

# Mitigation Practices for Frequent Accidents in High Rise Building Construction

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## ABSTRACT

High-rise building construction accidents are observed within the construction industry in Sri Lanka. These accidents represent a significant loss for the construction industry in terms of lives, cost, time, and the reputation of the construction company. To overcome those losses, this research aimed to develop the framework as guidance to mitigate frequently happening accidents in high-rise building construction in Sri Lanka. It was achieved by three main objectives, identify the frequent accidents in high-rise building construction, investigate the causes of frequent accidents happen and analyze the strategies to minimize them. The first two objectives were completed by literature review, and the third objective was completed by data collection while developing the second objective. The data collection was done through semi-structured interviews with 12 professionals who work as health and safety officers, project managers, engineers, and quantity surveyors in high-rise building construction. Only those who work in the Colombo area were considered here as a limitation. Under the first objective, scaffolding accidents, struck by falling objects, plant, and machinery accidents, falling from a height, and fire accidents were identified as frequent accidents in high rise building construction, and causes were listed below the human factors, material, and equipment factors, environmental Factors, safety technology factors, and management failures as the second objective. Essentially risk assessment, developing the site conditions, conducting training programs establishing safety system with the procedure control system, and establishing penalty procedure were the discoveries of the third objective, and those are categorized separately in the pre-construction stage and post-construction stage. According to all these findings, the framework was developed to identified relevant mitigation practices for the causes of high-rise building construction accidents, and this research recommended for government to introduce new regulations for safety while strictly following up the safety system of the high-rise building construction sites to reduce the accidents.

**KEYWORDS:** *Construction. High Rise Building, Accidents, Causes, Mitigation*

## 1 INTRODUCTION

The construction industry is one of the major developing industries in the whole over the world (Brito & Saikia, 2012). It makes a large job market, instead of these contractions have to do with the big effort of different employers. However, these construction industry employers have to face down these unpredictable situations as the industry circumstance (Kasapoğlu, 2018). Especially, high-rise buildings' construction remains predominant in the high accident rates recorded annually, and it is important to accurately estimate safety matters (Md Sofwan et al., 2016).

High-rise buildings can define generally as the building which has more than 7 floors (Ahrens, 2016). These high rises buildings works are contained different machinery and conceivably dangerous building materials (Sikora, 2016). Therefore, the cost in terms of human life in the man-made accident will be a huge amount, and safety of life must become the main consideration, beginning from the conceptual phase in high rise buildings (Perera et al., 2017b). These accidents related to high-rise buildings have taken place in Sri Lanka as well. Mr. Koneswaran Nidharshan died due to falling from

the Lotus Tower's 13 floor is one example of it. According to the news he had fallen down the lift shaft of the building (Teenage worker falls to his death from Lotus Tower : mirrorcitizen.lk, 2018). In the early hours of 29 December 2019, Mr.Kokila Samandaperuma, was killed in the elevator of the Green Lanka Towers at Nawam Mawatha in Colombo. The reason for it was the elevator stalled on the ground floor and fell underground. At that time elevators were in the construction stage (Mudugamuwa, 2019). In addition to that most nearly, there was a fire accident which happened in a high-rise building at Hyde Park in Colombo, and that building was collapsed due to the fire (Daily Mirror - Fire breaks out at Hyde Park Corner, 2020).

According to those previous cases, which happened nearly illustrate that still there are happening accidents in high rise buildings. In order with that, high rise building accidents became a problem that wants a proper accident mitigation method immediately in Sri Lanka. As the solution for that issue, the research aim was to develop a framework for aimed to develop the framework as guidance to mitigate frequently happening accidents in high-rise building construction in Sri Lanka with the three objectives, identify the frequent accidents in high-rise building construction, investigate the causes of frequent accidents happen and analyze the strategies to minimize them.

