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ENSURING INDUSTRIAL CONSTRUCTION WORKERS SAFETY THROUGH PROFESSIONAL MATERIAL HANDLING SYSTEM

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Keywords	***Abstract***
Material handling, Construction safety, Mechanical equipment, Ergonomics.	In industrial construction environments, the handling of heavy and hazardous materials poses significant risk to workers safety. Accidents resulting from improper material handling remain one of the leading causes of injuries and fatalities on industrial construction sites. This project explores the implementation of a professional material handling system, and improve overall material handling and operational efficiency, by integrating mechanical equipment, ergonomic practises, and worker training, PMHS minimizes human error and physical strain. The study also examines the role of automation and smart technologies in material handling practises. Through detailed analysis of system components, safety benefits, and case studies, this project underscores how adapting a professional approach to material handling can significantly reduce accident rates, ensure regulatory compliance, and foster a culture of safety in industrial construction.

1. INTRODUCTION

The construction industry, specifically the industrial sector, is intrinsically hazardous due to its dynamic work environments, heavy machinery, and elevated work areas. Among the various occupational risks in the construction industry, material handling systems are essential for the

efficient movement, storage, protection and control of materials throughout a project. These systems incorporate a variety of methods and equipment designed to facilitate the safety and effective handling of materials, which is crucial given the intrinsically risks associated with construction work. Industrial construction projects are complex, involves numerous workers, hazardous materials and machinery. Prioritizing safety is not just a good practice; it is absolutely critical. A reliable safety program protects worker from injury, prevent project delay and ensures the successful completion of projects. This introduction will delve into why safety is important in industrial construction, highlighting the key areas of concern and benefits the proactive approach. We will explore the potential risks, the importance of regulations and the impact of a strong safety culture. Pre-site safety training is integral and if poorly executed by attempting to convey general safety protocols is not site-specific, it can create further gaps in understanding unfamiliar site hazards, increasing the chances of accidents occurring. To resolve this issue, there is a need to develop an all-encompassing safety induction. Such program equips personnel with crucial information on hazards unique to the location, proper handling of equipment, emergency procedures, and comprehensive safety regulations.

2. OBJECTIVES

1. To identify the common risk hazards associated with manual and mechanical material handling in construction environments.
2. To analyse current material handling practices and assess their impact on worker safety and productivity.
3. To introduce professional, Ergonomic and mechanized material handling solutions tailored for industrial construction sites.
4. To evaluate the effectiveness of these system in reducing injuries, Fatigue and Accidents.
5. To promote a culture of safety compliance through training, standardization and integration of safety protocols in material handling processes.
6. To recommend guidelines based on international standards (e.g., ISO 45001:2018, OSHA 29 CFR 1926 Subpart H) for safety and standardized material handling practises.

3. REVIEW OF LITERATURE

The published research by various authors on topics related that are closely related to the Manual Material Handling (MMH) risks include back injuries, fatigue, and falls. Mechanical handling risks involve machine entrapments, collisions and dropped loads. Contributing factors include improper training, lack of PPE, and poor site planning.

The construction site and material handling literature on safety focuses on great challenges and solutions in both manual and mechanical operations. Poor training, a lack of personal protective equipment (PPE), and failure to plan often contribute to such MMH risks as back injuries, fatigue, and falls and to such mechanical risks as entrapments, collisions, and dropped loads. To comply with these problems, standards, such as OSHA and ISO 45001:2018 focus on proactive safety controls

