

Barriers to the implementation of safety leading indicators in civil engineering projects

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Abstract

As existing studies have shown, the barriers to implementing safety-leading indicators in civil engineering projects are multifaceted. These barriers encompass various categories, such as management commitment, safety culture, behaviour, and awareness. Safety management, which involves a range of formal and informal practices, is pivotal in preventing occupational accidents and injuries. Meanwhile, adopting a proactive approach to safety has been observed to aid in accident prevention and workers' safety. This study identifies and highlights the barriers that hinder the implementation of safety-leading indicators in civil engineering projects by reviewing existing literature. Identifying these barriers provides insights into achieving safety in the construction industry. In addition, it is a step closer to addressing this issue to achieve the safety and well-being of workers in the construction industry.

Keywords: Health, Safety and Environment, Safety Indicators, Barriers

1. Introduction

Various scholars have concurred that civil engineering projects are amongst the most dangerous working environments compared to other sectors. Despite their important socioeconomic role, civil engineering projects have a high rate of accidents, making it an unsafe, highly dangerous, and complex industry (VanHeerden, et al., 2018). Despite the knowledge gained and the various acts and regulations, e.g., Occupational Health & Safety Act 85 of 1993 in place that, if followed, should improve H&S performance on civil engineering project sites, numerous serious accidents continue to occur (Haupt & Pillay, 2016). Ghosh, et al., (2023) revealed that civil engineering projects had the greatest rate of fatalities among all industrial sectors in 2020, with 1,008 instances, followed by manufacturing with 340 and mining and oil and gas extraction combined with 78 fatalities for the same year. According to Bureau Of Labor Statistics, (2022), Despite a 2.6-percent decrease in fatalities from 2020, the civil engineering projects occupation had the second highest number of occupational deaths (951) in 2021. This occupation's fatality rate fell from 13.5 deaths per 100,000 Full Time Employee (FTE) workers in 2020 to 12.3 in 2021. The statistics highlighted in the study show that the current Health & Safety interventions are not helping curb the scourge of civil engineering project accidents. Some other safety interventions and concerted efforts must be implemented to eliminate accidents in civil engineering projects.

Implementing safety-leading indicators (predictive measures) aims to enhance safety protocols by identifying potential hazards and risks in advance, thereby mitigating the likelihood of accidents and promoting a proactive approach to ensuring a safe work environment. Various scholars agree that implementing safety-leading indicators in civil engineering projects can assist in curbing accidents that result in fatalities, property damage and production loss. According to the study by Xu, et al. (2021) Safety leading indicators' predictive usefulness is based on their ability to track system performance over time, providing early warnings of potential changes that could lead to accidents or injuries, and motivating steps to avoid negative consequences and achieve continuous improvement. Safety leading indicators seek to reduce errors and identify and reinforce positive aspects of Health & Safety systems (Xu et al. 2021).

This study is also supported by Mousavi et al. (2020), who articulates that proactive and prognostic measurements known as safety leading indicators assist in detecting possible risks and mitigating hazards at their source. Costin et al. (2019) agree that active leading indicators have the potential to detect safety hazards and prompt action to prevent occurrence. The study by Hinze, et al., (2013) also agrees with Xu, et al. (2021) & Costin, et al., (2019) that the safety leading indicators are intended to monitor civil engineering project safety

processes. When the measures reveal a flaw in the process, some type of intervention is initiated. That is, leading indicators allow you to track or monitor the performance of a process as it occurs, or they can show whether a specific process or processes are being implemented as planned.