## **2 LITERATURE REVIEW**

### **2.1 Construction Industry**

The construction industry is an important role in the socio-economic development of all over the world while providing infrastructure facilities, sanctuary facilities, and employment(Fu et al., 2019). This industry has various sectors that produce immobile, unique, heavy, bulky, complicated, durable, and costly heterogeneous products (Mohamed Babikir Ibrahiem, 2015). To cater to the nature of the product and service, the construction industry is a dangerous industry that has a considerable amount of firms while making a large job market(Faizal, 2010). Due to a large number of participants in the construction industry in general, the complexity of their cooperation, and the relationships between workers, their tools and machines, and materials and operations, the number of occupational accidents outperforms other industries (Radosavljević & Vukadinović, 2020). Furthermore, these accidents in the construction industry can make the danger in terms of valuable lives, time, cost overruns, which be the black mark to the construction industry reputation (Perera et al., 2017a).

### **2.2 Accidents**

According to the International labor department (2019), over two million people die from work-related diseases and 321,000 people die each year from occupational accidents. Furthermore, there are at least 60,000 fatal accidents occur each year on construction sites around the world, and one of every six fatal accidents happens at the construction sites (International labour organization, 2019). In industrial countries, 25% to 40% of work-related deaths happen in construction sites, even there is only 6% to 10% of the workers (Somavia, 2005). Furthermore, As the Labor Department's Industrial Safety Division in Sri Lanka, normally 2500 to 3000 accidents were reported while been 40% to 60% were fatal and 30% were construction accidents among them. In the construction work zones there happen two different types of accidents such as work area and traffic near to site accidents near to site area (Mohan & Zech, 2005). In this research, focusing is happening with work area accidents. That accident can categorize into four types according to the Workmen's Compensation Ordinance No. 19 of 1934. There are death, Permanent total disablement, permanent partial disablement, and Temporary disablement (Legislative Enactment of Democratic Socialist Republic of Sri Lanka., 1980). As this is a dangerous industry all four accidents can happen. To that, health and safety practice is mandatorily considered in the construction industry.

### **2.3 Health and Safety**

Health and safety is a public health field that investigates trends in illnesses and injuries in the worker community and suggestions and implements strategies and rules to avoid them (Correll, 2020).

Furthermore, this system of health and safety should be responsible and accountable for the potential hazards and it should be included with the procedures of eliminating the hazards and identification of factors that make the path for uncertain accidents (Muiruri & Mulinge, 2014). In the construction industry, the contractor must make sure the encourage the medical staff, first aid equipment, and store persons at the site throughout the contract period (FIDIC, 1999). However, most of the construction companies use only mandatory standards as the health and safety management strategy even despite the high cost of accidents at work (Shibani A et al., 2013). Even though, simply adhering to these regulations may not be enough to ensure perfection in the performance of health and safety. (Shibani A et al., 2013). To that, the health and safety issues like accidents have to manage while identifying the injuries, evaluating the risk posed by these injuries, and controls for risks are chosen according to a risk control (Medilife, 2012). However, accidents caused in High Rise building construction are one of the major areas that should have managed the accidents instead of high-rise buildings having more danger than the construction of the small building (Rajendran et al., 2009).

## 2.4 High Rise Building Accidents

High-rise buildings are the recent demand in the construction industry these days instead of lack of land space (Giyasov & Giyasova, 2018). These High-rise buildings can define as buildings that have more than seven floors and those can categorize into four such as 7-12 floors, 13-24 floors, 25- 49, and 50 floors or more (Ahrens, 2016). It is typified by continuous variations, use of many various sources, lack of working conditions, stable work failure, harsh environments such as vibration, noise, dust, load handling, and denudation to stochastic fundamentals such as conditions of weather, soil types, and road accidents (Zaini et al., 2015). To that performing the safety of the workers while preventing accidents is a major challenge with these circumstances.

The previous researchers identified the types of high-rise building accidents as below.

Table 1 - Types of High-rise building construction accidents

Author	Types of High-rise building construction accidents
(Zhou & Pang, 2013) (Goh et al., 2016)	Scaffolding accidents People falling from a height Struck by falling objects Plant and machinery accidents
(Alam, 2015)	ladders Falling debris Falling from height Electrical shock and Machinery Trips and Slips Crane and hoist operation
(Su, 2014)	Falling height Object against accidents machine, and crane accidents electric shock accident Fire

By adhering to those categorizations, the types of high-rise buildings are taken as scaffolding accidents, falling from a height, plant and machinery accidents, struck by falling objects, and fire accidents.