and risk management integration in their requirements. Material management is an important aspect which contributes to the success of a project and therefore, Rajyaguru (2023) emphasizes that alignment of material logistics with organizational policies should be laid out. According to Shakantu et al. (2022), the automation of construction material handling in Nigeria is insufficient, which slows the interaction and makes it more costly. Safety training of workers is an important way of improving awareness, and thus, reducing accidents, as discovered by Anil Kumar et al. (2013) and, according to Albert et al. (2017), safety performance is improved when hazard recognition intervention is used and is specific to the type of hazard. The areas in focus are also ergonomics and biomechanics. OWAS system was presented by Karhu et al (1977) to examine and transform the working posture that results into enhanced workplace design. According to the study of Ning et al. (2014), and Antwi-Afari et al. (2017), the carrying positions significantly contribute to minimizing the spinal stress and fatigue when the loads are lighter, and the muscular loads are associated with a higher value of strain and lower endurance. According to Inyang et al. (2014), ergonomic risks include awkward or repetitive motion which leads to musculoskeletal disorders (MSDs), and thus, ergonomic should be incorporated into planning. Recent reviews by Wang et al. (2015) among others have pointed out the usefulness of newly found risk assessment methods such as wearable sensors and vision-based technologies. Repetitive handling tasks have been improved by exoskeletons that have been proven to reduce lower back strain and improve comfort and usability (Antwi-Afari et al., 2021) and Zhu et al., 2021). Safety outcomes are also initiated through training and awareness. Virtual safety training is a risk-free and immersive learning experience and was found effective in developing work-at-height development (Rey-Becerra et al., 2021). Dale et al. (2017) note that less complex ergonomic solutions are taken more readily than complex ones, which is why it is essential to resort to simple designs. In India, Patel and Jha (2016) estimate the high number of annual constructions related fatality due to low number of fatality reporting and inaccurate safety statistics whereas Vigneshkumar and Salve (2018) found a high level of disparity between residential construction sectors and commercial construction sector in the awareness of an occupational safety and health management system (OHSMS). Altogether, the literature points to the absolute necessity of comprehensive training, combination of ergonomics and automation technologies, powerful regulation, and active safety culture as the elements of the construction site safety and efficient handling of materials.

4. METHODOLOGY

1. Research Design

This research in follows a systematic and analytical approach to review the relevance of the Professional Material Handling Systems (PMHS) in ensuring safety improvement of the construction workers in the industrial sector. It involves an integration of literature-based analysis of the framework, field observation, regulatory analysis, identification of hazards, and application of particular interventions as means of eliminating risk in the operations of handling materials.

2. Regular Standards and Compliance

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The OSHA standards, in specific 29 CFR 1910 Subpart N, specify the handling and storage of material at workplace. They make an emphasis on safer lifting method, stacking and usage of machine tools and equipment such as forklifts, which is specifically governed by 29 CFR 1910.178. OSHA also requires proper use of personal protective equipment (PPE) as well as constant training of workers in order to avert accidents and injuries. These efforts can be further supported on an international level, through the ISO standards that provide standard guidelines, applicable in countries around the world, including the ISO 45001, which defines the requirements of an occupational health and safety management system. The ISO 3691 also details the aspects of safety pertaining to the design, operation and handling of industrial trucks whereas ISO 11228 series is an overview of ergonomic action on manual handling.

3. Material Handling Framework

Six major components are used to evaluate the material handling process and they are movement, quantity, time, control, safety and analysis. These aspects will lead to a review of the manner in which materials are moved, monitored, maintained and even kept on ground. Alliance of timely and safe and controlled nature of handling materials is the most basic in risk reduction of operations and gain of efficiency.

4. Classification of Material Handling

Material handling operations can be grouped in two broad categories:

Manual Material Handling (MMH)

Manual handling of loads by use of hands through lifting, pushing, pulling or carrying weight. These activities also tend to be associated with musculoskeletal disorders (MSDs) such as sprains and strains as well as occupational overuse syndrome. Workers that are older have a greater chance of risks, given the limited recovery capability and fatigue.

Mechanical Material Handling (MMHE)

The mechanical handling involves the use of tools like the forklifts, cranes and the cherry pickers which are used to move the bulk or heavy materials. As much as the mechanical systems increase the efficiency, they bring along new dangers such as machine failures, crashes, and human mistakes. The paper highlights the importance of preventive maintenance, training the operators and abiding by the safety rules to curb these risks.

5. Data Collection

Primary data were collected in form of the observational studies carried in the active construction sites. They were observed in order to record the worker movements, time spent in each task, what type of equipment was used, and the delay pattern. Moreover, near-misses and unsafe actions were studied in order to identify the systemic risks and domains that should be intervened.

6. Risk Assessment

The hazard identification and prioritization were carried out using Job Safety Analysis (JSA) and probability-severity risk matrix. An example of risk classification can be as shown in table 1:

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Table 1: Hazard Identification

Hazard	Likelihood	Severity	Risk Level	Control Measures
Manual lifting of heavy loads	Likely	Major	High	Use hoists, ergonomic training, task rotation
Slips and trips near handling zones	Likely	Moderate	High	Housekeeping, PPE
Musculoskeletal injuries from repetition	Almost Certain	Moderate	High	Ergonomic redesign, Rest break
Contact with moving Machinery	Possible	Major	High	Guarding, LOTO procedures

7. Interventions

As per the analysis of the data and risks identified, a set of interventions was realized as follows: Despatch of Professional equipment,

- Skid Steer Loaders: This is used in the moving and removing process of other materials like soil and debris.
- Palfinger Cranes: Applied in order to implement fine movement and placement of building materials in restricted areas.
- Rock Breakers: These are used in demolishing and breaking large materials during excavations.
- Cherry Pickers: They are applied in installation and inspection works, together with safe vertical access.

