Safety Considerations in Mega Construction Projects

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The construction business is known for its decentralised nature and high levels of mobility, making safety culture all the more critical. All sites and workers of a top construction business and its subcontractors were surveyed using a thorough safety climate questionnaire. Because of the inherent risks in the construction industry, there must be a greater emphasis on safety measures and an improvement in the safety performance of organisations operating in this sector. Since ensuring one's own safety is neither a perk nor a perk that can be disregarded, it is critical to have a mechanism in place to forestall any danger. seeks to discover a novel approach to facilitating the gathering of data and information from professional expertise on successes, failures, and innovations in health and safety management for megaprojects, with the purpose of drawing valuable lessons to guide better practice in this area. Due to a lack of safety education, the results show that construction workers have a poor degree of behavioural safety awareness. Misuse of safety equipment or ignorance about its appropriate use increases the accident rate. Workers on the job site often have a negative attitude towards safety because they are under pressure to meet deadlines and prioritise productivity above safety. It is believed that a more proactive strategy for safety management is necessary to turn around the trends of rising accident and death rates. To successfully decrease risks, it is necessary to promote behavioural safety among workers, tackle the underlying reasons of insufficient safety awareness, and establish a culture that prioritises safety above expediency.

Keywords: Safety culture, Construction industry, Behavioral safety awareness, Proactive safety management.

1. Introduction

Megaprojects are very large-scale endeavours, sometimes costing one billion dollars or more, and posing difficulties for principal contractors due to their unique and inherent risks. The construction industry has a higher injury and fatality rate than other sectors, making safety and health concerns among the most significant risks in megaprojects (Aminbakhsh et al. 2013).

There has been a slowdown in the pace of advancements in construction safety, despite safety being the primary problem (Chen et al. 2017). People from all around the world work together on multicultural megaprojects as designers, contractors, subcontractors, and suppliers. International teams of designers, builders, subcontractors, and suppliers must coordinate their efforts to complete the project successfully. Overall, society benefits from megaprojects since they create more jobs and encourage the growth of related sectors (Marrewijk, 2007).

There are much more accidents and more serious injuries in high-rise building construction compared to medium- and low-rise structures due to the high-altitude activity and the excavation of deep foundation holes. Constant danger exists in the form of injuries and deaths caused by falls and the impact of falling items. A tremendous increase in the amount of high-rise development has been seen throughout East Asia, namely in China, due to the region's booming economy and fast urbanization (Qazi et al., 2016).

Strict regulations need to be established and well executed in order to improve the project's safety features. The schedule, money, and other parameters of the project are affected by this. There is a pressing need for the construction industry to reevaluate and tackle the new challenges in order to achieve a safe working environment, especially with megaprojects and other unique construction projects that include a lot of uncommon and hard labour (Giezen, 2012).

Ensuring that no one involved in the massive construction project is at risk of accidents requires a well-defined goal, a methodical approach, and a constant dedication to improving the process from the initial design phase all the way through the rest of the project. Therefore, it is necessary to develop more intricate and stringent methods to ensure and enhance the safety performance of megaprojects, which directly impacts the safety protocols implemented in their individual projects. Construction companies have substantial obstacles in complying with health and safety laws in MCPs (Hollmann, 2017). Studies indicate that the construction sector incurs significant financial losses each year due to unforeseen repercussions resulting from inadequate safety management. The ultimate sum is influenced by mortality, healthcare expenses, and insurance fees.

Research has indicated that the construction industry is ranked as the second least safe and healthy sector (Flyvbjerg et al., 2007). This is due to the fact that its workplaces include distinctive characteristics, intricate elements, and may involve potential hazards. Accordingly, it is important to think about and work to increase safety measures in addition to developing better tools and systems to avoid these losses (He et al., 2019).

The aim

1. Ensuring the safety of workers, the public, and the environment during the construction and operation of mega projects.