### **2.4.1 Scaffolding Accidents**

Scaffoldings are used for support to carry out the building works which are done at height but also places that have poor access (Błazik-Borowa & Szer, 2015). General needs for scaffolding are capacity, scaffolding platform construction, suspended scaffolding criteria, Supported Scaffolds Criteria, entry requirements, usage requirements, fall protection requirements, and protection against falling objects (U.S. Department of Labor, 2002). There can happen hazardous incidents which are related to the uncertain activity that makes dangers the worker in the scaffolding areas such as injuries (Abas, Noridan, et al., 2020). To that Scaffoldings have to prepare with considering sustainability for accidents and encourage skilled laborers while considering documentation about the preparation of scaffolding, selection of the assembly elements of the scaffolding, assembling the scaffolding, scaffolding exploitation, and disassembling the scaffolding has to be done correctly with proper knowledge. (Błazik-Borowa & Szer, 2015).

### **2.4.2 Struck by a falling object**

Most of the construction sites are full of people or ancillary activities without sufficient space and it makes a path for most common accidents like striking against or being struck by objects (Fung et al., 2010). The research done in Johor shows that the percentage of the striking which related to materials is 65% while which related to equipment is 35%. (Abas, Heong, et al., 2020) According to Wu et al (2013), most hazardous strikes happen while hoisting or lifting. Furthermore, it is 41% percentage from including all the types of struck objects (Wu et al., 2013). Struck can be happened by the equipment, private vehicle, falling materials, vertically hoisted materials, and horizontally transport materials (Goh et al., 2016).

### **2.4.3 Plant and machinery accidents**

Plant and machinery are some of the most significant resources that need to complete the construction stage of a project (Manaf & Razali, 2007). Especially earthmoving and carrying machinery are more important machinery among them which can handle various soil and materials (Dadhich et al., 2016). However, according to the factory ordinance in 1942 the parts of the machinery must be guarded or protected while moving or in service, except when those parts are inevitably exposed for examination and any lubrication or adjustment as soon as possible required by that examination (Department of Labour, 1942). Furthermore, As per Occupational Safety and Health Administration (OSHA) requirement, employers are only allowed to purchase machines that have capable guard and security measures in place to protect workers from amputation accidents (Az, 2017).

### **2.4.4 Falling from height**

A fall can be defined as a movement towards the ground and that kind of physical hazard that happens while the worker's body balance is lost (Liy et al., 2016). As a result of the main hazard in high-rise buildings is correlated with working at height and vertical transportation of materials, falling objects or the fall of the worker accident can happen (Fung et al., 2010). However, these accidents mainly happen in construction as the reason for construction characterized by long-term production cycle, large mobility, heavy labor, and complex operations (Zhou & Pang, 2013). Falling from height is can happen in the area of scaffolding, structure, or working structure (Arifuddin et al., 2020). The suggestion for the system of fall protection should be flexible, passive, simple, feasible, protective while maintaining less cost (Cecen & Sertyesilisik, 2013).

### **2.4.5 Fire accidents**

In high-rise building construction, a large number of hazard elements are used which can simply make a path for fire accidents. This difficulty is forward to the usage stage from the construction stage (Chen et al., 2012). Most of the High rise buildings are covered with combustible materials which spread the fire than the other buildings (Lamont & Ingolfsson Sigurjon, 2018). The reason for it is high-rise buildings are consist of staircases, elevator shafts, pipe shafts, cable shafts, and many other verticals shafts than the others which can act as the passage to spread the fire if there have not proper fire separations (Liu et al., 2012).

