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RESEARCH PAPER

Risk Assessment of Human Error in Orange-line Metro Depot Operation

[1]Muhammad Awais * [2]Prof. Dr. Engr. Shahid Naveed and [3]Dr. Shahan Mehmood Cheema

1. M.Phil. Scholar, Business & Management Sciences Department of The Superior University Lahore, Punjab, Pakistan
2. Professor, Business & Management Sciences Department of The Superior University Lahore, Punjab, Pakistan
3. Assistant Professor, Business & Management Sciences Department of The Superior University Lahore, Punjab, Pakistan

***Corresponding Author:** awaisarshad456@gmail.com

ABSTRACT

This research paper employs a comprehensive risk matrix approach to analyze the potential risks associated with the Orange Line Metro Rail Transit System (OLMRTS). The major focus of this study revolves around two critical safety variables: human error and equipment failure, with a particular emphasis on human error as the most significant contributing factor. The research methodology involves the development of risk assessment models based on various incident scenarios. To identify potential hazards and assess their severity, historical incident data from a range of sources was collected and analyzed. This data made it possible to identify a number of potentially hazardous circumstances that could have an adverse impact on OLMRTS depot operations. The frequency and severity of each hazardous event were carefully evaluated based on the historical incident data, providing valuable insights into the potential risks faced by the system. The key findings of this investigation highlight that human-related activities emerge as the most significant potential cause of risk within the context of OLMRTS. The data analysis indicates a high level of risk associated with human error, underscoring the importance of addressing and mitigating these risks to enhance the overall safety and reliability of the OLMRTS system.

KEYWORDS Equipment Failure, Human Error, Historical Incident Data, Rail Mass Transit, Risk Assessment, Risk Matrix

Introduction

The Orange Line metro rail transit system is a joint venture of Norinco Cooperation Pvt. Ltd., Guangzhou Metro China, and Daewoo Pakistan. It is the first metro project in Pakistan. Metro refers to an urban rapid transit system that typically operates underground or on elevated tracks. Metro systems often consist of multiple lines, stations, and trains. The Orange Line spans a distance of 27.12 km, running along Multan Road from Dera Gujran to Ali Town via GT Road, which runs through the heavily populated city and contains a variety of historic buildings and precincts. The track is 25.4 km in elevation and has a 1.72 km cut and cover section. A total of 26 stations (elevated: 24; cut & cover stations: 2). The Orange Line consists of 27 trains with 135 cars, a 100-metre-long train, and a 750-volt third rail with a maximum speed limit of 80 km/h.

The Metro Rail Transit System is a vital component of modern urban transportation, offering numerous benefits to cities and their citizens. Shojaei et al (2023)The railway is one of the effective transportation lifelines in the world. (Nguyen et al., 2022)Rail transportation has become one of the most popular modes of transportation because of its high degree of safety, huge capacity, and affordability. For sustainable urban living, to lessen traffic, and to promote economic growth, cities must develop and expand their effective public transportation systems, such as the Metro Rail system. Kyriakidis et al (2012) Metros have the notable characteristic of being the safest form of transportation in the cities in which they run. It is designed to provide a quick, reliable, and comfortable means of commuting for large numbers of passengers, easing traffic congestion and reducing environmental impacts. Shvetsov et al (2023)Modern transport uses the most modern and sophisticated technologies and systems.

Understanding the elements, dependencies, and interactions of the modern railway system is necessary to evaluate and enhance its performance. Furthermore, for a railway to be efficient, it is vital to comprehend this for the various forms of railway operation, such as the main line and depot/stabling yard.

Zhou and Lei (2020) The railway is a vital means of transportation for human. Even though railway safety has improved over the past few decades, train-driving-related incidents and accidents continue to occur often. The dynamic nature of human thought, inadequate equipment structure, actions in both the internal and external surroundings, and inappropriate management can all lead to the emergence of various risk factors throughout operation. Each of the mentioned components could result in serious incidents and accidents without careful attention to detail that could cause human accidents, damage to the system, monetary losses, or possibly result in fatalities if not managed correctly. The key concept to observe when operating a rail system is the safety-first, efficiency-second principle. Chen et al (2018)Progressively, risks in metro operations came to be comprehended, and risk analysis is now an essential step in safety management.