2. Minimizing the risk of accidents and incidents through the implementation of effective safety management systems and protocols.

3. Complying with relevant safety regulations and standards, and continually improving safety practices to maintain a safe working environment.

2. Methodology

In megaprojects, safety concerns include minimising accident-related costs, keeping workers safe, and complying with regulations. A construction company's primary safety programme should include a comprehensive safety plan, appropriate training, safety signage, PPE, regular equipment inspections, open communication, and assessments. The researcher conducting this study searched many databases, including PubMed, Embase, Springer Link, Web of Science, Google Scholar, and the Cochrane Library, in search of literature discussing safety considerations in megaprojects. In order to expand the scope of the study, we looked at the references of other studies that met our inclusion criteria and discovered more articles to include. Mega building projects are the focus of this article. The definitions, characteristics, causes impacting, issues faced, and advantages of MCPs are only a few of the many subjects covered in this research review. This study has examined the forms of construction accidents, the variables that contribute to them, and lastly, the standards of occupational health and safety management systems.

3. Result and Discussion

Megaprojects pose unique and critical safety concerns due to their size, complexity, and potential impact. Due to their immense scale, high cost, and lengthy duration, megaprojects necessitate adherence to stringent safety protocols in order to safeguard individuals, locations, and assets. Smith et al. (2019) emphasize the need of performing thorough risk assessments to identify and address potential issues. These exams encompass physical, chemical, ergonomic, and psychological variables. To ensure the safety of your project personnel, it is imperative to implement a robust safety management system that includes well defined rules, practices, and standards (Jones and Wang, 2020). These systems facilitate ongoing enhancement and offer a methodical approach to safety through the execution of periodic evaluations and audits (Brown, 2018).

An essential element of safety concerns involves ensuring that megaprojects adhere to the multitude of local, national, and international safety regulations and legislation (Johnson, 2021). Projects that adhere to these criteria will be safer overall, while also fostering a culture of accountability and responsibility. Chen et al. (2022) suggest that including safety elements into the design and engineering controls of a project is a very effective strategy for implementing preventative measures from the outset.

Comprehensive strategies for evacuation, communication, and cooperation with emergency services are crucial for ensuring the safety of megaprojects (Taylor and Brown, 2019). Technological solutions, such as automation and real-time monitoring using sensors, enhance security by enabling swift reactions to possible safety hazards (Lee and Kim, 2020). The success of any safety system depends on the concerted effort of all parties involved, including suppliers, contractors, and government agencies (Davis and Wilson, 2017).

3.1 Definition and Characteristics of Mega Construction Projects

3.1.1 Definition of Mega Construction Projects

Mega construction projects, which last over two years, cost over a billion dollars, and prioritise public infrastructure, have a major influence on society, economy, and politics. The PN.O.L.D.C. Approach helps understand megaprojects by concentrating on Project nature, Objective, Location, Duration, and Cost. Crosby (2017), Sun et al. (2011), and Marrewijk (2007) suggest that government-commissioned megaprojects are long-term infrastructure investments with significant social impacts spanning 50 years.

The Stakeholder Approach recognises that significant construction projects are complicated, ever-changing, and include several stakeholders with various interests, according to Mok, Shen, and Yang (2015). Mok, Shen, and Yang (2015) note that megaproject stakeholders generally have diverse vocational and professional backgrounds, reflecting their different levels of involvement in the project. This technique considers stakeholders and organisation structure for large-scale undertakings.

Flyvbjerg et al. (2003) also mention the Economic Business Approach, which views big construction projects as a way for a nation to improve its worldwide status. Flyvbjerg et al. (2003) believe that megaprojects boost national status and influence worldwide, making them vital to many economies.

The Risk Approach, detailed by Albishri (2015) and Flyvbjerg, Bruzelius, and Rothengatter (2003), shows how megaprojects are unstable. Albishri (2015) noted that megaproject milestones and phase transitions connect stakeholders and builders. This technique defines megaprojects as hazardous because they may fail or delay at any stage in the project life cycle.

