

## A study on crane accidents: investigating the role of hand signals in construction site communication

### Un estudio sobre accidentes de grúas: investigación del papel de las señales manuales en la comunicación en el sitio de construcción

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#### ABSTRACT

Construction industry is one of the largest industries in the global economy. In today's construction industry, where time and profit margins are crucial, modern construction equipments plays a crucial role. Hand signals are frequently used by construction workers on the job site to communicate, as they are easy and effective. However, there can be a risk of miscommunication or misinterpretation with hand signals, resulting in mistakes and potential hazards on the construction site. This paper presents a comprehensive study on crane accidents in construction sites, with a particular focus on the communication between crane operators and signal men through hand signals. The study begins with a literature review on the causes and effects of crane accidents, statistics and incidents on construction sites. The study then investigates the current practices of hand signals on construction sites and highlights the associated safety concerns. The study concludes that the misinterpretation of hand signals between the signal man and the crane operator is a significant contributor to crane accidents. To address this issue, the paper recommends the development of a real-time hand signal detection system for material handling using machine learning and computer vision. The proposed solution will reduce the strain on signal men and improve communication between the signal man and the crane operator, thereby enhancing safety in construction sites.

Keywords: Safety Study, Crane Accidents, Construction Sites, Human Error, Hand Signals, Material Handling, Construction Safety, Signal Man.

#### RESUMEN

La industria de la construcción es una de las industrias más grandes de la economía global. En la industria de la construcción actual, donde el tiempo y los márgenes de beneficio son cruciales, los equipos de construcción modernos desempeñan un papel crucial. Los trabajadores de la construcción utilizan con frecuencia señales manuales en el lugar de trabajo para comunicarse, ya que son fáciles y efectivas. Sin embargo, puede existir el riesgo de falta de comunicación o mala interpretación con las señales manuales, lo que resulta en errores y peligros potenciales en el sitio de construcción. Este artículo presenta un estudio integral sobre accidentes de grúas en sitios de construcción, con un enfoque particular en la comunicación entre los operadores de grúas y los señalizadores a

través de señales manuales. El estudio comienza con una revisión de la literatura sobre las causas y efectos de los accidentes de grúas, estadísticas e incidentes en las obras de construcción. Luego, el estudio investiga las prácticas actuales de señales manuales en las obras de construcción y destaca las preocupaciones de seguridad asociadas. El estudio concluye que la mala interpretación de las señales manuales entre el señalista y el operador de la grúa contribuye significativamente a los accidentes de grúa. Para abordar este problema, el documento recomienda el desarrollo de un sistema de detección de señales manuales en tiempo real para el manejo de materiales mediante aprendizaje automático y visión por computadora. La solución propuesta reducirá la tensión sobre los señalizadores y mejorará la comunicación entre el señalizador y el operador de la grúa, mejorando así la seguridad en las obras.

Palabras clave: Estudio de seguridad, Accidentes de grúas, Sitios de construcción, Error humano, Señales manuales, Manejo de materiales, Seguridad en la construcción, Señalizador.

## INTRODUCTION

The construction industry is an ever-growing sector with a significant influence on a nation's economy. However, the construction industry is often ranked as one of the most hazardous industries due to the high number of accidents, injuries, and fatalities that occur on construction sites. Cranes are essential equipment on construction sites, used for lifting heavy materials and equipment to high elevations. However, the use of cranes also poses significant risks to workers and the public. It is essential for ensuring the safety of workers and the successful completion of projects on time. There are several methods of communication that are commonly used during the operation of cranes on construction sites. The paper presents a comprehensive review of the literature on crane accidents on construction sites. The review includes a safety study, causes of crane accidents, effects of crane accidents, statistics, and incidents. The study aims to identify the common causes of crane accidents and the impacts they have on construction sites. The paper also presents an investigation on current practises of hand signals on construction site.

## LITERATURE REVIEW

A. Safety Study: Abdul R.A.H. et al. (2019) examines crane accidents at construction sites in Malaysia, highlighting their causes. The authors conduct a literature review, including studies from Malaysia and other countries, to identify common causes such as operator error, equipment failure, and inadequate maintenance. The survey results show that operator error is the most common cause in Malaysia, followed by equipment failure and inadequate maintenance. The study emphasizes the need for greater attention to crane safety in the construction industry, recommending comprehensive safety measures. George Y.H. Yu (2017) explores forensic investigation techniques used in analyzing crane accidents. The author discusses potential hazards and highlights various techniques such as site investigation and computer simulations. The study emphasizes accurate data collection and analysis for identifying accident causes. Case studies illustrate the importance of forensic investigation and effective communication among all involved parties. Ivanov G. et al. (2020) provides a comprehensive analysis of accidents