Theoretically speaking, there is a risk of failure due to the complexity of the interactions, which could result in safety incidents and accidents. Marchetta et al (2023) Similar to other modes of transportation, the railway system exposes its users to potential hazards that may result in unfavorable outcomes. Risk is expressed as the product of the severity of the effects and the probability that the hazard will emerge.

There is no study published on this topic yet. It is the first study of the orange line regarding the risk assessment of human error. The first author of this research paper is already working on an Orange Line train; he personally experienced the faults, errors, and countermeasures in an Orange Line Metro Rail Transit System, and he is going to present an article on this topic along with their professors.

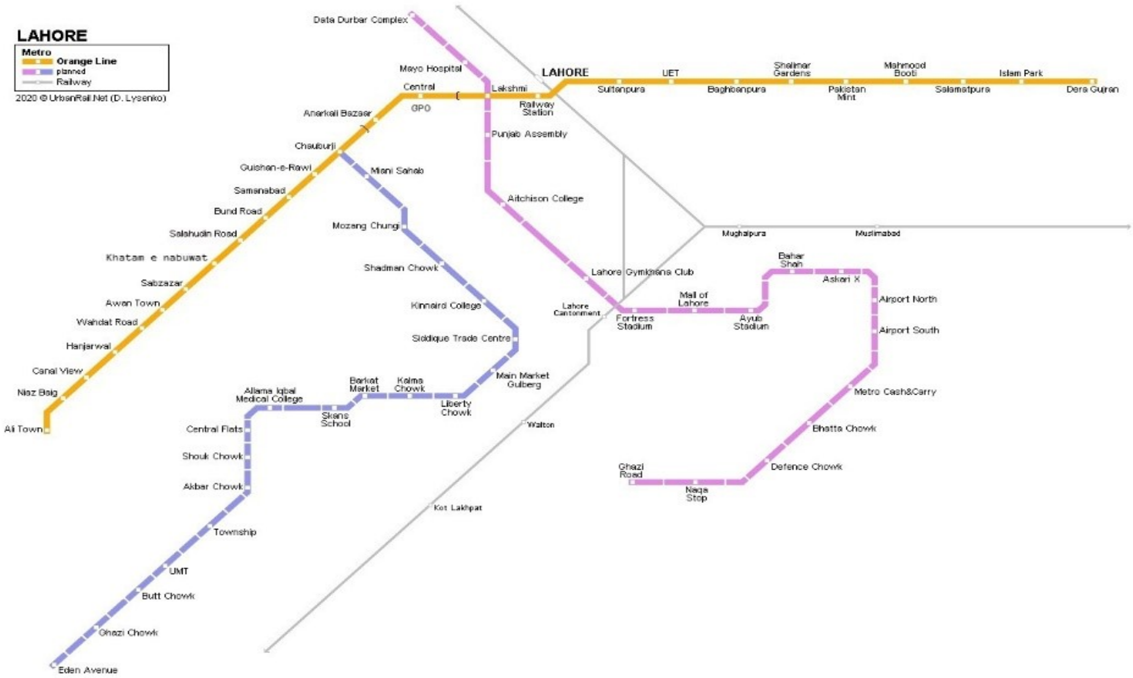

Fig 1, Orange line Metro rail transit network and its proposed future study purple and blue lines route map.

Literature Review

General Risk Management Procedure:

Risk management is crucial when it comes to the safety of railway systems. Defined as the process of recognizing possible hazards and acting appropriately to lessen or eliminate them, the major goal of risk management is to bring risks to a level that is considered acceptable while also ensuring efficient control, tracking, and making others aware of these dangers.

Nguyen et al (2022)The risk management process used for a railway system essentially adheres to the standard safety method, which consists of the following steps: (i) developing the context to identify the scenario that needs to be examined; (ii) risk (hazard) assessment to identify the risk associated with a specific scenario through risk identification, analysis, and evaluation; and (iii) risk mitigation by choosing risk-reducing interventions.

In a variety of industries, including engineering, manufacturing, construction, and transportation, risk assessment is a critical process for identifying and evaluating potential hazards or threats. In railway operations, human error plays a significant role and can have serious repercussions. The goal of the research is to create practical methods to mitigate these risks, enhance the standard for safety in metro railway operations, and encouraging more secure environments for employees.