8. Ergonomic Redesign of Workstation

Ergonomic changes were made to decrease stress and potential of injury. These were positioning the tools and materials at waist levels, adoption of light, and bouncy gadgets, as well as teaching workers safe ways of lifting.

9. Safety Training and PPE Audits

Safety meetings were held on regular basis to increase the awareness of workers, in terms of handling equipment, identifying hazards and acting in case of an emergency. PPE audits were also used to make sure that safety gear was used according to requirements, building a culture of responsibility and prevention of risk.

5. RESULTS

The implementation of a professional material handling system in industrial construction settings has yielded significant improvements in worker safety, operational efficiency, and risk mitigation. Based on observations, data analysis, and safety audits conducted at construction sites, the following results were documented:

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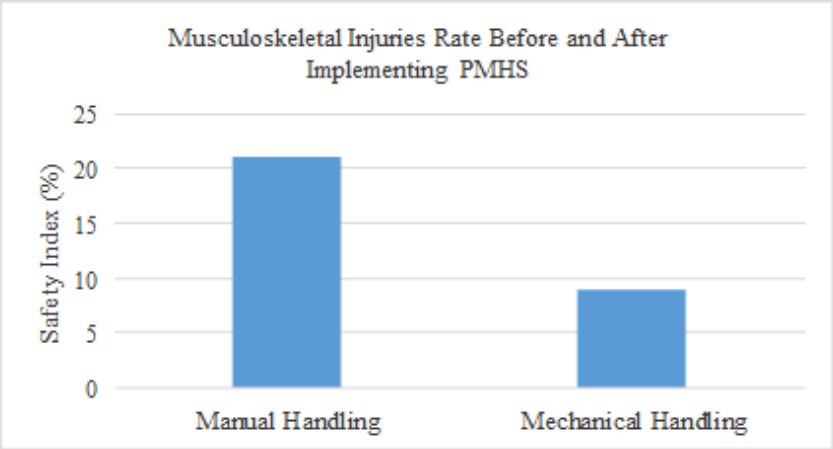

Figure 1: Musculoskeletal Injuries Rate Before and After Implementing PMHS

The above bar graph Fig 1 illustrates the Musculoskeletal injuries dropped by 21%, especially in areas where forklifts, cranes, and hoists replaced manual lifting and carrying. Workers reported less fatigue and strain due to ergonomic tools and mechanical assistance.

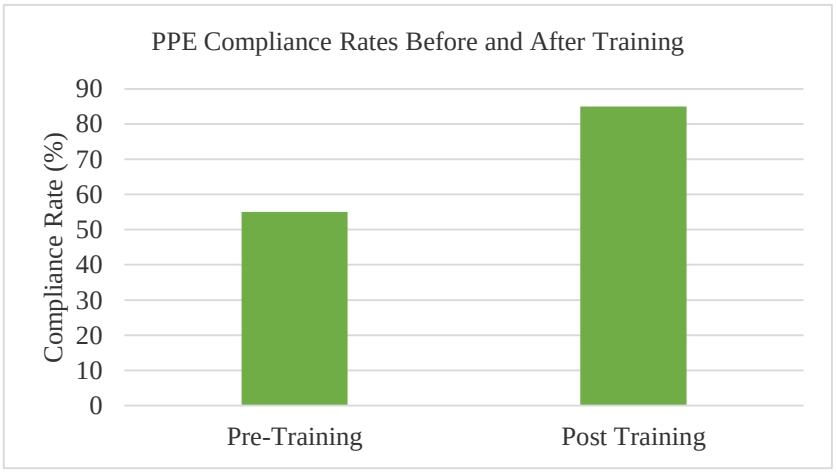

Figure 2: PPE Compliance Rates Before and After Training

In the safety induction, the use of PPE was mandated as indicated in the Fig 2. Compliance with the use of PPE also elevated from 55% to 85%. This reinforces that training placed emphasis on the proper usage of safety equipment, as deemed essential. Elevated use of PPE is critical in preventing injuries while handling equipment.