Mok, Shen, and Yang (2015) say the P.S.E. Approach emphasises significant construction projects' multifaceted roles in strategic development. Megaprojects address personal, social, and economic needs, promote a country's prestige, and host big international events, according to Mok, Shen, and Yang (2015). Megaprojects impact environmental sustainability, social dynamics, and political systems, according to this strategy.

Finally, Gerald's (2009) Complexity Approach examines megaprojects' complexity. Many see complexity as a drawback, however Gerald (2009) claims it makes megaprojects more unique and difficult to manage. This strategy considers megaprojects' constraints and complexity to anticipate complications. Many new criteria for identifying huge construction projects have been presented. Books and articles have covered certain strategies more than others. Complexity and PN.O.L.D.C. are the most prevalent huge construction project classifications. Table.1 shows the numerous definitions of Mega Building Projects in literature from 1998 to 2018. Based on the PN.O.L.D.C and complexity methods, this research used the most extensive definitions.

Table.1 Approaches of MCPs Definitions

Author	Definition	Critical analysis of the definition
(Crosby 2017) (Sun, et al., 2011) (Marrewijk, 2007)	"Mega construction projects are usually described as substantial investment (more than 1 billion dollars) long schedule (over two years) public infrastructures, which usually have long life time of 50 years and more, and generate multiple social impact and invested or commissioned by governments"	Project nature, Objective, Location, Duration and the Cost of the project (PN.O.L.D.C) Approach .
(Mok, Shen and Yang 2015)	"MCP often involve various stakeholders of diverse occupational and professional backgrounds who have different levels and types of interests in the project"	Stakeholder Approach according to the stakeholder and performing organization structure.
(Flyvbjerg, Bruzelius and Rothengatter 2003)	" many countries take mega project as an important tool to lift the status in global political and economic systems."	Economic Business Approach focused on defining mega construction projects as an important tool to lift the status of economic systems.
(Flyvbjerg, Bruzelius and Rothengatter 2003)	" the world of megaproject preparation and implementation is a highly risky one where things happen only with a certain probability and rarely turn out as originally intended.	Risk Approach depends on defining them as including many risk factors that can cause delays or failures during the project life cycle.
(Albishri, 2015)	" mega-project's process contains project phase transitions and milestones which connect, by providing spatial and temporal platforms, the interests of project actors, interest groups and constructors".	Project Process and Technical Requirements (PP.TR) Approach .
(Mok, Shen and Yang 2015)	" MCP play three major roles in the strategic development of a society: (1) satisfying human, economic and societal needs; (2) elevating a country's social image; and (3) delivering leading international events".	Political, Society and Environment (P.S.E)Approach
(Gerald, 2009)	"complexity is something' undesirable that made a project unique, more complicated and more difficult to execute, manage and control or even an 'excuse' for mistakes.	Complexity Approach leans on investigating the complexity and constraints associated with the project and their consequences.

3.1.2 Characteristics of Mega Construction Projects

We may better understand Mega Construction Projects (MCPs) by looking at them from several aspects. MCPs are large-scale systems with numerous interdependent pieces, according to the PN.O.L.D.C. Approach (Marrewijk, T. Zidanea, Johansenb, Ekambaramb,

Diaz Orueta, and S. Fainstein, 2009, Othman, 2013). Careful planning, development, financing, and construction of these projects costs a lot. MCPs in hostile or faraway places have a strange lifespan-urgency ratio. MCPs often last longer due to programming urgency. This technique benchmarks megaprojects above $1 billion to show their magnitude and complexity.

Kardes et al. (2013) and Jia, Chen et al. (2011) use the Stakeholder Approach to study MCP stakeholders' complicated relationships. Complex interests and relationships are inherent to these projects' many stakeholders. These parties' complicated dynamics must be understood to overcome their ineffective communication. Effective stakeholder management is essential for MCP success, which requires techniques to navigate stakeholder relationships.