Hazard Identification

Nguyen et al (2022)Defined as an event that has the potential to cause an accident, such as damage to vehicles, machinery, people, property, or the environment. The goal of the hazard identification stage is to list all reasonably foreseeable risks connected to the system's intended functioning in its typical operating environment. In the next steps, these hazards are examined and quantified in further detail. Leitner (2017)The hazard identification phase of the study focused on understanding and defining hazards in railway operations, including accident sequences and their development. This involved setting boundaries for hazard identification, identifying risky events, and planning preventive measures. It also included creating accident appearance scenarios to clarify relationships between these elements and developing accident progress scenarios considering influential factors while maintaining a hazard log. Mara et al (2013)Focus on assessing the risks associated with human errors in metro railway depot operations. The study investigates the potential for human mistakes and their implications on safety and operational efficiency within metro depots. By analyzing past incidents and identifying common error patterns, the research aims to provide valuable insights and recommendations for mitigating human-related risks in this critical transportation sector."

Risk Assessment Approach

Zhang and Fom (2022)To enhance the safety and reliability of railway transportation systems, particularly during the initial phases of operation, and to evaluate the risks connected to Abuja's rail mass transport system, the study utilizes a risk matrix technique. Leitner (2017)constructed a model based on accident scenarios, identifying potential hazardous events leading to casualties through analysis of accident reports and consultations with railway safety experts. These models will be instrumental in evaluating the accident risk within the Slovakian railway system. Human reliability is a critical concern in various fields, including the assessment of safety systems like railway signaling. Catelani et al (2021)describe that the method for analyzing human reliability, known as RARA (Railway Action Reliability Assessment), is effective but relies heavily on expert judgement, making it subjective. An et al (2011)Present a risk assessment methodology consisting of five key phases: problem definition, data collection and analysis, hazard identification, risk estimation, and risk response. This systematic approach aims to identify and manage high-risk areas in metro railway depot operations. The proposed model combines Fuzzy Risk Assessment (FRA) and Fuzzy Analytic Hierarchy Process (Fuzzy-AHP) to assess the risk factors involved.

Critical Conclusion

The literature review has offered a comprehensive insight into the landscape of risk assessment concerning human error in metro railway depot operations. Different risk management procedures and methodical approaches to hazard identification have been explored, emphasizing their crucial role in enhancing operational safety. The risk matrix method, particularly in the context of OLMRTS, has been recommended as a key approach. This review section extensively examined established standards for risk management and organized techniques for classifying and identifying hazards based on facts, highlighting their influence on operational safety across different railway types. The risk matrix was identified as a useful tool for determining the degree of danger connected to a system. The evaluation within this literature review aims to evaluate fundamental errors and failure frequencies contributing to train operation, utilizing the risk matrix methodology to determine probability and calculate the severity of hazards. The focus of most studies in the literature has been on human errors and equipment failures in metro railway operations, providing a global perspective for the study. Importantly, this literature review lays the foundation for the first-ever analysis within the Orange Line Metro Rail Transit System, drawing from globally analyzed literature. It serves as a valuable reference for assessing human error risks in metro railway depot operations. In conclusion, the risk matrix approach emerges as a valuable tool for assessing human error risks in metro railway depot operations. However, it should be complemented with a broader array of methodologies and a deeper understanding of human factors to ensure the highest level of safety. Future research should concentrate on refining and evolving these approaches to continuously enhance the safety of metro railway operations.

Material and Methods

This study is based on historical data, past incidents, gathered by the incident reports that occurred in the years 2022–2023 in OLMRTS. The purpose of the study is to obtain data regarding the two safety requirements that have been noted in the literature. The two primary issues discussed in this paper are errors by humans and equipment malfunctions. The likelihood of a failure is calculated using the measure or probability that it will occur. The outcome of an event on an item is the consequence or impact of these failures (such as casualties, damage to property, injuries, effects on the environment, and so forth). Early occurrences like train collisions and derailments on mass transport train networks are examples of sudden occurrences that can result in risk. The potential exists for human error and equipment malfunctions that can play a role. Shipunova et al (2022)Define the primary source of risk in transport as direct human-machine interaction.

A risk assessment can be performed after potential hazards and contributing factors have been identified to ascertain the likelihood and effects of each hazard. Risk matrices, risk registers, and other risk assessment tools can be used for this.