involving tower cranes on construction sites. The authors review previous studies and analyze accident reports from Bulgaria. They find that human factors, such as operator error and lack of training, are the primary causes. The study recommends improved training programs, stricter regulations, and increased awareness to prevent accidents. Krantiraditya D. et al. (2018) aims to identify crane accident causes using a decision tree methodology. The authors emphasize the complexity of these accidents and the need for rigorous analysis. The decision tree analysis identifies factors related to crane operation, environment, and human factors. The authors stress the interrelationship of these factors and advocate addressing them all to reduce accident risks. The study suggests the decision tree methodology can be useful for analyzing incidents in other industries too. Muhamad Z. H. M. D. and Wan Faida W. M. A. (2022) discuss the impact of crane accidents on construction cost among contractors. They highlight the prevalence of crane accidents, their negative effects on project schedules, costs, and reputation. The authors review studies that quantify the financial impact of crane accidents and emphasize the importance of risk management strategies, including safety training, maintenance, and safety technologies. Rahnamayiezekavat P. et al. (2021) conducted a systematic review of crane safety requirements. They emphasize the significance of safe crane operations and outline their methodology for the review. The authors identify 64 relevant studies and categorize them into six main topics, providing a comprehensive overview of crane stability, operator qualifications and training, maintenance and inspection, safety devices and technology, safety management systems, and accident analysis. The study highlights key findings and recommendations, such as regular inspections, advanced safety technologies, and remote monitoring. Richard Skiba (2020) presents best practices and methodology for crane operator training. The study emphasizes health and safety, vocational training, work practices, risk management, and high-risk work. The author discusses the hazards associated with inadequate training and stresses the importance of effective training programs. Different training approaches and certification methods are analyzed, including the use of simulators and practical assessments. The paper also emphasizes the role of risk management in crane operation and the need for ongoing training and education. Shapira Aviad et.al (2017) focus on identifying and analyzing risk factors associated with crane-related accidents and near-miss incidents. They review 206 incidents reported to the Israeli Ministry of Labor and Social Affairs, classifying them based on factors such as crane type, work type, incident cause, and resulting injuries or damage. The study finds that tower cranes and human error are the most common factors involved in incidents. The study provides valuable insights for developing interventions to reduce crane-related risks, including improved training and safety regulations.

*B.* Causes of crane accidents in construction sites: Crane accidents in construction sites can occur due to various factors, including equipment failure, improper use of equipment, operator error, and environmental factors. [1,2,3] However, one of the most common causes of crane accidents is the lack of proper communication between the signal man and crane operator [3,5]. Here are some reasons why communication is critical to preventing Clear signals are essential for crane operators: Crane operators rely on clear and accurate signals from signalmen to maneuver the crane safely [3,5,10]. If the signalman fails to communicate effectively, the crane operator may not be able to understand the intended movement, leading to dangerous or unintended actions [10,12]. Miscommunication

between the crane operator and signalman can cause errors that lead to accidents [2,10,12]. In some cases, the signalman and crane operator may not have sufficient training or experience to work together effectively can result in misunderstandings and accidents [3,5,7]. Construction sites can be unpredictable, and changes in work conditions can make communication between the signalman and crane operator more challenging [2,9,10,12].

C. Effects of crane accidents in construction sites: Crane accidents due to improper communication between the crane operator and the signal man can have severe consequences. Crane accidents due to improper communication can cause severe injuries and fatalities [2,3,4,10,11]. Crane accidents can cause significant damage to property [4,9]. Crane accidents can delay the completion of construction projects [10,11]. Injuries and fatalities can cause work to come to a standstill, leading to a delay in project completion [2,3]. Delay in project completion can result in the loss of revenue for the construction company [3,8]. The cost of repairs and compensation for damages can also add to the loss of revenue [3].

D. Statistics and incidents: Crane accidents in Indian construction sites have led to an increase of 38% in deaths between 2014 and 2019 (The Hindu, 2021). In the US, crane accidents account for approximately one-third of construction site fatalities, causing an average of 71 deaths and 264 injuries each year (OSHA, 2022). In the Indian mining sector, there were 38 fatal crane accidents reported in 2021 (DGMS, 2022). Communication errors were identified as a significant contributing factor in crane accidents in Europe, accounting for 13% of cases (European Agency for Safety and Health at Work). Lack of communication was also found to be a cause of a crane accident investigated by the UK Health and Safety Executive in 2016. A study on the Turkish construction industry revealed that communication errors contributed to 43% of crane accidents between 2005 and 2015 (International Journal of Occupational Safety and Ergonomics). Specifically in India, 144 construction workers lost their lives in crane accidents in 2019 (NSCI, 2020). A significant number of these accidents were attributed to improper communication between the signalman and the crane operator (NSCI, 2020). In September 2021, a crane accident in a construction site in Noida, Uttar Pradesh, shown in Fig.1, resulted in one worker's death and four injuries due to a snapped rope from a tower crane (TNN, 2022). This incident emphasizes the importance of proper communication in crane operation.