Sheehan et al. (2016) is of the view that Safety Lagging indicators focus on past incidents and injuries. This view is supported by Sinelnikov et al. (2013), who also agree that the typical method for evaluating the effectiveness of a safety programme is lagging indicators, which are the number of previous occurrences such as accidents, illnesses, and deaths. The study by Jazayeri & Dadi (2017) concurs with the other scholars on the safety lagging indicators they record “after the fact” failures. Lagging indicators are the traditional safety metrics used to indicate progress toward compliance with safety rules. These are the bottom-line numbers that evaluate the overall effectiveness of safety at organization’s facility. They tell you how many people got hurt and how badly. Lagging indicators are traditional safety metrics that measure past incidents like injury frequency, severity, OSHA recordable injuries, lost workdays, and worker's compensation costs (Jazayeri & Dadi, 2017). Moreover, they evaluate the overall effectiveness of safety by showing how many people were hurt and how badly. However, relying solely on lagging indicators can be limiting as they focus on past events and may not reflect how well a company prevents future incidents. Janackovic, et al., (2013) also alluded that, traditionally, safety performance is evaluated after a loss (e.g., accident rate, injury rate, cost of injury). This implies that to evaluate this performance, there needs to be an incident or an injury to someone. Thus, the indicators cannot give the information required to prevent similar incidents in the future. We call these performance indicators trailing or outcome indicators (Janackovic et al., 2013). According to the study by Xu, et al. (2021) safety leading indicators' predictive usefulness is based on their ability to track system performance over time, providing early warnings of potential changes that could lead to accidents or injuries, and motivating steps to avoid negative consequences and achieve continuous improvement. Safety leading indicators sought to reduce errors and identify and reinforce positive aspects of Health & Safety systems. Xu et al. (2021) & Costin et al. (2019) agree that active leading indicators can detect safety hazards and prompt action to prevent occurrence/accident. Occupational health and safety (OHS) accidents in civil engineering projects are significantly higher in developing countries than in developed ones. As a developing country, South Africa is not immune to that predicament (Kheni et al., 2008; Adekunle et al., 2023).

2. Civil engineering projects and safety

Civil engineering is a branch that focuses on the design, construction, and maintenance of infrastructure and large-scale projects essential for society's well-being (Middle East College, 2019). Middle East College (2019) highlighted some examples of how civil engineering projects contribute to enhancing people's lives through Highways and Transportation: Civil engineers design and construct highways, roads, and transportation networks to facilitate the movement of goods and people, reducing travel times, congestion, and improved safety. 2. Buildings: Civil engineers are involved in the design and construction of buildings, including schools, hospitals, offices, and residential complexes. They ensure the structural integrity, functionality, and safety of these structures. 3. Water Resources: Civil engineers work on projects related to water supply, drainage systems, and wastewater treatment plants. They design reservoirs, dams, and canals to manage water resources, ensuring a sustainable water supply for communities. 4. Bridges: Civil engineers are responsible for designing and constructing bridges that connect communities, allowing safe passage over obstacles such as rivers, valleys, and highways.

Despite the concerted efforts of government officials, industry practitioners, and researchers to enhance construction safety, the construction sector worldwide continues to be plagued by the persistent reoccurrence of similar types of incidents (Chan, et al., 2022). Moreover, according to Chan et al. (2022), between 2000 and 2020, the US construction industry experienced 23,067 accidents involving individuals falling from elevated positions. Annually, an average of 150 employees perish, and hundreds get injuries as a result of accidents occurring in construction projects in Bangladesh (Ahmed & Hoque, 2018). In 2017, the Bangladeshi construction projects industry experienced a total of 179 fatalities among its employees because of accidents (Ahmed & Hoque, 2018). Furthermore, this number was higher than the figures recorded in 2016 and 2015, which stood at 145 and 172 employee deaths respectively (Ahmed & Hoque, 2018). Civil engineering projects account for 19% of all industrial fatalities in the United States, and it was reported that civil engineering projects had the highest fatality rate (10.1 fatalities per 100,000 workers) of any industry (Chan et al., 2018). For South Africa, the statistics show similar evidence (Allsopp, 2020). The civil construction industry in South Africa significantly contributes to the prevalence of work-related events in the country, frequently resulting in injuries or fatalities (Allsopp, 2020). The below incident statistics for the South African building industry (Civil Engineering Projects) were gathered from the Federated Employers Mutual Assurance Company (Pty) Ltd (FEM, 2023).

Table 1: Breakdown of fatalities related to Civil Engineering Projects Activities. (FEM, 2023).

	Fatal Accidents	Lost Days	Number Of Accidents	Permanent Disabilities Resulting in Pension
Total For 2023	14	1,192	1,313	5
Total For 2022	47	58,188	6,16	18
Total For 2021	59	77,61	6,975	23

Civil engineering projects contribute to economic growth and gross domestic product (GDP) (VanHeerden et al., 2018). Despite its important socioeconomic role, civil engineering projects have a high rate of accidents, making it an unsafe, hazardous, and complex industry (VanHeerden, et al., 2018). Van Heerden et al. (2018) believe that accident rates in civil engineering projects are unacceptably very high, and workers, organizations, society, and countries all suffer because of poor health and safety standards. This view is supported by FEM (2023), which reported that there were 120 fatal accidents in South Africa between 2021 and 2023 related to civil engineering projects.