According to Flyvbjerg's (2014) Economic Business Approach, MCPs play a crucial role in ensuring economic sustainability. These innovative initiatives provide significant financial profits, rendering them crucial for fostering economic expansion. Their ability to allure tourists and attract investment enhances the local economy, demonstrating their extensive and widespread economic effects. This approach presents MCPs as versatile economic catalysts with extensive advantages beyond their infrastructural initiatives.

According to Gyoo Kim (2011) and Flyvbjerg, Bruzelius, and Rothengatter (2003), the Risk Approach demonstrates the vulnerability of MCPs. Master Control Programs (MCPs) often experience financial and time delays as a result of inaccurate initial project estimations. This notion acknowledges the intricate and uncertain nature of megaprojects and suggests a proactive approach to managing risks. The Risk Approach anticipates potential challenges that may occur during the project's duration by taking into account the probability of encountering difficulties.

The Project Process and Technical Requirements (PP.TR) Approach emphasizes the importance of design knowledge, thorough front-planning, and creative integration in MCPs, as stated by Flyvbjerg (2014), T. Zidanea, Johansenb, Ekambaramb (2013), and Kardes et al. (2013). Efficient execution need the expertise of technical specialists, namely project managers. Given the intricate technological requirements of megaprojects, logistical assistance is crucial. This technique reveals the difficult and rigorous MCP success processes.

Bornstein (2010), Othman (2013), and Jia, Chen, et al. (2011) highlight the P.S.E. Approach, which emphasises MCPs' impact beyond construction aims. These programmes seek outside money to develop cities. MCPs also enhance residents' life, which benefits society. However, the technique shows that environmental consequences may be neglected and requires a more complete megaproject ecological impact assessment.

The Complexity Approach classifies MCPs as enormous and uncommon, increasing complexity, according to Thomas and Mengel (2008) and Duy Long et al. (2004). The magnitude and uniqueness of these projects make them harder to accomplish than typical construction jobs. Projects are complicated enough without budget and schedule overruns. This strategy emphasises the importance of knowing megaproject details.

Complexity, political rules, environmental legislation, stakeholder management, economics, time, and project management of mega construction projects are related (Table 2). Most writers agree that mega projects include multiple project organisations, such as the government, many

investment corporations, and citizens with varied cultural origins, manners, political systems, and languages. This variability complicates efforts.

Table 2. Characteristics of Mega Construction Projects with respect to different approaches.

Approach	Author	Characteristics of the Approach
P N.O.L.D.C Approach	(Mackhaphonh and Jia 2017) (T. Zidanea, Johansenb and Ekambaramb 2013) (Othman 2013) (Diaz Orueta and S. Fainstein 2009) (Marrewijk 2006)	A large-scale system is typically characterized by its substantial size and composition of several system components, which exhibit intricate interactions with one another. A capital asset is necessary for the purpose of strategizing, conceptualizing, funding, and constructing. Situated in distant and inhospitable vast regions. Extended duration, yet program urgency. Project with a budget exceeding $1 billion
Stakeholder Approach	(Kardes, et al. 2013) (Jia, Chen, et al. 2011)	The building of MCPs includes multiple stakeholders with complex interdependent relationships and ineffective communication among them.
Economic Business Approach	(Flyvbjerg 2014)	They maintain the economic sustainability of the entire nation by generating substantial wealth. Their significant and delegated influences attract visitors and investments, so contributing to the attainment of communal advantages.
Risk Approach	(Gyoo Kim 2011) (Flyvbjerg, Bruzelius and Rothengatter 2003)	Rising expenses and prolonged timelines sometimes result from insufficient initial cost projections.
PP.TR Approach	(Flyvbjerg 2014) (T. Zidanea, Johansenb and Ekambaramb 2013) (Kardes, et al. 2013)	Extensive expertise in design and meticulous front-end planning, along with exceptional integration efforts. Proficient technical expertise and extensively trained personnel, particularly in the realm of project management. Provision of logistical assistance.
P.S.E Approach	(Othman 2013) (Jia, Chen , et al. 2011) (Bornstein 2010)	Draw in external investment and completely reshape a city. Enhanced living standards for inhabitants. Underestimated ecological consequences.
Complexity Approach	(Thomas and Mengel 2008) (Duy Long, et al. 2004)	These entities are characterized by their immense size and distinctive characteristics, which contribute to their increased complexity. They are vulnerable to the possibility of budget and schedule overruns, which further complicates the projects.