Paglioni and Groth (2022)Risk control is carried out if existing and running control have not been able to reduce the level of risk from danger to the level of as low as reasonably practicable (ALARP) acceptable to the modern railway system.

A matrix is constructed between probability and impact, which is assigned to individual risk events. The degree of hazard risk is calculated in a hazard evaluation matrix table by multiplying the probability of a hazard accident occurrence by the impacts of a likely accident severity. A straightforward system can be assessed using standard hazard risk grade evaluation criteria

- Risk = Likelihood x Severity

The hazard risk level is then used to derive the risk value associated with every hazard. The risk score is useful in categorising the risk and guiding risk mitigation strategies. As indicated in Table 4, the risk score is determined by multiplying the likelihood by the severity.

Collection of Data

Observation of Depot Operations

The Orange Line metro rail transit system has two depots. Dera Gujran north side, and Stabling Yard, south side. Critical infrastructure, storage facilities, train and locomotive parking, shunting, train washing, train maintenance, training, and train preparation activities are conducted in the depot and stabling yard. He observed and performed the operations in the depot and stabling yard, even though most of the tasks were performed under his supervision. His observations covered all the relevant areas of the depot and stabling yard. By assessing compliance with safety standards and regulations and interacting with depot staff to gain insights and gather observations, he has knowledge of all of the relevant work done as well as the safety protocols in the depot, identifying potential hazards and risks during operations.

After the observation and on the basis of his working experience in an orange line train, they conducted this study and selected this topic for their thesis and research paper. Conducting systematic observations of various depot areas and activities. Integrating observed data into the overall risk assessment process.

Analysis of Incident Reports and Historical Data

Data Sources: Incident report data is retrieved from the depot and stabling yard incident reporting records, which are then compiled. Review the collected data for completeness and accuracy. He analyzed incident reports, near misses, and other relevant historical data to understand past safety issues. Study standard operating procedures (SOPs) and safety protocols to identify and understand incidents.

Analyze: Categorize incidents and events into different types based on factors such as severity, location, cause, and frequency. Develop a clear classification system to organize the data effectively. Assess the severity of each incident to understand its potential impact on safety and operations.

Use a severity scale to rank incidents from minor to critical. Conduct a root cause analysis for each significant incident to determine the underlying causes. Analyze factors such as human error and equipment failure. Identify patterns and trends in the data. Look for recurring incidents or common contributing factors. Use data visualization tools like tables and graphs to make trends more apparent. Determine the frequency of specific types of incidents or near-misses.

Evaluate whether certain incidents are occurring more frequently than others, indicating areas of higher risk. Assess the level of risk associated with each identified incident type or trend. Consider the severity, frequency, and potential consequences. Prioritize risks based on their significance to depot safety and operations. Compile the findings and recommendations into a comprehensive report.

Discussion with Metro Depot Staff

Staff-level discussion with our colleague and seniors for a better understanding of historical data. In this discussion, the metro depot staff collaboratively examines historical incident data to identify patterns, root causes, and areas for improvement in safety and operations. Regular reviews of incident data can help enhance the overall reliability and safety of the metro system.

Risk probability assessment

- Risk Identification: We identified and listed all potential risks that could impact our operation or goal. It is done through brainstorming, historical data analysis, and discussion with experts.
- Risk Definition: Clearly define each risk in terms of its potential consequences, triggers, and context. This step ensures that everyone understands the nature of each risk.
- Data Collection: Gathered data and information relevant to each risk. This includes historical data that is helpful to assess the likelihood of the risk occurring.
- Risk Assessment: Assessed the probability of each identified risk occurring. It is done using qualitative assessments.
- Risk Analysis: Analyzed the potential impact or consequences of each risk that occurred. Depending on the risk and the available data, this is performed in a qualitative way.
- The Prioritization of Risk: Risks may be prioritized according to both the estimated likelihood and possible outcomes. Common prioritization techniques include risk matrices and risk scores.
- Mitigation Planning: Developed risk mitigation strategies for high-priority risks. These strategies aim to lessen the risk of an event's impact or likelihood.
- Risk Monitoring: Continuously monitor the risk landscape to detect changes in risk probability.

Risk probability assessment is an ongoing process in the management of risk. In order to safeguard their interests and accomplish their goals while navigating an uncertain future, it assists organizations in making well-informed decisions and prudent resource allocation.

