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Comprehensive Risk Assessment and Mitigation Framework for E.O.T. Cranes in Material Handling Systems

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Abstract: *Material handling is a primary component of the manufacturing industry, ensuring the correct amount of raw materials is delivered to required destinations efficiently. While not a direct production process, it accounts for 30% to 75% of total production costs. This research paper investigates the hazard identification and risk assessment (HIRA) of Electric Overhead Travel (E.O.T.) cranes at Steel Processing and Distribution India Limited, located in Jharkhand, India. The facility employs approximately 250 personnel and utilizes 13 E.O.T. cranes for various processes including slitting, pickling, cut-to-length, and corrugation. Through comprehensive methodology involving Job Cycle Checks (JCC) and quantitative risk scoring, this paper proposes actionable engineering and administrative controls to achieve the company's vision of Zero Lost Time Injury (LTI) by 2026.*

Keywords: *E.O.T. Crane, Material Handling, Hazard Identification and Risk Assessment (HIRA), Industrial Safety, Steel Processing, Ergonomics, Job Cycle Check (JCC), EHS Mitigation.*

I. INTRODUCTION

Material handling is defined as the movement, handling, storage, and controlling of materials throughout the manufacturing process. A properly sound material handling system ensures cycle time cost reduction, minimized delays, and reduced product damage. Key factors in designing such a system include the form of the material, flow demands, available handling equipment, labor competency, and capital availability.

Figure1: EOT Crane View

A crane is a mechanical lifting device equipped with a rope drum, wire rope, and sheaves used to lift, lower, and move materials horizontally. In the subject company, Steel Processing and Distribution India Limited, approximately three-quarters of the total plant activity is related to material handling.

1.1. Equipment Profile The plant utilizes the following equipment for material handling:

- Electric Overhead Travel (E.O.T.) Cranes: 13 Units

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- Forklifts: 3 Units
- Rigging Tools: "C" hooks and Metal Slings

1.2. Objectives of the Study

- To study and identify hazards related to unsafe practices during E.O.T. crane material handling.
- To recommend safe practices and make the system more ergonomic and safe.
- To mitigate risks to ensure employees are not placed at risk during operations.

II. LITERATURE REVIEW

Extensive literature exists on crane safety and material handling. Neitzel et al. (2001) discussed data collection on crane-related injuries and safety device recommendations. Bramley (2024) explored ergonomic considerations for crane cabin design. Das & Sen (2024) conducted ergonomic studies on machine control and C-hook movements, noting that control movement compatibility is often absent, and recommended low-cost solutions.

Further technical evaluations include Yogi Raval's analytical study (2022) optimizing crane wheel size, and Suratkar & Shukla's (2021) 3D modeling and finite element analysis of E.O.T. cranes. Patil and Nirav (2021) analyzed major crane components like pulleys, ropes, and drums using Indian Standards such as IS:4137-1985 and IS:807-2006.

III. E.O.T. CRANE COMPONENTS & HAZARDS

3.1. Basic Components

Girders: Take vertical loads and deflection within permissible limits. Box girders are most popular due to design efficiency.

- **End Carriage:** Houses the wheels on which the entire structure travels.
- **Hoist Machinery:** Consists of a motor, gearbox, brake, coupling, drum, wire rope, and bottom block.
- **Long Travel Machinery:** Constructed with a motor drive, coupling, brakes, gearing, and wheels for bi-directional travel.

3.2. Major Operational Hazards

- **Electrical Hazards:** Nearly 50% of E.O.T. crane accidents result from contact with electrical power sources. Danger zones include a 10-foot radius around powerlines.
- **Overloading:** Exceeding load capacity causes 80% of crane upsets and structural failures. Causes include swinging loads, sudden dropping, and human error.
- **Material Falling:** Improper securing leads to slipping loads. Preventive measures include regular hoist maintenance and strict use of Personal Protective Equipment (PPE).

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3.3. EOT Activity Flow Sheet

EOT ACTIVITY FLOW SHEET

Position the crane over the 'C' hook stand
↓
Lower down the crane hoist
↓
Fix the 'C' hook with crane hook
↓
Lift the hoist with 'C' hook and move to required place.
↓
Position the 'C' hook over the coil to be lifted
↓
Lower down the hoist and support the coil on 'C' hook
↓
Lift the hoist with coil load to required height
↓
Move the crane with load to required direction
↓
Stop the L.T at required place and position the coil for placement on saddle with C.T.
↓
Lower down the hoist and align the coil for centering on saddle
↓
Slowly place the coil on saddle
↓
Remove the 'C' hook from coil bore.