## **2.5 Causes of frequent accidents happen**

Most of the time these accidents happen because the people did not give the priority to safety well compared to the size of the workload, searching for easy methods to save the times and unfair thinking such as that accidents never happen to me (Haslam et al., 2005). Furthermore, they elaborated that causes of accidents can be classified as the operation of the workers and material factors. Other than that causes of the accident can divide into human and physical factors (Gibb et al., 2001). In addition to that Zhou and Pang (2013), they classified the accident causes as human factors, environmental factors, material and equipment factors, and safety technology factors. Here the causes are going to discuss mainly under those four causes. Other than that, according to Hamid et al, there is a cause called management failures and it also going to consider here.

### **2.5.1 Human factors**

This human error can categorize into two types such as the individual approach and the systematic approach (Selby et al., 2000). The individual approach focuses on dangerous actions, which are mainly seen as a result of abnormal mental disorders problems such as inattention, neglect lack of motivation, and recklessness while the systematic approach considers human error as a consequence than a cause (Ye et al., 2018).

### **2.5.2 Environmental Factors**

The site environment is the victim of an accident operates. Effect of sunshine on the summer season, Possibility for Slipping from scaffolding on the Rainy season, inadequate light at the night while constructing and there is no sign to identify the dangerous areas which are excavated can be causes for these accidents happen in high rise buildings under environmental factors (Zhou & Pang, 2013).

### **2.5.3 Material and equipment Factors**

Building materials were the main source of injuries from construction accidents in this category, with metal building materials, pipes, channels, and pipes, and lumber being the main culprits (Jones, 2017). According to Zhou and Pang (2013), the quality or damaged materials such as safety nets, safety belts, safety helmets, and ladders and not having proper safety and job requirement are the causes of these high-rise buildings accidents.

### **2.5.4 Safety Technology Factors**

Certify about the good technical skills and experience should have to take as the very much important to workers (Haslam et al., 2005). Lacking the knowledge to use technological innovation to expand safety ineffective and lack of technical advice when carrying out construction work causes are lead to happen accidents under this safety technology factor (Memon et al., 2017).

### 2.5.5 Management Failures

Accidents are symptoms of mismanagement and safety goals must be consistent with business goals if good safety performance is to indicate successful management (Häkkinen, 1995). Furthermore, Hamid et al (2019) said that, under incorrect or nonexistent work procedures, structural failure, unsafe working methods or circumstances, and lack of supervision are the most ordinary contributing causes to fatal accidents can happen.

All the causes under these factors should have been understood to find the proper way to reduce the number of accidents that happen in high-rise building construction.

### 2.6 Available Mitigation Practices in the construction industry at Sri Lanka

According to research about the Study of construction accidents in Sri Lanka, contractors could develop safety programs, if the Industrial Safety Division of Sri Lanka does the analysis and distributed the data about the accidents (Rameezdeen et al., 2006). Furthermore, they said that Work order and approaches to performing certain work activities can be changed to reduce the risk that can be done under that. Other than that construction accidents can mitigate by making sure the wearing safety equipment is mandatory at the site (Perera et al., 2017a). In addition to that, there should be prestart briefing meetings by the supervisor and there should be proper permit systems to carry out the difficult areas such as excavation and hot work as per their findings. According to Darshana (2017), there should be a systematic performance review based on independent monitoring and audit data from the system of the entire health and safety management. In addition to that, there should be an engagement in continuous development including risk management policies, systems, and techniques (Darshana, 2017). However, all the accidents can mitigate through administrative controls, engineering control, and by using the PPE other than accidents that happen due to unsafe behavior and unsafe acts (Mudiyanselage et al., 2016).

## 3 METHODOLOGY

To carry out this research the philosophy was taken as Interpretivism. To this interpretivism, the paradigm theoretical approach was taken as inductive with the qualitative research design. This qualitative research design is mainly used to collect answers about the thoughts and feelings of research participants, which can help to understand the meaning people attach to their experiences (Sutton & Austin, 2015). Under that, objective one was competed with related literature to identify frequently happened accidents in high rise building construction. The Second Objective, to investigate the causes of frequent accidents was achieved through a literature review once the first objective had been completed. The final objective was achieved through primary qualitative data collection by using semi-structured interviews while developing the second objective through it. These semi-structured interviews were used here to gather in-depth insights into high-rise building construction accidents. These interviews were done with the participation of 12 professionals who had more than 5 years of experience in high-rise building construction such as health and safety officers, engineers, project engineers, and quantity surveyors while developing the second objective through it. Other than that, the factory ordinance act which is published in 1942 ad previous findings were considered and, did the data analysis and discussion by using NVivo 12 software while selecting the most suitable mitigation practices as per the participants recommended according to their experience. At the end of the discussion, the framework was buildup based on it.