Risk Severity Assessment

The criteria and metrics used to evaluate the potential consequences or severity of human errors in depot operations. The Same steps will be followed as mentioned in the risk probability assessment approach. Risk probability assessment is a crucial part of risk management. It involves evaluating how likely various risks are to occur. Here are the key steps:

- Qualitative Assessment: chose a qualitative approach and developed descriptive scales for each impact category.
- Impact Assessment: Assessed the potential impact of each risk event within the identified impact categories. Consider the worst-case scenario and its consequences. Use the selected assessment method (qualitative) to rate each risk's severity.
- Severity Rating: Assign a severity rating to each risk based on its assessed impact within the chosen categories. This rating represents the overall seriousness of the risk. Used the defined numerical or descriptive scales for this purpose.
- Risk Prioritization: Prioritize risks based on their severity ratings.
- Mitigation Planning: Developed risk mitigation strategies for high-severity risks.
- Continuous Monitoring: Continuously monitor the risk severity and update accordingly.

Risk Score

Risk score assessment is a method used to quantify and evaluate the level of risk associated with a particular event, process, or entity. The methodology for risk score assessment can vary depending on the specific context, but here is a general approach to conducting a risk score assessment:

- Identify Risks: List all potential risks.
- Collect Data: Gather relevant information about each risk.
- Assign Scores: Give numerical scores for impact and likelihood.
- Calculate Exposure: Multiply impact and likelihood scores for each risk.
- Prioritize Risks: Focus on high-risk items.
- Mitigate Risks: Developed strategies to manage or reduce high-priority risks.
- Monitor and Adjust: Continuously review and update risk assessments as needed.
- Risk Assessment: Assess the probability of each identified risk occurring.
- Impact Assessment: Assess the potential impact of each risk event within the identified impact categories.

Results and Discussions

A total of 20 incident reports were gathered, of which the majority were caused by human errors, and the rest were equipment failures used to assign the parameters for likelihood and severity, which are subsequently utilized to evaluate the response of the risk. 13 incidents that were caused by human errors are as follows: miscommunication, wrong route setting, wrong turnout operation, unauthorized access of personnel in the power area, violation of safety protocol, violation of construction tickets, assignment of an incorrect group or train number, and assignment of an incorrect status card. (See Table 6). There are seven risks influenced by equipment failure: turnout malfunctions, track equipment failures, ATS malfunctions, and electrical switch issues. (See Table 7). Each risk and hazard incident analyzed and added to tables 6 and 7, along with their severity factors, likelihood, and risk score. Tables 1 and 2 display the likelihood and severity variables that can be used for risk analysis and as indicated in Table 4, the risk assessment can be accomplished. Techniques for risk analysis using matrices consist of:

1. To ascertain the risk's probability

2. To assess the severity.

3. To establish the matrix of risk scores.

Table1, presents the probability of risk occurrences with their defined scale. A number of phrases, including "rare," "unlikely," "moderate," "likely," and "expected," are used to describe the likelihood. The likelihood category "Expected" has a high scale of 5, while "Rare" has a scale of 1 with a minimum probability.

Table 1
An illustration of the likelihood of hazards and Scale

Likelihood	Scale	Description
Expected	5	Highly likely to occur. Has occurred in previous incidents, and conditions exist for it to continually experienced.
Likely	4	Probable to occur. Has occurred in previous incidents.
Moderate	3	Possible to occur
Unlikely	2	Most likely will not occur. Infrequent occurrence in past incidents.
Rare	1	Highly unlikely to occur. May occur in exceptional situations.

The phrases describe the severity level: "minimal", "minor", "medium", "critical", and "catastrophic". Category "catastrophic" has a highest severity level of '5' while "minimal" has a minimum severity level of '1' as described in the table, along with the consequence to the service, which shows the system or equipment's major and minor damage conditions.

