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Climate Change Impacts on Occupational Health and Safety of Façade Maintenance Workers: A Qualitative Study

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Abstract: At present, climate change is considered a considerable future threat due to its possible catastrophic impacts on humans, their properties, and also the environment. Therefore, most people and organizations have paid attention to this area. Thus, special consideration should be given to building operations, as buildings and building operations are capable of being impacted by various negative consequences of climate change. As façade-maintenance workers experience considerable climate change impacts as they perform their work for prolonged hours, at height, on the exterior of buildings, this study focuses on identifying the impacts of climate change on façade-access methods and façade-maintenance workers. Thus, in this study, a qualitative research approach was undertaken with an interview research design. A comprehensive literature review was conducted along with 12 semi-structured expert interviews selected through judgmental sampling. Software-aided thematic content analysis was carried out to analyze the collected data. The findings indicated that climate change could have significant impacts on building operations, as the attention paid to climate change adaptation by building operations is negligible in various countries, especially in developing countries. A significant impact was identified on façade-maintenance workers and façade-access methods caused by climate change, creating various risk factors for their occupational health and safety. Furthermore, the research methods that have been applied in this study are also capable of expanding to address various other probable operations. Accordingly, this research is exploring a new field of study that should be given more consideration by researchers due to its significant importance in scenarios that are experienced worldwide.

Keywords: façade maintenance; façade-access methods; climate change; façade-maintenance workers; occupational health and safety

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1. Introduction

The climate is changing at a considerable rate [1]. Thus, climate change can be identified as the most concerning environmental issue in the 21st century, impacting people's health either directly or indirectly [2]. Therefore, at present, sudden variations in general climatic conditions are experienced, which are capable of causing catastrophic impacts at unexpected levels [3]. According to the National Climate Assessment, climate change is continuing to increase the frequency and intensity of extreme weather conditions such as hurricanes and heavy rainstorms [4]. Therefore, a considerable number of countries have been affected by extreme weather conditions over the last 15–25 years [5]. Thus, climate change has been identified as a catastrophic environmental threat for almost all countries worldwide at present [6]. The catastrophic impacts of climate change have been noticed in most geographical areas [7]. Accordingly, the global climate, which is subjected to frequent variations, is considerably complicated [8]. Thus, climate can be defined as the mean weather conditions at any location, namely, temperature, the condition of wind, solar light gain, and rainfall [9]. Moreover, the average weather conditions that prevail in a particular location for a prolonged period can be identified as the climate [5]. The sudden variations in the occurrence of droughts, floods, heat waves, rainfalls, sea waves, global warming, and cyclones can be stated as some examples of climate change [10]. These climate changes are capable of negatively impacting the social, economic, and physical attributes of the world [7]. Sri Lanka is a small island in the Indian Ocean that is particularly susceptible to the extreme consequences of climate change. Sri Lanka is experiencing storms, landslides, floods, and droughts as a result of climate change at present [11].

Climate change can cause unusual occurrences in the surrounding environment, health and safety, and the economy [12]. Organizations are considerably impacted by climate change, which is identified as the most critical environmental issue at present [6]. The built environment is also considerably affected by climate change [13] The building industry experiences various challenges as it is unable to predict the ways in which climate change will affect a building's performance [14]. Hence, special attention should be paid to the construction, maintenance, operation, and control of buildings due to their ability to be impacted by climate change [15]. Thus, a broad range of workers in various fields have already been subjected to the impacts of climate change [12].

More consideration should be given to the various risks for indoor and outdoor workers caused by climate change [16]. The impacts of climate change have generated a considerable risk for the OHS of the workers, especially workers in outdoor workplaces under hot conditions [17]. Therefore, outdoor workers are more severely impacted by climate change than indoor workers [2]. Accordingly, outdoor workers are subjected to various changes in climate, namely increases in temperature, extreme weather conditions, and poor air quality [18]. Outdoor workers have considerable opportunities for exposure to ozone and varied ventilation rates as they spend more time outdoors with a higher amount of physical activity [19]. Respiratory and cardiac diseases could occur due to the increased rate of exposure to air pollution, and skin cancer, acute photokeratitis, cataracts, and conjunctivitis can be caused by exposure to ultraviolet (UV) radiation [20]. Extreme weather conditions can have various impacts on the OHS of outdoor workers, namely asthma from thunderstorms, and the spread of vector-borne communicable diseases, fatalities, heart problems, and hypothermia from storms [20]. Accordingly, outdoor workers attempt to accelerate their work due to sudden weather changes, which could lead to an increase in the occurrence of accidents [20]. For example, the acceleration of work activities by outdoor workers before a storm may lead to accidents, which could even lead to the death of those workers [20]. Hence, the impacts that climate change has on the OHS of workers and possible ways of mitigating these effects and adapting to these conditions can be identified as a considerable challenge [21]. Few or no measures regarding adaptation to climate change involving outdoor workers undergoing physical labour have been found [2].