Figure2: EOT Crane View

Table 1: Identified E.O.T. Crane Hazards and Control Measures

Hazard Identification	Hazard Control
Equipment or control failure	Check controls before proceeding; Do not exceed SWL.
Crushing	Ensure work area is clear.
Unexpected movement	Position slings correctly; check load balance.
Incorrect Stacking	Ensure all materials are stacked stably.
Slinging	Only qualified persons use slings; check color code and angles.
Pedestrian interface	Nobody is allowed to walk under suspended loads.
Obstructed view	Use a competent person for clear verbal/physical instructions.

IV. METHODOLOGY: RISK ASSESSMENT FRAMEWORK

The study employs a systematic risk assessment process involving Hazard Identification, Risk Analysis, Risk Evaluation, and Risk Treatment. Risk is calculated as the product of Consequence (C), Exposure (E), and Probability (P).

Formula:

Risk = Consequence x times Exposure x times Probability

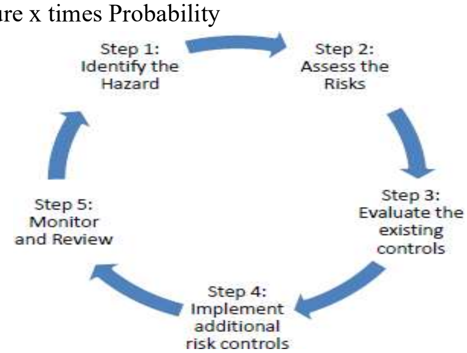

Figure 3: Steps Of Risk Assessment

Table 2: Risk Scoring Parameters

Parameter	Max Score (100-10)	Mid Score (50-3)	Min Score (2-0.1)
Consequence (C)	Numerous fatality (100)	Fatalities (25)	Medical case (1)
Exposure (E)	Continuous (10)	Occasional (3)	Very rare (0.5)
Probability (P)	Almost Possible (10)	Unusual but possible (3)	Practically impossible (0.1)

Table 3: Risk Classification

Risk Level	Score Range	Action Required
Very High Risk (VH)	> 400	Work must not start until risk is totally removed.
High Risk (H)	200 - 400	Immediate control measures must be introduced.
Substantial Risk (S)	80 - 200	Efforts should be made to reduce risk carefully.
Moderate Risk (M)	20 - 80	Monitoring required to ensure controls are implemented.
Acceptable Risk (A)	< 20	No serious action required.

The study implements a Hierarchy of Controls: Elimination, Substitution, Engineering Control, Administrative Control, and PPE. Standard operating methods, Safe Work Permit Systems (SWPS), and Pre-Start Safety Reviews (PSSR) are mandatory.

V. PLANT OBSERVATIONS AND ENGINEERING SOLUTIONS

Field visits revealed specific hazards during routine operations, necessitating engineered solutions.

5.1. Coil Handling with "C" Hook

- **Current Practice:** Manual insertion of the "C" hook, leading to incomplete insertion.
- **Proposed Solution:** Fix a sensor at the inner end of the "C" hook. The hoist motor will only start lifting after the sensor detects complete insertion.

5.2. Centering Coils on Saddles

Current Practice: Relies on operator estimation, causing dislodging during mass production.

Proposed Solution: Equip the Cross Travel (C.T.) with a laser centering device that aligns with markings on the floor, eliminating human error.

Figure 4: Coil Handling with "C" Hook

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5.3. Crane Movements and Collision Risks

- **Current Practice:** Uncontrolled travel due to brake contactor malfunctions or track sagging risks crane collisions.
- **Proposed Solution:** Install a laser-based anti-collision sensor to read track obstructions and cut power at safe distances (10m for slowdown, 6m for stop).

5.4. Hoist Free-Fall Prevention

- **Current Practice:** Brake contactors stick, causing loads to fall uncontrolled.
- **Proposed Solution:** Implement an in-house Automatic Protection Circuit (plug & play) to detect malfunctioning brakes and prevent free-falls.

VI. RESULTS AND DATA ANALYSIS

6.1. Hazard Identification and Risk Assessment (Production) Evaluations of production tasks yielded specific risk scores requiring mitigation.