Table 2
An illustration of the severity of hazards according to Scale

Severity	Scale	The effect on people or the environment	The consequence to the service
Catastrophic	5	Fatalities or several severe injuries and significant environment damage.	Major system Lost and disruptions
critical	4	One fatality, serious injury, or notable environmental harm.	Major system Loss
Medium	3	Minor injury and/or a significant environmental threat.	Severe system damage
Minor	2	Possibly mild injury	Moderate system damage
Minimal	1	no injury	no system damage

The 5*5 Risk Matrix depicts the correlation between risk severity and likelihood. A matrix is constructed that assigns likelihood and severity to individual risk events. To categorize a risk as intolerable (red condition), undesirable (orange condition), tolerable (yellow condition), or negligible (green condition), an organization needs to determine what combinations of impact and probability are present. The score of the risk aids in classifying the risk and directing the actions taken in response to it. Higher-level analysis is probably required for high-likelihood and high-impact hazards. Lower-risk situations might only need to be put on a watch list for monitoring.

Table 3
Illustration of the Risk Matrix Table

	Minimal	Minor	Medium	Critical	Catastrophic
Expected	5	10	15	20	25
Likely	4	8	12	16	20
Moderate	3	6	9	12	15
Unlikely	2	4	6	8	10
Rare	1	2	3	4	5

The level of risk and its acceptability or unacceptability define the acceptance criteria. Terms like "negligible," "tolerable," "undesirable," and "intolerable" are employed as well to characterize the risk level in order to illustrate. The acceptance criteria are explained in Table 4.

Table 4
Illustration of the Outcome of Risk Evaluation and Reduction/Control of Risk

Outcome of risk evaluation	Reduction/Control of Risk
Intolerable	The risk needs to be removed as quickly as feasible.
Undesirable	Check risk state, process action if risks are out of acceptable limit
Tolerable	Acceptable with adequate control
Negligible	Acceptable risk

Table 5
Illustration of the Risk Score

Risk evaluation output	Risk Score
Intolerable	>16
Undesirable	10-16
Tolerable	4-9
Negligible	1-3

Table 6
An illustration of the identified risks caused by humans at OLMRTS

Sr. no	Human Error	Likelihood	Severity	Risk Score	Evaluation Results
1	Miscommunication of Operation in turnout during construction	3	4	12	**Undesirable**
2	Wrong route setting	4	3	12	**Undesirable**
3	Wrong route setting/ operate wrongly	4	3	12	**Undesirable**
4	Signal couldn't reopen yellow, it turns red when	3	1	3	**Negligible**

	using cancel function button/ Wrong operation				
5	Turnout blinking red due to not restoration after construction completion	3	3	9	**Tolerable**
6	Emergency break triggered due to assigning wrong group no.	3	1	3	**Negligible**
7	Unauthorized access of staff in Powered Area DED6	4	4	16	**Undesirable**
8	Incorrect Status card issuance report	3	1	3	**Negligible**
9	(workers) performing grass-cutting activity without registered construction	3	4	12	**Undesirable**
10	Emergency break triggered due to route safety issue	3	3	9	**Tolerable**
11	Violation of construction ticket	3	4	12	**Undesirable**
12	Violation of safety Protocol	3	3	9	**Tolerable**
13	Wrong turnout operation	3	4	12	**Undesirable**

Table 7
Risk associated with equipment that fails

Sr. no	Equipment malfunctions	Likelihood	Severity	Risk Score	Evaluation Results
1	Purple Band appeared near L-15, Turnout 13	4	2	8	**Tolerable**
2	Purple Band appeared near L-15, Turnout 13/ Manual turnout operation	4	2	8	**Tolerable**
3	Speed inconsistent fault appeared	1	1	1	**Negligible**
4	Power transmission in non-power zone Blue cabinet light On DED4	3	4	12	**Undesirable**
5	Purple band appeared, track circuit at 11-DG	4	2	8	**Tolerable**
6	ATS Malfunction	3	1	3	**Negligible**
7	Turnout 22 malfunction in Stabling yard	3	1	3	**Negligible**

Human error can be defined as the impact or results of human action, the cause of an incident, as well as the deed itself. With the highest number of hazards indicating 13 hazard sources, the vast majority of hazards are those that are caused by humans. A risk score of 10 or more: "Miscommunication, wrong route setting, unauthorized access of staff in the power area, construction work without authorization, violation of construction safety, wrong turnout operation". Which belongs to the group that requires additional attention (which is undesirable and intolerable). The fundamental building block for the secure operation of systems is the equipment; inside entities like locomotives or track facilities, these are component parts, fragments, or equipment. If they malfunction, there may be a train derailment, a collision, and other mishaps. A system's exposure to severe accidents and possible consequences can be reduced by identifying the risks associated with this equipment and depot and stabling yard facilities at a preliminary phase of system functioning. The following failure factors were taken into account for the assessment of risks in this article: Turnout malfunction, ATS malfunction, electric isolation switched closed, track circuit failure The failure can be linked to a number of factors, including inadequate equipment maintenance, design issues, exceeding the equipment's design lifecycle, and incorrect installation and operation. Table 7 depicts the equipment failures that have occurred at OLMRTS. Figs. (2) and (3) show the graphic representation of human error and equipment failure.