Implementing safety leading indicators in civil engineering projects involves various processes and considerations. According to Ejohwomu, et al. (2021) there are various examples of safety leading indicators that have been described, such as Organizational commitment, safety auditing, training and orientation, project level (client engagement, designer engagement, contractor engagement, supply chain and workforce engagement, safety design, plan for safety, hazard identification and control, safety learning, recognition and reward, and site communication). This study confirms that the positive safety culture (organizational commitment) as a safety leading indicator plays a pivotal role in reducing accidents and fatalities in civil engineering projects.

Management behaviour is gaining more academic attention as a significant organizational antecedent of worker safety behaviour (WSB) because it is the root cause of occupational safety accidents (Fang, et al., 2015). The study by Feng & Trinh (2019) defines the term "organizational culture" as the collective behaviours, attitudes, norms, and values exhibited by individuals and groups within an organization. It encompasses their perceptions, thoughts, and overall mindset that shape the organization's dedication, approach, and effectiveness in relation to its safety system. Furthermore, organizational culture influences how personnel behave and respond in the context of the company's ongoing safety performance on civil engineering project sites.

Ejohwomu et al., (2021), revealed that civil engineering project tasks have inherent occupational health and safety (OH&S) risks. According to a study conducted by Ejohwomu et al. (2021), civil engineering projects were responsible for at least 100,000 deaths worldwide, accounting for 30% of all fatal injuries. Poor safety culture is one of the main factors that causes injuries and deaths in civil engineering projects (Machfudiyanto et al., 2016). Highway construction and maintenance operations, as one of the civil engineering projects, frequently require personnel to work near moving traffic, posing significant safety risks to both construction workers and motorists (Awolusi et al., 2019).

According to Machfudiyanto, et al., (2016) the term "safety culture" refers to an organization's or industry's attitudes, beliefs, perceptions, and values regarding safety, as well as the collective behaviours and practices that prioritize safety and promote a safe working environment. Lately, more construction managers, supervisors and workers have been travelling to different regions or countries to execute civil engineering project work; the construction projects industry's increasing globalization has created new safety challenges as the migrant workers from other regions are not conversant with health and safety culture of the other regions in the world (Wei, et al., 2020).

Wei, et al., (2020) suggest that to avoid health and safety accidents, workers from other countries must understand the local health and safety culture and regulations e.g.; in South Africa, there have been several Asian civil engineering project workers who migrated to the country and their health and safety culture is different to the one of the South Africans. So, they must be conversant with the positive health and safety culture of the country where they are employed. Zohar as cited by Hu, et al., (2020) proposed that safety climate perceptions as a safety leading indicator can motivate safety performance because they define a work context in which employees perceive that (a) safety is a priority in their workplace and that (b) safety behavior (e.g., adherence to safety rules and procedures) is valued and supported by the organisation's top management. Several meta-analysis studies have supported the positive relationship between safety climate and safety performance (Hu, et al., 2020).

One method of demonstrating a commitment to developing and promoting a positive Health and Safety

culture and safe working practices is to provide employees with adequate training, which is also a legal requirement (Skeepers, 2015). Moreover, civil engineering projects involve high risks and employees must be engaged on all levels and thus require training designed to correct observed shortcomings in employee knowledge, skill, and health and safety attitudes (Skeepers & Mbohwa, 2016). In civil engineering projects, supervisors play a critical role in the planning, organization, and facilitation of daily work activities of predominantly subcontracted workgroups in construction, and they are the conduit through which organizational priorities are communicated to the workforce, despite having little formal management training (Lingard, et al., 2019). This study highlights the importance of employee training as a safety leading indicator in civil engineering projects.

3. Barriers to the implementation of Safety Leading Indicators in civil engineering projects

Implementation of safety leading indicators in civil engineering projects might be hindered by certain factors the organisations might face. To ensure smooth implementation of safety leading indicators, those barriers must be identified to achieve the desired safety outcomes. This section will focus on exploring the barriers to implementing safety leading indicators that can be used to improve safety and health outcomes in civil engineering projects. According to several sources, various barriers hinder the implementation of safety leading indicators in civil engineering projects. Regarding safety leading indicators, it is important to identify relevant and accurate indicators that can help improve safety outcomes in civil engineering projects. Leading indicators determine the quality of activities that prevent adverse outcomes and can be used as early warning signs to prevent accidents and injuries (Janackovic, et al., 2013). To overcome the barriers to implementing safety leading indicators in civil engineering projects, it is important to prioritize data collection initiatives related to occupational diseases and injuries, establish a national occupational health and safety policy and strategy, and improve OHS regulation and enforcement.