The timeframe and duration of the seasons, which are changing as a result of climate change, may affect the occupation of façade maintenance workers [22]. Moreover, excessive heat and air pollution can endanger the health of outdoor workers, including those who maintain façades [23]. The exterior layer of a building, commonly referred to as cladding or façade work, acts as a protective skin to insulate the interior from the weather and offer aesthetic appeal. This can be constructed from a wide range of substances, including glass, metal, stone, brick, and wood [22]. Façade work is a multi-stage process that includes planning, construction, fabrication, and installation [23]. Maintaining a building's durability and structural stability requires façade maintenance and, additionally, is crucial to environmental sustainability and energy-efficiency [22].

Façade-maintenance workers are also facing various challenges and difficulties due to climate change as they spend most of their time outside at a higher elevation. The research has generally addressed climate change's impacts on the OHS of workers. However, research articles addressing climate change's impacts on the OHS of façade-maintenance workers cannot be found. Therefore, a knowledge gap can be identified in finding climate change's impacts on the OHS of façade-maintenance workers. Hence, the main outcome of this research will be addressing a new research area that should be paid more attention by researchers in the present context. Therefore, this research will provide a great opportunity for researchers to fill this research gap by extending their knowledge in this research area.

2. Literature Review

2.1. Climate Change and Related Impacts

At present, climate change is considered a critical global environmental issue [6]. Therefore, climate change can be considered a global emergency [24]. These changes in the weather system have occurred over decades [25]. Thus, climate change can be referred to as the variations in the climate that are affected, either directly or indirectly, by the activities of humans and global atmospheric composition [1]. The sudden variations in the occurrence of droughts, floods, heat waves, rainfall, sea waves, global warming, and cyclones are some examples of climate change [10]. Accordingly, climate change is a risk to the climate system, the foundation for the life and health of human beings [17]. Changes in normal climate conditions are occurring and their impact is likely to be hazardous [3].

The impacts of climate change can be identified at almost all levels: worldwide, regionally, by country, and at municipal unit. They fulfil the requirements for a multi-level set of actions, and climate change is capable of negatively impacting the social, economic, and physical attributes of the world [7]. As per the predictions, climate change will considerably affect basic human needs, namely the requirements for clean water, good food, and unpolluted air, which helps to sustain the health of human beings [17]. Accordingly, the impacts of climate change are widespread, resulting in considerable various socio-economic hindrances throughout Sri Lanka [7]. Currently, Sri Lanka is in 97th place among 191 countries in the INFORM Risk Index due to its moderate experiences of risk from disasters [26].

2.1.1. Temperature Variations

Global temperatures have risen by approximately 1.1 degrees Celsius above pre-industrial rates, and this trend is expected to continue in the coming decades [27]. The linear trend in average surface temperature is 0.74 °C (from 0.56 °C to 0.92 °C) over a 100-year period (1906–2005) [27]. Temperatures in Sri Lanka have also risen significantly over the last few decades and Sri Lanka's median temperature has risen by 0.16 degrees Celsius per decade since the 1970s [28].