## 4 DATA ANALYSIS AND DISCUSSION

The data were collected through open-ended semi-structured interviews with the professional bodies who are involved with the high-rise building construction Colombo area in Sri Lanka. There were 12 interviews in different construction organizations' high-rise building projects. The findings of the research had analyzed and explained accurately in a logical systematized manner.

The basic information about Causes of frequent accidents in high rise building construction which collect through interviews categorized as the Human Factors, Environmental Factors, Material and equipment factors, Safety technology Factors, and Management failures as per the literature findings. Table number 2 is used to shown analyze the obtained data from the semi-structured interviews, literature, and factory ordinance in 1942 as below.

Table 2. Causes of high-rise building accidents

Factor	Causes
Human Factor	<ul style="list-style-type: none"> <li>• Negligence of the workers</li> <li>• Unconfidently about safety equipment</li> <li>• Poor Supervision</li> <li>• Unsafe Behavior</li> <li>• human stress level</li> <li>• Human disaster</li> </ul>
Environmental Factor	<ul style="list-style-type: none"> <li>• Changes in weather</li> <li>• Unsafe condition at the site</li> <li>• Site space</li> <li>• salinity of wind</li> </ul>
Material and Equipment Factor	<ul style="list-style-type: none"> <li>• Low quality of the material and equipment</li> <li>• Wrong material Usage</li> </ul>
Safety technology Factor	<ul style="list-style-type: none"> <li>• Lack of knowledge</li> <li>• Safety measures do not implement</li> </ul>
Management Failure	<ul style="list-style-type: none"> <li>• Focusing only about target only</li> <li>• Poor human resource management</li> </ul>

As per the result regarding the causes of accidents of high-rise building construction the mitigation practices were identified with the collected data. According to them, the mitigation has to be done with both the pre-construction stage and the post-construction stage.

**Risk assessment** is important to mitigate all accidents and it can mitigate the hazard level of the project as per the participants in the pre-construction stage. Furthermore, preventive measures could be drawn up and implemented per it. Other than that, there had five participants mentioned that **studying the health and safety standards and the conditions of the contract** in this pre-construction stage is a must and the contractor should check the safety precision which was given by the client is adequate or not and if not have to discuss for establishing the systems for mitigating got prevent the accident. Furthermore, as their thoughts, the client party should check the safety records of the contractor and the local and international health and safety standards followed by the contractor.

In the post-construction stage, **giving proper training** for the workers was mentioned by all the participants. Other than that, according to the Factory ordinance part III, no young person may work on a machine unless is fully aware of the hazards associated with the machine and precautions that must be observed and adequately trained to work the machine. . To that training is a must and the fairest decision among given answers about training sessions, is conduct the safety training should be once a week and there should be an instruction session daily basis. Other than that, they proposed to have special training for the special tasks once the time it has to do. In order with that, this can use to improve the knowledge of workers and guide the workers on the correct path which can use for mitigating the safety technology causes of high-rise building construction. As parral wit that, **handling awareness program** was proposed as mitigation practice by the five number of participants. As the fairness decision from their experiences, it should be happening daily basis for workers and once a month for the management. As per that this is considered a good mitigate practice for resolving human causes and management failures. **Providing the PPE** is mentioned as compulsory to mitigate the accidents by all the participants and

there should have to use safety helmets, eye protection, gloves, safety footwear, high-visibility clothing, and safety harnesses under that. Furthermore, those PPE must be in accordance with the standard. This will be beneficial to mitigate the accidents due to the human factor, material and equipment factor, and environmental factors.