3.2 The safety in mega Project

Construction site accidents have increased during the previous two decades. An increase in building and expanding capacity, a proliferation of heavy machinery, an overwhelming quantity of materials, intricate procedures, and multiple points of contact between entities are all not adequately addressed by current safety regulations.

3.2.1 Factors hindering behavioral safety among the site operatives

Based on the findings of the exploratory factor analysis, the four factors that contribute to inadequate behavioural safety are discussed in this section.

1. Lack of safety knowledge

Unsafe conduct is most often caused by a lack of safety understanding, with 27.527% variance. Insufficient safety knowledge means an employee may not realise the hazards of their job. This may be further impacted by the employee's cognitive capacity to make correct and timely decisions, which promotes their inclination to recognise dangers to avert accidents (Li, 2019). Some personnel are innately risk-takers, even when management provides proper safety devices. (Choudhry, 2012) reported that just 4% of Botswana site workers used eye protection. On mega projects, forklift operators claim that their supervisors put them under pressure to work at unsafe speeds, which could cause accidents with other vehicles and even other employees (Khosravi et al., 2014).

2. Employees' poor disposition to safety

It is the second factor leading to risky conduct among construction workers on Mega Projects, with a variance of 23.023%. When workers operate in good weather and in bad weather with an adverse weather policy, safety is improved (Behavioural Safety, 2017). If there is no adverse weather policy, employees won't know what to do, which causes uncertainty on site and sometimes leads to unsafe conduct. In adverse weather, workers risk slips, scaffold falls, electrocution, and other risks, which are exacerbated by heat. Extreme noise at construction sites may cause temporary hearing loss and work mishaps. Uncontrolled noise from site activities like explosions, hammering, welding, heavy equipment, and other machinery noises can cause occupational deafness or loss of concentration, which can lead to other health risks (Wu et al., 2020).

3. Putting production ahead of safety

Construction site safety might be compromised if production and deadlines take precedence. To safeguard site workers, the construction sector must prioritise site safety despite pressure to fulfil cost, schedule, and quality requirements. However, this factor group's variance of 14.492% makes it the third factor leading to unsafe behaviour, suggesting that the urgency of completing mega projects quickly may be contributing to employee unsafe behaviour. According to their research on construction project aspects and accident causality, a confined project length causes time pressure on site. This supports Mattila and Hyödynmaa's, 1988 findings that language barriers hinder site worker contact and safety management. The research reveals that deadline-driven companies have degraded safety and encouraged risk-taking among construction workers.

4. Improper safety gear

PPE like hardhats, gloves, and goggles are crucial for workers in the business with the highest fatal injury rate, and might save their lives. The mega project's high accident and fatality rate is due to workers' inappropriate usage or absence of safety gear. Some workers intentionally ignore guards while operating a cutting machine to finish the task on time. Construction workers' health and safety are also threatened by improper attire (Musonda and Smallwood, 2008). In this circumstance, some workers will wear sandals, bathroom slippers or other shoes other than the specified toe steel cap safety shoe.

3.2.1 Strategies for enhancing behavioural safety in mega construction industry

Based on the findings of the exploratory factor analysis, the six strategies for entrenching behavioural safety are discussed in this section.