Accordingly, the consequences of climate change are experienced in all areas of Sri Lanka, with resultant temperature variations generally being recorded in the lowlands in Sri Lanka, resulting in temperature fluctuations concerning the rise in altitude [6]. Thus, climate change can impact people's health and alter the natural systems of the country, which are interconnected with the biodiversity, ecosystem, and water cycle [29]. Various sectors in the country, namely the construction sector, manufacturing sector, tourism sector, and agricultural sector, are impacted by extreme weather events, with a negative impact on the country's economy [30]. The propagation of vector-borne illnesses and water-borne illnesses could increase due to the extreme heat conditions in both nighttime and daytime throughout the country [30]. Working people will be considerably affected by the extreme temperature in Sri Lanka [31]. Illnesses related to heat can occur in employees who perform jobs that require more physical labour [18]. Exposure to heat during work may cause chronic dehydration, heat rash, heat syncope, dehydration, and psychological illnesses such as suicide, depression, and anxiety [12]. Heat exposure may also lead outdoor workers to breath of various forms of windborne dust containing harmful toxins [32].

2.1.2. Extreme Weather Events

Extreme weather events are frequently experienced in almost all regions of the world due to climate change [10]. Thus, a considerable number of countries have been affected by extreme weather conditions over the last 15–25 years [5]. In addition, extreme weather events such as floods and droughts are becoming more frequent and severe in Sri Lanka [33].

Sri Lanka is subjected to various forms of floods, namely flash flooding, river flooding, and coastal flooding, and although higher levels of vulnerability to the occurrence of floods can be seen in most parts of the country, an increase in the vulnerability to floods can be identified in the Western province [26]. Moreover, Sri Lanka is ranked at the 56th level for exposure to floods, including flash floods and riverine, in the INFORM 2019 Risk Index [26]. A higher vulnerability to the occurrence of landslides can also be seen in Central Hill Country [34].

Furthermore, climate change can cause extreme weather conditions, namely wildfire, drought, and flooding. These have affected the health of human beings [18]. Moreover, these extreme weather events are capable of impacting the world's economy and global biodiversity [29]. Furthermore, buildings and infrastructures can be destroyed by extreme weather events [21]. Various sectors in the country, namely the construction sector, manufacturing sector, tourism sector, and agricultural sector, are impacted by extreme weather events, with detrimental effects on the economy of Sri Lanka [30].

2.1.3. Sea Level Rise

Between 1901 and 2018, the sea level increased by a mean of 15 cm (6 inches). If GHG emissions are not considerably decreased, sea-level rises could increase by up to 1 m (3.3 feet) by the end of the 21st century [35]. Sri Lanka is a small island nation, which is particularly susceptible to sea-level rises. Sea levels may increase by approximately 0.61 m by the century's end, with a significant impact on Sri Lanka's coastal areas [28].

All coastlines worldwide will be impacted by the sea level rises at the end of the 21st century; for example, lowlands in the coastal areas of some countries will be submerged due to the rise in sea levels [36]. Therefore, a considerable area of land and some people may be displaced by rising sea levels [37]. Further, ground and surface water salinization through saltwater intrusion, erosion, inundation, a higher water table or impeded drainage, flooding, and wetland degradation, will occur as a result of the rise in sea levels [38]. The country's economy will also be impacted by the sea level rises due to their impacts on some of the major industries that contribute to the country's economy [7]. Thus, disturbances to marine recreational activities, the destruction of ocean biodiversity, coastal erosion, and saltwater intrusion also will be caused by sea-level rises [30]. Moreover, sea-level rises will have significant impacts on the built environment [30]. The country's economy will also be impacted by sea-level rises, which will have impacts on some of the major industries contributing to the economy of the country [7]. Sea-level rises will also have significant impacts on the built environment [30].

2.2. Façade-Access Methods

When glass was first used more frequently as a large-scale construction material, the demand for façade access emerged [39]. Windows on single-story buildings could be cleaned by hand with relative ease, but as buildings expanded in height, it became more difficult to reach their windows and other exterior surfaces [39]. Thus, the method of accessing façades is selected based on the height of the building [40]. Façades are accessed through a rope system up to 12 floors and other façade-access methods are used for buildings with more than 12 floors [40]. Thus, different façade-access systems have been used for façade-maintenance activities to date all around the world, as represented in Table 1 [39].

Although façade-access systems are still a new discipline, it is critical to understand the consequences of deciding on a façade-access system early in the design process [39]. However, even though façade access is still considered the latest technology, the means of accessing façades should be given significant consideration so that the façade-maintenance activities can be conducted appropriately [39]. Thus, special consideration should be paid to the façade-access system so that façade maintenance can be performed properly [39]. Accordingly, safe means of access to façades should be provided [41]. Furthermore, only competent employees should be involved in façade access [42].