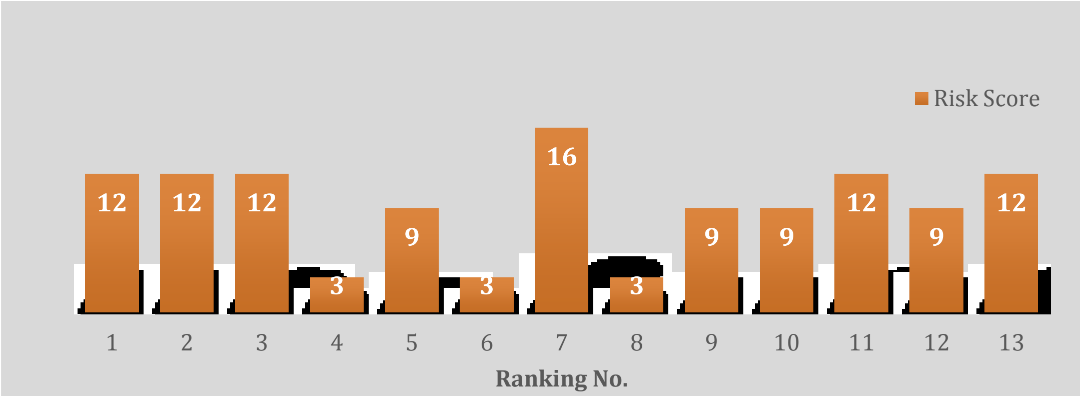

Fig 2. Human Error

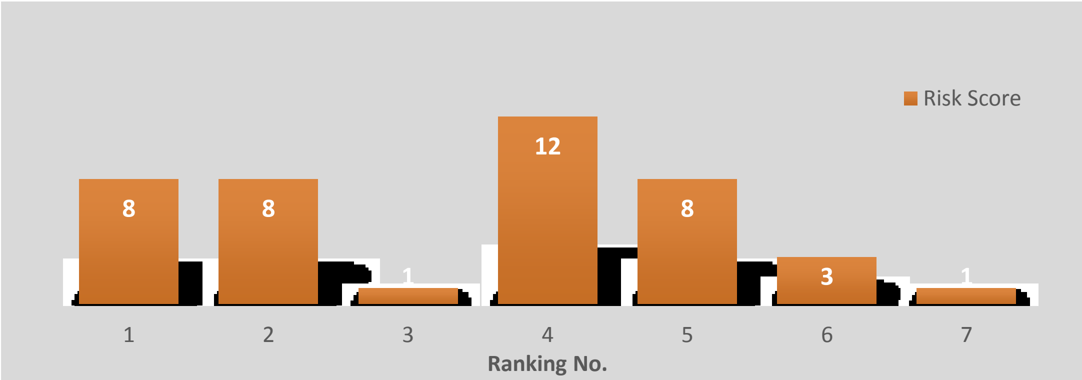

Fig 3. Equipment Failure

Discussion

Milioti et al (2022) The need for risk minimization and safety motivation has drawn attention to security and stability in public transit in recent years**.** This study was conducted to highlight the faults and errors that occur in the Orange Line metro rail transit system. They counted the frequency and aggregated each fault and error. The majority of the errors occur due to human errors, which could lead to severe consequences. OLMRTS is associated with several risks, which are investigated in this thesis by identifying and analyzing the historical data. The degree of risk connected to a system is ascertained using the risk matrix. The approach was selected due to the insufficiency of data to make the implementation of recent risk identification techniques practical. Zhang and Fom (2022)characterize the risk matrix technique as a straightforward and unambiguous technique that categorizes hazards according to the probability and seriousness of their occurrence. It may be utilized to rapidly assess which dangers are to be ignored and which need to be addressed right away.