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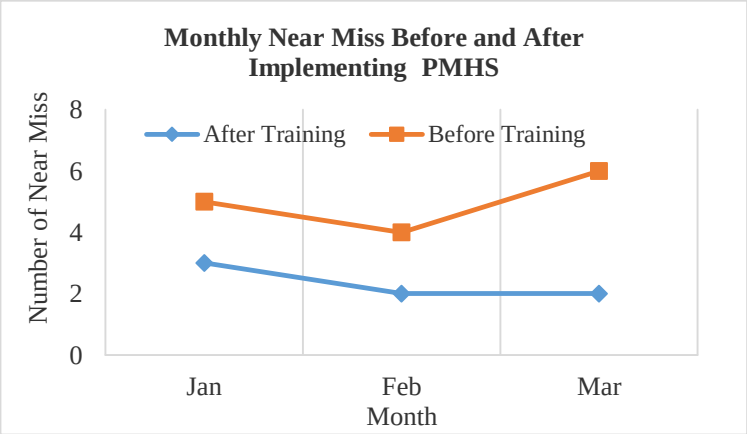

Figure 3: Monthly Near Miss Before and After Implementing PMHS

This line graph Fig 3 depicts the monthly recordings of safety incidents and near misses over three-month periods prior to and following the induction program. The reduction in incident rates following the program indicates a positive contribution to site safety. This reinforces the assumption that site-specific equipment handling training is effective not only in reducing accidents but also improving safe work practices among employees.

As observed the graph Fig 4 Worker Satisfaction Before and After Implement shows that workers were highly satisfied use professional material handling system.

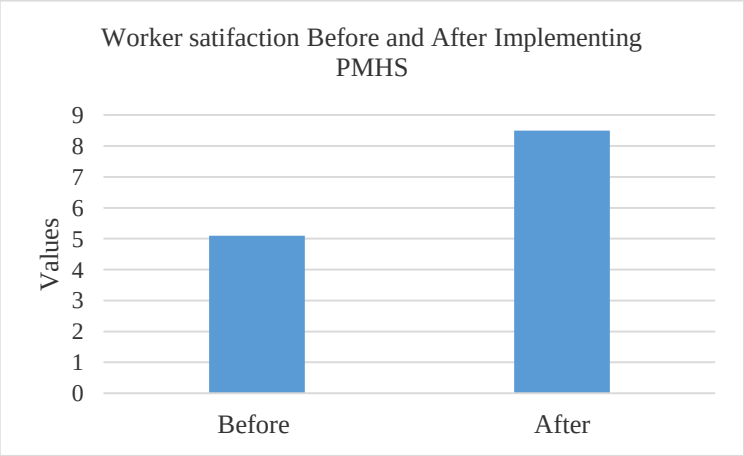

Figure 4: Worker Satisfaction Before and After Implementing PMHS

A 52% reduction in crush and struck-by incidents was observed after deploying skid steers, cherry pickers, and automated lifting tools with proper safety protocols. Use of material handling equipment with built-in safety features (alarms, sensors, limit switches) minimized uncontrolled movements and unexpected hazards.

Use of tracked loaders, hook loaders, and articulated cranes like Palfinger allowed for faster and safer movement of materials, reducing idle time and congestion. Material flow on site was optimized, decreasing delays by an average of 18% across projects.

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6. CONCLUSION

The integration of professional, mechanized systems material handling systems into the construction processes is a great improvement to the safety as well as the efficiency of its worker. These systems mitigate most of the common hazards in the work environment because they reduce the use of manual work and use equipment, e.g., a rock breaker vehicle, cherry pickers, skid steer loaders, as well as truck mounted cranes, plus good maintenance, training, and regulatory compliance. Though the initial costs and the training burden might have been an issue, as could be the case of smaller contractors, the overall payoff in terms of reducing the number of injuries, minimizing insurance claims and preventing project delays proves conclusively that such systems are not singularly productive tools but rather significant components of a holistic and successful approach to work site safety.

7. AUTHOR(S) CONTRIBUTION

The writers affirm that they have no connections to, or engagement with, any group or body that provides financial or non-financial assistance for the topics or resources covered in this manuscript.

8. CONFLICTS OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

9. PLAGIARISM POLICY

All authors declare that any kind of violation of plagiarism, copyright and ethical matters will take care by all authors. Journal and editors are not liable for aforesaid matters.

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