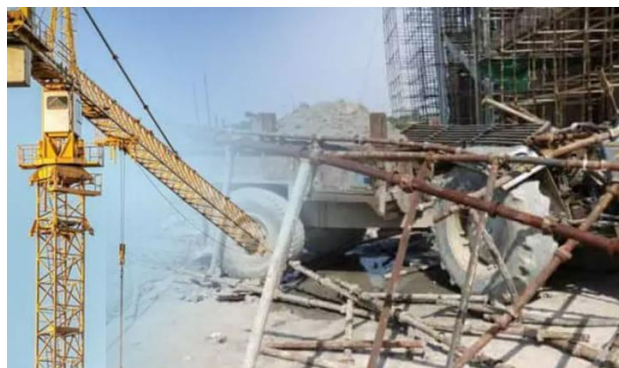


Fig.1 Crane accident which happened in Sector 132, Noida. (Source: Haribhoomi,2021)

In Mumbai in 2020, a crane collapse at a construction site resulted in ten fatalities and multiple injuries. The incident occurred due to improper communication between the crane operator and the signalman, causing severe damage to the building and equipment. In August 2021, a crane accident occurred at a Metro construction site in

Chennai, India, causing three injuries and significant damage to a nearby Metropolitan Transport Corporation (MTC) bus. The crane carrying a reinforcement cage overturned, causing the cage to fall onto the MTC bus, shown in Fig.2 due to a misunderstanding between the signalman and operator, leading to a serious accident and multiple injuries.



Fig.2 Crane accident at the Metro Rail site on Mount-Poonamallee Road Source: The Hindu,2021)

Improper communication between crane operators and signal persons is a leading cause of crane accidents on construction sites. The use of hand signals can be misinterpreted, leading to incorrect crane movements and accidents. To enhance crane safety, clear and standardized communication protocols, including proper training and concise communication, are crucial. By implementing these measures, the risks associated with crane operations can be reduced, ensuring the safety of workers.

#### HAND SIGNALS IN CONSTRUCTION SITE: AN INVESTIGATION

Hand signals are commonly used on Indian construction sites for communication between the signalman and crane operator. This traditional method persists due to limited access to modern communication systems and inadequate worker training. However, relying solely on hand signals poses various challenges and risks, including inefficiency, lack of personal protective equipment (PPE), and a high potential for accidents. The section presents a detailed analysis of site visits to construction sites in Ernakulam district, Kerala. The purpose was to evaluate the current communication practices between crane operators and signalmen. It emphasizes the importance of effective communication and the potential for enhancing safety through real-time detection of hand signals using computer vision. During the site visit, it was observed that hand signal communication was the primary means of communication between the crane operator and the signal man, shown in Fig 4. However, in some cases, hand signal communication was used along with radio communication. Workers from different job roles, including riggers, supervisors, and site engineers, were seen giving hand signals. It was noticed that workers from different cultural backgrounds were also involved in signaling, which may lead to miscommunication due to language barriers. It is essential to ensure that all workers understand the hand signals and their meanings to prevent accidents caused by miscommunication.



Fig.4 Hand Signal given to the crane operator to swing the boom of the crane



Fig.5 Unsafe behavior of Signal Man by standing on top of bars without safety gears

During crane operation, workers were engaged in various activities, such as welding and connecting materials, in the area where the crane's boom rotates, shown in Fig.6. The signal man, who lacked proper safety gear and designation, was observed standing on bars without safety belts, shown in Fig.5, which was highly risky. These unsafe practices can result in severe accidents.



Fig.6 Construction worker giving signals without safety boots

It is crucial to provide adequate training to workers and enforce proper safety protocols. There is no proper designation for signal man like in foreign countries, and the worker who gave a signal was not seen wearing safety boots or PPE, shown in Fig.6. There were also instances where the signal man was not visible to the crane operator, creating a potential risk of accidents. Ensuring the signal man's visibility to the crane operator is essential for safe operations. To enhance safety on the site, it is crucial to improve communication between the crane operator and the signal man. Real-time detection of hand signals given by the signal man using computer vision technology can

pave the way for a human-computer interface, allowing for safer crane operations.

#### CONCLUSION AND RECOMMENDATION

On construction sites, it is common for workers to rely on hand signals to communicate and express thoughts due to their simple but effective nature. However, hand signals may not always be captured timely or interpreted correctly in the fields, which easily lead to construction errors and even accidents. A safety study was conducted to analyze the accidents occurred due to heavy equipments, mainly cranes. The paper has presented a review of the literature on crane accidents on construction sites and highlighted the misinterpretation of hand signals as a potential cause of accidents. Also, an investigation was done to know the communication practices on a construction site during the material handling operations using heavy equipments. The findings suggest that effective communication is critical in ensuring safe and efficient crane operations on construction sites. To address this issue, the paper proposes the development of a real-time hand signal detection system using machine learning and computer vision. The system detects and displays hand signals, improving communication between the signal person and crane operator. It offers benefits such as enhanced safety, increased efficiency, and reduced strain on the signal person. This technology has promising future potential, revolutionizing hand signal communication and improving material handling operations. With further advancements in machine learning, computer vision, and IoT integration, even more sophisticated systems can be developed to adapt to different conditions and ensure optimal safety and productivity. Implementing this solution in the construction industry can minimize accidents and injuries, making it a valuable innovation for crane operations.

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