Train Derailment, collision, red Signal crossing, operation delays, Electric hazards, amputation, and major injuries including casualties can occur due to these faults and error. These are all the risks connected to the Orange Line metro train transport system.

Zhang and Fom (2022) The purpose of system risk assessment is to give decision-makers evidence-based knowledge and analysis so they can decide intelligently how to address a particular hazard. The main advantages of risk assessment are that it informs decision-makers, exposes risks and uncertainties, and complies with the internal regulatory requirements of the business. This is achieved by risk identification, which enables system managers to decide how best to reduce the possibility of losses happening. To reduce potential losses to a manageable level, one can either accept the risk, minimize it, or invest in sufficient internal protective measures. Investing in external indemnity.

Pan and Wu (2020)Emphasizes the significance of human reliability analysis (HRA) in enhancing the reliability of the human-machine interface, particularly in metro railway depot operations, where human-induced accidents are of concern. Kyriakidis (2013) suggested two different perspectives on human error: the individual's and system aspects. Each offers various ideas of error management along with their own distinct models of error causes. Both methodologies have been extensively employed in the process of comprehending the causes of human mistakes in the railway sector. Hong et al (2023)Causation extraction in railway accident analysis is crucial for identifying cause-and-effect relationships between events, enabling a structured description of accidents. Baysari et al (2008) summarize relevant accident causation research regarding human errors. Ahmadi Rad et al (2023) Determine the contributing elements and the complete cause-and-effect sequence that resulted in the accident.

Employee safety training ought to be planned, and work briefings should always be conducted before employees start any task. As the risks associated with metro operations came to light over time, risk analysis became an essential step in safety management.

A monthly test and drill should be conducted to handle emergency situations. 2 to 3 days of training sessions for all staff shall be arranged in a month. Refresher courses and online sessions must be arranged in a week or a month. Other departments, like equipment and maintenance, are interconnected with the routine work of the DCC depot and stabling yard. So, interactions with these staff members to share knowledge of the routine work are fruitful for understanding the background work. Monthly staff evaluations shall be organized including these factors, to enhance the safety and security of the system. They have concluded this study in the conclusion section.

Conclusion

- Safety is of the utmost importance in this company, according to a risk assessment and analysis of human errors in metro railway depot operations.
- Human error has a major influence on the occurrence of events, and there are many and different potential risks associated with metro railway depot operations.
- After analyzing 13 distinct risk-hazard sources, the study's results indicate that human-related hazards are the most likely sources of danger at the OLMRTS.
- Therefore, it is essential to give safety top priority in metro railway depot operations and to take precautions to lessen the possibility of human error.
- The potential equipment failure events that need to be monitored first in order to improve safety—ATS malfunctions, turnout failures, and track circuit malfunctions—are assessed as well.
- The ultimate objective of this particular form of an assessment is to lessen the likelihood of errors and the consequences they could have thereby enhancing safety and system performance as a whole.

Recommendations

The study presented in this article creates an outline for assessing the factors that influence metro railway depot operations performance and evaluating employee performance for various operational scenarios. Expressing the assessment in terms of the relative probability of errors is one way to do it. Still, the findings provide several possibilities for additional study. They consist of:

- It's crucial to look for ways to pinpoint and define the causes and mitigating measures of such errors because the majority of serious incidents on metro trains are brought on by human errors.

Vandalism

For the safety and security of metro railway depot operations, vandalism poses a real threat.

Fire and explosion in the Depot

Fire and explosion Metro railway depots need to take meticulous safety precautions due to the possibility of fire and explosions.

Power substation outage

Substation power outages may have an impact on metro railway operations.

Terrorist Attack in Depot

Attacks by terrorists may have disastrous effects on metro rail operations.

Above are the recommendations of the Orange Line metro rail transit system. Studies should be conducted on this subject to address these recommendations.

In addition, some more recommendations have to be added; all the stations on the Orange Line metro rail should be converted to solar energy to save electricity. Take advertisements from different companies for promotion and generate revenue. These recommendations, when implemented effectively, can contribute to the sustainability and financial viability of the Orange Line metro rail transit system. The transition to solar energy can reduce the system's reliance on conventional electricity sources while showcasing its commitment to environmentally friendly practices. Simultaneously, generating revenue through advertisements can help offset operational costs, improve services, and enhance the overall experience for passengers.

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