**Appointed role of safety supervisor** also mentioned by all the participants and they thought certified about the quality level and standards of material, plant, and equipment, maintain a tool checklist, ensure about safety system establishment, conduct safety training and awareness programs, certified about workers training and investigate health and safety complaints the duties that safety supervisors should follow. The factory ordinance also mentions maintaining the standards of plant and machinery. In order with that, this appointment of safety officer role can mitigate the all the causes than the management failures. Other than that, five participants mentioned that there should be used **only the skill laborers for dangerous work** like working at height to prevent from the safety technology causes like lack of knowledge. Furthermore, they recommend involving technological knowledge workers such as those who take proper training from technical colleges. If the contractor uses this skill labors, they can mitigate the human causes and safety technology causes that lead to accidents due to their knowledge.

**Implementing the safety systems** are mitigation practices that are very important to reduce accidents due to safety technological causes as all responders thought. Under that, they mentioned there should have to be a guard rail system, warning line system, control access zone, safety net system. Positioning device system, personal fall arrest system, canopy system, and fall restraint system are the system that looks forward to that total safety system. Other than that, ten participants mentioned accidents can happen due to turbulent movement when the other accident happens, and there should be a technical solution for it like a dedicated vehicle for emergency cases, intercom system, maintain first aid facilities, establish fire extinguishers, displaying emergency numbers, trained for casual canteen were the proposed **procedure control systems** for it. The factory ordinance in 1942 also showed about first aid facilities, as those have to maintain inaccessible boxes or cupboards. However, this was taken as mitigate practice that can use to reduce the damage of the accident. In addition to that, **develop of site conditions** is one proposed mitigation practice by the two participants for environmental causes. Furthermore, the factory ordinance mentions that there should be proper cleanliness to manage the overcrowding, temperature, ventilation, and lighting at the site.

As the last mitigation practice, three participants nominate the **penalty procedure** and they proposed to have given only the 3 chances for the workers. As their thoughts, the first time there should have given a warning letter and the second time there should have to give a signing letter through management. Although if it is the third time the workers should have to resign from the job. The researcher proposed that it is better to establish in every construction company and it can mitigate the human causes which lead to high rise building accidents.

#### 4.1 Suitable Mitigation Practice Framework for high rise building accidents in Sri Lanka

This Framework was prepared as the final step to achieve the aim of the research while given a Suitable Mitigation Practice Framework for causes that lead to high-rise building accidents in Sri Lanka.

##### 4.1.1 Steps for the development of the proposed framework

This section is included with the steps which were followed by the researcher for the final objective according to the data analysis outcome.

Step 1: Identifying the frequent high-rise building through the literature review.

Step 2: Investigate the causes for those frequent accidents semi-structured interview.

Step 3: Analysis of the strategies to minimize the causes from the interview.

##### 4.1.2 Use of the proposed framework

These are the steps to use the framework that the contractor must follow to select a suitable mitigation practice. The framework is attached in figure 1.



- Step 01: Identified the accidents that can happen in high-rise building construction.
- Step 02: Investigate the causes that lead to those accidents.
- Step 03: Identify the factor it was to categorize.
- Step 04: Select the mitigation practices which can apply to it

However, according to the organization's strategies and location, these practices can be changed.