Table 1. Overviews of different façade-access systems that are used worldwide.

Façade-Access Method	Description
• Direct access	Generally, direct access from the inside of the building is used for washing windows in low-rise buildings. However, most of the buildings refrained from using this method due to the importance of airtight façades and the height of the buildings.
• Water-fed pole systems	Windows in façades are cleaned from a safe level with the help of this method, in which a telescoping pole is connected to a waterline and a brush at the corner is used by the user.
• Mounted suspension systems	Abseils were the first mounted suspension system, in which the window-washer is hung from one support line tied to the roof and effectively moves down the façade for access. Thereafter, Bosun's chairs or Boatswain's chairs were introduced, in which suspended seating or a chair from the roof is provided for the user to sit and conduct cleaning activities.
• Aerial work platforms	This method comprises mobile ground-based systems that enable access to building façades for maintenance and development. In current practice, a wide range of equipment is used, with different mechanical mechanisms in terms of work platform positioning (either wheels or tracks) that meet the needs of the users. All of these systems, regardless of their vertical or horizontal reach, should be combined with a personal fall-protection platform for employees, and the system operation must be terminated under strong wind conditions according to the requirements of the applicable laws. 1. Boom Lift Access to façades with a wide range of heights can be obtained through this equipment, which can be applied to high-rise buildings. Boom lifts are categorized into two types: telescoping boom lifts, which are capable of expanding during use and contracting and storing and articulating boom lifts that are capable of increasing their positioning with the help of hinges. Both slewing and luffing movements can be performed with both types up to a height of 46 m. 2. Scissor Lift One aerial work platform can be used to access vertical heights of up to 18 m using a scissor-type mechanism. Horizontal movements cannot be performed through scissor lifts. 3. Mast Lift This is an aerial work platform that can be used to access shorter heights. Mass lifts are categorized into two types, namely mast boom lifts and vertical mass lifts. Vertical mass lifts are the same as the scissor lifts and only vertical heights of up to 18 m can be reached by moving parallel to the equipment. Mast boom lifts follow the same mechanism as vertical mass lifts; however, a specific component, which is referred to as a boom arm, is used in this equipment, which enables horizontal access to the façades. Mast booms can only reach heights of up to 10 m, with a 4.4 m movement. Equipment with slewing is capable of rotating the platform by 360 degrees. 4. Spider This system is also known as a cherry picker or articulated lift. It is installed on the outside of the building and the transport basket is constructed in a collaborative procedure. 5. Temporary Platform Gondola System
• Rope access	As this equipment is flexible, durable, and easy to use, it is widely used in the industry. Two independent lines of ropes, known as primary and secondary ropes, are fixed to the roof above the working area, with anchors in which workers can perform maintenance activities. When accessing the façades through ropes, safety tiebacks will provide more safety for the rope-accessing people, who are equipped with a harness. Rope access can be easily and safely performed with the help of track systems, eyebolt anchors or davits. Pod bags are used by the workers to carry the equipment and tools in this method.

Source: [39].

2.3. Façade Maintenance

Façade maintenance is an important aspect of a building maintenance schedule because a building's exterior not only contributes to its aesthetic appearance but also provides protection to the inside of the building [43]. The BS 8210:2012 Code of Practice for the cleaning and surface repair of buildings is one of the most internationally accepted standards for building façade maintenance [44]. The British Standards Institution (BSI) created this standard to provide recommendations on the examination, cleaning, and maintenance of building façades, stating that building façades should be evaluated periodically to detect any faults or damage [44]. The frequency of inspections will vary depending on the type of facility and location; however, inspections should be performed at least once a year, as it is critical to use appropriate maintenance procedures and products while cleaning building façades to prevent harm [45]. Other standards may apply to façade maintenance in addition to BS 8210:2012, based on the location and type of building [45]. Accordingly, façade maintenance schedules should be prepared by considering the possibility of safe access to façades without disruptions and the maintenance frequency required by the façades according to the durability of the façade components, as shown in Table 2 below [41].

Table 2. Maintenance frequency of the façades based on the durability of the façade components.

