactive reporting and shared ownership of safety.
- 2. Increasing transparency and feedback loops.
- 3. Aligning individual behaviours with organizational safety goals.

### 6.3 Challenges and Limitations

- 1. Data Quality: Accuracy depends on consistent and honest data entry.
- 2. Technology Adoption: Workers require training and motivation to use digital tools.
- 3. Customization: SPI models may require adaptation for different contexts.

## VII. RECOMMENDATIONS

To maximize the impact of IT-based SPI tools:

- 1. Executive Support: Leadership must champion safety metrics and digital transformation.
- 2. Training and Communication: Regular training to ensure user competence.
- 3. Continuous Refinement: Update indicators based on evolving risks and feedback.
- 4. Integration with ESG Goals: Align safety performance with environmental, social, and governance reporting.
- 5. Scalability: Extend the tool to additional divisions and functions.

## VIII. CONCLUSION

SPI has engaged the workforce at all levels, promoting a sense of ownership and participation in safety practices. The emphasis on compliance with lead indicators motivates employees to contribute to safety goals actively. Departments are encouraged to achieve high scores, fostering healthy competition and collaboration among team members. The systematic review process involves not only senior leaders but also officers, non-officers, and contractors, creating a

comprehensive safety culture across the organization. This inclusivity ensures that everyone has a role to play in maintaining safety, leading to a more engaged and safety-conscious workforce.

Workforce involvement helped us harness the following benefits from these initiatives:

- (i) Understanding of KPIs amongst Leadership team and Line management has improved, as it is getting reviewed in DICs/ AICs/ Contractor AICs.
- (ii) Pull from Line management on compliance of Safety KPIs has increased- Previously it happened due to push from Safety Team.
- (iii) Performance on Safety KPIs got improved- Annexure 9, Compliance of Incident recommendations, Logging of Near Miss etc., Incident investigation in time.

Moreover, this initiative has also contributed to the Data Culture of the organization and people across levels have started understanding and improving data structures, logics, flow, and performance calculations. More than 100 tickets were also logged for improvement in the various IT systems, due this initiative.

Departments and their entire workforce, including contractors get motivated whenever they score a high rank at the organisational level. Every month the top 10 departments across the organisation, are appreciated by CEO & MD. At different Tata Steel's locations, people who have done maximum contribution to ensure high SPI scores, are also appreciated by respective Vice Presidents. This healthy competition always keeps the workforce involved and attentive towards improvement in leading metrics. More suggestions, Kaizens, recommendation closures etc. get generated at the shopfloor.

Positive movement across KPIs, indicate 100% of the employees and contractors contributing to the SPI of the department. It also indicates an increased connect between the leadership and the shopfloor.

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