Table 2: Barriers to Implementation of Safety Leading Indicators

Barriers to implementation of SLI	Source
Lack of management commitment	Maliha, et al., (2021)
Organisations not making provision for health and safety costs.	Aghimien, et al., (2018)
Organisations lack the resources and technical expertise to comply with the relevant OHS regulatory requirements.	Amoah & Mlenzana, (2022)
Lack of employee H & S and on-the-job training	Maliha, et al., (2021)
Insufficient supervision	Maliha, et al., (2021)
Gross under-reporting of accident and injury	Okoro, et al. (2016)
Lack of equipment maintenance.	Maliha, et al., (2021)
Non-implementation of H&S regulations	Maliha, et al., (2021) & Buniya, et al., (2021)
Lack of H&S risk management knowledge (SMME)	Belayutham & Ibrahim, (2019)
Management lacks engineering or construction background	Belayutham & Ibrahim, (2019)
lack of financial capability	Belayutham & Ibrahim, (2019)
Language barrier in H&S communication	Oswald, et al., (2019)
Tight project schedule	Buniya, et al., (2021)
Lack of collaboration between stakeholders	Buniya, et., (2021)

3.1 Lack of management commitment: Maliha et al. (2021) and Xu et al. (2022) have identified several barriers to implementing safety leading indicators in civil engineering projects. These include insufficient supervision, lack of management commitment, weak implementation of health and safety regulations, and not integrating the safety management system into business strategies and other functions. Additionally, not providing sufficient resources and a safety budget, not having a safety leadership, and not having a management

commitment to safety policies and rules are also identified as impediments to implementing safety-leading indicators in civil engineering projects. These studies emphasize the importance of safety leadership and management's commitment to safety policies and rules. These studies' findings are categorized into four dimensions: an unfavorable work environment, poor governance, a lack of safety awareness, and an unsupportive transactional business model.

3.2 Organizations not making provision for health and safety costs: The study by Aghimien, et al., (2018) indicated that civil engineering contractors are in an unfair position because they may lose tenders or negotiations to competitors who are less committed to health and safety by not making provision for health and safety costs, as the overall costs will increase. This is a problem for site safety because it allows contractors to relinquish proper safety implementation to be awarded or win construction projects. As a result, the contractor's organization may develop a poor safety culture, which leads to unsafe worker behavior and invariably site accidents. This is one of the barriers to implementing safety-leading indicators in civil engineering projects.

3.3 Organizations lack the resources and technical expertise to comply with the relevant OHS regulatory requirements: Amoah & Mlenzana (2022) explained that emerging contractors are often ill-equipped to deal with OHS requirements for site work, and principal contractors often push the burden of OHS for their sites onto subcontractors who lack the resources and technical expertise to comply with the relevant OHS regulatory requirements. This is a serious issue, as OSHA requires all contractors and subcontractors in the construction industry to provide a safe workplace for their employees and not create safety hazards for the employees of other contractors. OSHA prohibits contractors and subcontractors from requiring any labourer or mechanic employed under the contract to work in surroundings or under conditions that are unsanitary, hazardous, or dangerous to their health or safety. To address this issue, contractors and subcontractors must develop necessary safety and health programs and provide resources to their employees to ensure compliance with OSHA regulations.

3.4 Lack of employee H & S and on-the-job training: The study by Maliha, et al. (2021) found that safety training is a crucial factor in improving health and safety levels in the workplace. However, some employers prioritize completing tasks quickly and getting paid over providing adequate employee training. This is a concerning issue as safety training is essential in reducing accidents and improving safety performance in the workplace. According to OSHA, providing training for all employees and workers is crucial, and training materials should cover the costs of accidents, the impact of good safety performance, and relevant legislation. It is also important to emphasize company safety objectives and client contractual relationships on safety issues.