1. Proactive approach towards safety by the management

This group has the biggest variation at 11.193%, indicating that a proactive approach to health and safety management, including frequent equipment and machinery checks, is ideal for fostering employee behaviour safety. The group name, ‘proactive approach towards safety by the management’, implies that health and safety managers and other management team members should do everything reasonably possible to prevent accidents and illnesses rather than reacting afterward. Management's proactive safety strategy gives positive messages to workers, which improves safety behaviour (Nunnally and Bernstein, 2008).

2. Effective communication and feedback

Healthy organisation safety culture relies on effective employee-management communication to allow employees to report dangers and management to address them. The factor analysis shows that this metric motivates safety and reduces accidents, with a variance of 10.595% and a ranking of second. If communication is clear, employees will report any dangers they encounter (OSHA. 2017). Effective communication between management and employees builds trust.

3. Provision of adequate equipment and safety monitoring

Construction, which has higher fatal accident rates than other sectors, requires proper PPE to avoid accidents and fatalities. Sometimes work is prioritised before safety, putting workers' health and safety at risk. Thus, to reduce accidents and fatalities, the safety management team must provide and monitor employees' use of appropriate safety gear for the work being done. Failure to monitor this suggests that safety managers may unintentionally promote dangerous activity on construction sites by neglecting to enforce safe behaviour and reproof it (Park et al., 2018).

4. Safety education and training

When workers get extensive safety training, behavioural intervention may be accomplished. This training may be organised around the events. This improves employee and management abilities and attitude. regarded safety training and education one of the best ways to promote construction safety. A mega project's international workers' language

difficulties may complicate training, yet safety signage and training as tactics for improving safety behaviour are crucial to getting safety messages across on construction sites. The employer must ensure that their employees are familiar with and understand the safety signs in their workplace, especially for inexperienced workers who may not understand some uncommon signs (Rawlinson, 2013).

5. Safety enforcement and appraisal

Inspecting the workplace prevents accidents and diseases. Critical workplace inspections detect and document dangers for remedial action. Safety committees may organise, report, and monitor inspections. If pre-sent, workplace inspections are essential to the health and safety programme and management system. Appreciation for working properly can inspire workers to perform their best knowing that their company appreciates safe work and that they might be fined or excluded for dangerous work, regardless of whether they cut shortcuts. Supervisory feedback and recognition are effective incentives for work success, according to (Stajkovic and Luthans, 1997). Giving feedback and incentives as carrots and penalties or exclusions as sticks will encourage construction workers to be safe.

6. Safety policy efficiency

Construction site safety depends on effective safety policy, which helps identify, monitor, and mitigate safety hazards. Safety policy shows an organization's commitment to workplace safety. The component group ‘safety policy efficiency’ recommends that an organisation must establish and periodically review its safety policy to successfully promote site worker safety. The construction site is one of the most dangerous and hazard-prone places to work (Park et al., 2018), so clear policy guidance on hazard identification, reporting, and mitigation will give site workers direction and encourage them to report safety risks and act safely. High-standard policies promote collective ideals and individual attitudes that improve safety performance and management attitudes (Nunnally and Bernstein, 2008).

4. Conclusion

Mega Construction Projects (MCPs) are defined and examined from all perspectives in this article. This research reveals that certain site workers may not follow safety guidelines, exposing them to new dangers. The fact that many personnel have fewer than five years of building experience compounds this. Although many construction teams are under pressure to deliver projects on time, within budget, and with the right quality, mega project teams are under even more pressure to deliver projects. This may explain why the research shows that productivity is prioritised above safety if work is done, regardless of health and safety. This suggests that workers intentionally bypass safety devices that may save their lives in an accident. Working overtime to achieve the deadline increases construction workers' weariness and accident risk. The findings also imply that inappropriate usage or absence of safety gear leads to mega project mishaps. When workers fail to utilise the right PPE due to a lack of education, a rush to finish, or a supervisor's indifference, accidents involving fatalities are common.

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