Table 4: E.O.T. Crane Activity Risk Calculation Extract

Activity	Associated Hazard	C	E	P	Score	Level
Loading/unloading coil with 'C' hook	Toppling of coil	25	3	6	450	VH
Handling Finish Goods with slings	Finger entrapment	15	3	3	135	S
Crane movement with load	Colliding with E.O.T.	25	3	6	450	VH
Movement of CT	Uncontrolled lowering	25	3	1	75	M

6.2. Hazard Identification and Risk Assessment (Maintenance) Maintenance tasks universally exhibited Severe (S) risk profiles due to the environment.

Table 5: E.O.T. Crane Maintenance HIRA Extract

Task	Hazards Identified	Harm	Score	Risk Level
Equipment Inspection	Electricity, Fall, PPE	Electrocution, Cut	90	Substantial (S)
Energy Isolation	Electricity, Non-compliance	Electrocution, Pinch	90	Substantial (S)
Crab Trolley Work	Fall, Improper Tools	Hit, Cut, Pinch	90	Substantial (S)

6.3. Incident and Near-Miss Trends Historical data indicates a significant reduction in near misses due to improved interventions.

Figure 1: Near Miss Reduction Trend (Representational Chart)

- **FY07:** 118 Incidents (Baseline)
- **FY08:** 100 Incidents
- **FY09:** 40 Incidents (66% Reduction)
- **FY10:** 22 Incidents (45% Reduction)

Table 6: Historical Accident Data (2014-2025)

Incident Type	Total Occurrences
Toppling of coil from 'C' hook	11
Dislodging of coil from saddle	10
Uncontrolled lowering of hoist	8
Colliding with other E.O.T.	4

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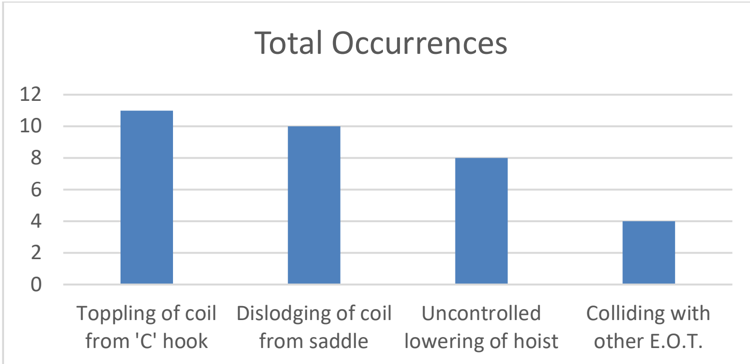

Figure 5: Coil Handling with "C" Hook

6.4. Job Cycle Check (JCC) Findings Audits of operator knowledge and practices revealed strict adherence to daily checks (battery, no-load functions, and brakes). However, a critical gap was identified: Operators and helpers do not maintain the mandatory 10-meter distance during operations, requiring immediate supervisory intervention.

VII. RECOMMENDATIONS AND FUTURE SCOPE

7.1. Operational Recommendations Based on continuous reviews and C.E.P. scoring, the following low-cost, ergonomic implementations are recommended to the EHS Department:

- Substitute metal slings with canvas lifting straps for Finish Goods (F.G.) packets to eliminate finger entrapment risks.
- Exercise extreme caution with forklifts moving between bays, as their design limits eye-level visibility and noisy environments mask their approach.
- Adjust pendant wire lengths to match operator heights for ergonomic benefits.
- Enforce a "one operator, one machine" policy.
- Conduct strict preventive maintenance every 15 days.

7.2. Future Scope of Research

- Develop real-time hazard detection integrating IoT sensors and computer vision.
- Incorporate Failure Mode and Effects Analysis (FMEA) and Fault Tree Analysis (FTA) into HIRA.
- Create AI-based predictive maintenance models analyzing wear-and-tear data.
- Ergonomically redesign crane cabins.

VIII. CONCLUSION

Material handling is a vital component of industrial profitability, dictating 30% to 75% of production costs. Because lifting activities inherently involve hazards, the primary method to eliminate accidents is through systematic hazard identification and control implementation. The checklist methodology utilized in this study proved effective for thoroughly surveying complex E.O.T. crane operations, demonstrating that stringent risk assessment can successfully bring operational hazards down to permissible, manageable levels.

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