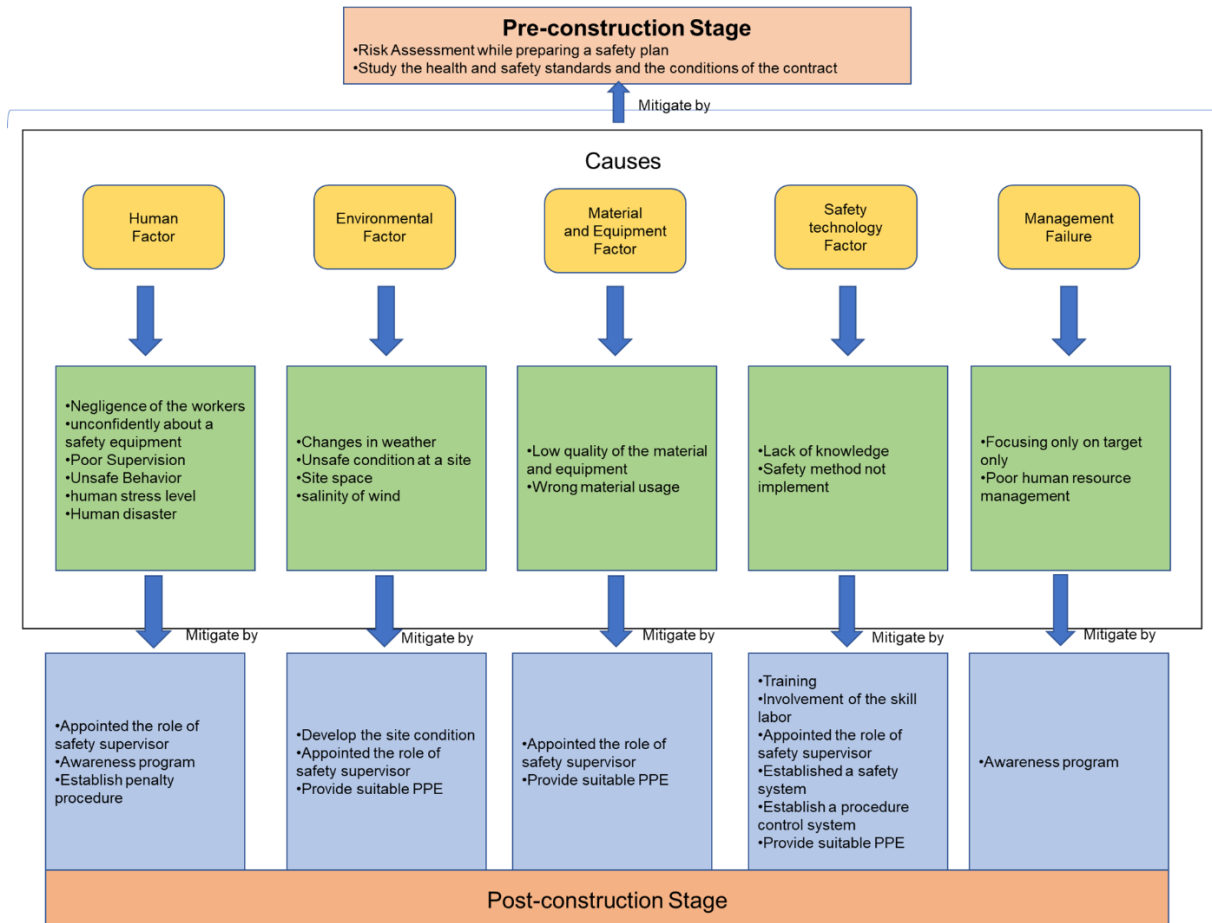


Figure 1-Mitigation Practices for Causes of High-rise Building Accidents

## 5 CONCLUSION

The number of accidents happening in the high-rise building construction industry is higher than the number of small building constructions. Due to that, finding the mitigation practices for those accidents is very important, and in order with that, this research aims to develop the framework to mitigate frequently happening accidents in high-rise building construction in Sri Lanka. To overcome that aim the high-rise building accidents were identified under the first objective such as falling from a height, struck by falling objects and scaffolding accidents, plant and machinery accidents, and fire accidents and the causes for those accidents classified under human factors, material and equipment factors, environmental Factors, safety technology factors, and management failures under the second objective. As the outcome of this research, the way of mitigating those causes was present through the framework and it consists of the mitigation practices such as the risk assessment, study the safety standard and conditions of the contract, developing the site conditions, conducting the training and awareness program, the involvement of the skill labors, establish penalty procedure safety system and procedure control system, appointed the role of safety supervisor and provide suitable PPE which analysis under the third objective. The data was collected through the literature review, factory ordinance act, and semi-structured interviews to achieve the aim. To develop this research area gap the researcher proposed to do further research on the topic of analysis of government involvement for health and safety

regulations in the construction and comparison between low rise building accidents and high-rise building accidents

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