3.5 Insufficient supervision: Maliha et al. (2021) state that insufficient supervision can be a major barrier to implementing safety-leading indicators in civil engineering projects. Safety supervision refers to the comprehensive supervision and inspection of the safety conditions and implementation of the safety responsibilities of the relevant subjects by the construction administrative departments and relevant government departments in accordance with laws, regulations, and relevant standards.

3.6 Gross under-reporting of accident and injury: The study by Okoro et al. (2016) found that there was gross under-reporting of accident and injury statistics, which made historical records unreliable and misleading as indicators of safety performance. The under-reporting occurred in some organizations, most likely because health and safety rates as a measure, particularly when linked to reward systems, could lead to such events not being reported to 'maintain' good safety performance. Several studies have examined the extent of under-reporting of workplace injuries and illnesses, with some finding that under-reporting rates were higher in organizations with poorer organizational safety climates or where supervisor safety enforcement was inconsistent.

3.7 Lack of equipment maintenance: Maliha et al. (2021) articulated that lack of equipment maintenance can be an impediment to implementing safety leading indicators in civil engineering projects, as proper maintenance of construction equipment is crucial to ensure that the equipment is functioning properly and safely. Equipment that is not maintained poses an H&S risk to the operators.

3.8 Lack of H&S Risk Management Knowledge: Lack of health and safety (H&S) and risk management knowledge is viewed as one of the barriers to the implementation of safety leading indicators in civil

engineering projects (Belayutham & Ibrahim, 2019). Risk management in civil engineering projects is designed to plan, monitor, and control those measures needed to prevent exposure to risk (Belayutham & Ibrahim, 2019). To do this, it is necessary to identify the hazard, assess the extent of the risk, provide measures to control the risk and manage any residual risks without this safety leading indicator it is possible that there might to risk of accidents, loss of money or time, damage to property, or loss of reputation.

- 3.9 Non-implementation of H&S regulations:** Non-implementation of health and safety (H&S) regulations is one of the barriers in implementing safety leading indicators in civil engineering projects. The construction industry is heavily regulated, and companies must comply with regulations to reduce health and safety incidents and financially protect themselves from penalties and delays. However, non-compliance with H&S regulations is a common issue in the construction industry (Buniya, et al., 2021). This non-compliance can be due to poor management, lack of attention to safety, outdated safety rules and regulations, and the belief that occupational safety procedures and requirements increase the cost of construction.
- 3.10 Management's Lack of engineering or construction background:** Belayutham & Ibrahim, (2019) explained that failures in safety compliance are caused by an inability to fully understand the construction process and requirements. Most of the owners and management staff are civil servants with no engineering or construction background.
- 3.11 Lack of Financial Capability:** Lack of financial capability is one of the barriers to implementing safety leading indicators in civil engineering projects. Implementing safety leading indicators requires resources and financial investment, which can be a challenge for some civil engineering projects, especially for small organizations (Belayutham & Ibrahim, 2019).
- 3.12 Language barrier in H&S communication:** Oswald et al. (2019) discovered that construction projects are becoming more nationally diverse as globalization and migrant movement increase. Language barriers present an obvious but largely unresolved H&S communication challenge in multinational workforces, with current strategies in use yet to be evaluated.
- 3.13 Tight project schedule:** Buniya, et al., (2021) revealed that another common impediment to the implementation of safety programs is a tight project schedule. Working on a tight schedule adds additional pressure and stress, which can lead to health and safety issues as well as decreased productivity.
- 3.14 Lack of collaboration between stakeholders in a project:** Lack of collaboration between project staff and safety personnel is a barrier to the implementation of safety leading indicators in civil engineering projects (Buniya, et., 2021). This lack of collaboration can lead to ineffective safety programs, poor risk management practices, and ineffective safety management Buniya, et., (2021).

4. Conclusion

The study identified the various barriers to a proactive approach to safety on civil engineering projects. Addressing these barriers requires a concerted effort from all stakeholders involved in civil engineering projects. Strategies to improve safety performance include but are not limited to management commitment to health & safety, providing a sufficient budget for health and safety provisions, incorporating safety as a pay item in contract documents, conducting regular training for employees, and ensuring compliance with safety standards through periodic inspections. Moreover, fostering a safety culture through active communication, information transfer, and recognition of safety achievements can significantly enhance safety practices on construction sites. By identifying, understanding, and actively mitigating these barriers, the construction projects industry can create a safer working environment, reduce accidents, and ultimately improve the overall safety performance in civil engineering projects.

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