Durability	Maintenance Frequency
Very Long	Maintenance is not performed during the design stage.
Long	First maintenance is expected to be performed from approximately 10 to 20 years.
Medium	First maintenance is expected to be performed from approximately 5 to 10 years.
Short	Maintenance is performed at shorter intervals, approximately 2 or 3 years, with decorative or aesthetic intentions.

Source: [41].

Moreover, the maintenance schedules of façades can be created based on the inspection frequency of the façade, as stated in Table 3 [41].

Table 3. Inspection frequency of the façade.

Frequency	Maintenance Inspection Activities
Routine	Regular inspections should be performed continuously by users and the results of these inspections should be considered.
General	Main elements should be visually inspected by qualified personnel at the time intervals detailed in the maintenance manual.
Detailed	The façade should be completely inspected by qualified personnel at the time intervals detailed in the maintenance manual. However, this period should not exceed five years.

Source: [41].

Cleaning the façade regularly is an important part of façade maintenance because it assists in removing dirt, contaminants, and other particles that can accumulate over time [43]. This can be accomplished through a variety of methods, such as pressure washing, chemical treatment, and abrasive cleaning [43]. The best cleaning method will be impacted by the kind of façade material and the amount of dirt and other particles [43]. Thus, safety at heights is the main consideration in façade maintenance [42]. Therefore, façade maintenance workers should be well-trained in both cleaning skills and best OHS practices so that work can be performed safely at the necessary height [42].

2.4. OHS of Façade-Maintenance Workers

Thus, OHS can be described as the protection of the health of workers in workplaces through the prediction, identification, analysis, and monitoring of hazards that could impact the surrounding environment and community [46]. Accordingly, OHS can be identified as a key component in the achievement of better working conditions in workplaces and protection of workers from illnesses, injuries, and various other risks [46].

Both workers and the working environment can be protected by complying with OHS practices concerning the variations in political, economic, social, and technological fields through the coordination of knowledge and skills [46]. Thus, medical inspections should be performed of façade-maintenance workers before the beginning of maintenance activities [43]. Pre-employment medical exams can be performed before starting work, in which employees should receive a medical exam to assess their fitness for working at heights and undertaking physically demanding tasks [43]. This checkup comprises a general health check, an eye exam, and a chest x-ray to rule out lung illness [43]. Moreover, regular medical checkups also can be performed, and workers should undergo periodic medical examinations to assess their current medical condition, particularly regarding the respiratory and musculoskeletal systems, to make sure that any potential health issues are identified and treated as soon as possible [43]. Thus, both active control systems, which are maintained by the workers while performing their work, and passive risk control systems, which are maintained by the original installers and do not need any adjustments while performing the work, should be considered regarding reductions in the possible risks for façade-maintenance workers [47].

3. Materials and Methods

Accordingly, a research methodology is required to establish a systematic way of resolving a research problem and help the researcher to perform the research scientifically by taking various steps to logically evaluate the research problem [48]. A review of the research area, present information, and previous studies regarding this issue can be identified in background research to assist in proving the suitability of the research problem and develop further studies [49]. A background study was conducted as an initial step of the research process to identify the research problem and research gaps, formulate the aims and objectives, and determine the scope and limitations of the research. Thus, a background study was performed after referring to journal articles, research papers, periodicals, books, conference proceedings, government and private-sector reports, and official websites.

Qualitative research is a research technique employed to gather information that is difficult to quantify [50]. Thus, qualitative research techniques are usually exploratory, aiming to comprehend the experiences, opinions, and perspectives of the individuals being studied [50]. Data for this type of research are gathered through open-ended questionnaires, interviews, findings, and focus group discussions [50]. A qualitative research approach was undertaken in this study. The qualitative research approach is appropriate for the exploration of concepts using a small set of respondents and can help to complete the research within a shorter period in a cost-effective way. Furthermore, this research approach is more flexible than other methods, as a specific format is not required for the data-collection process, which is focused on the subtlety of data.

The collection of data is an important phase of research, which entails gathering data on a specific question or hypothesis. Based on the research's purpose, the collected data can be of two kinds: qualitative or quantitative [50]. The objective of data collection is to acquire accurate and dependable data that can be used for analysis and interpretation to create important insights [50]. Thus, interviews are a set of prepared questions that are asked to the respondents in a sequence [48]. With the aid of interviews, primary data were collected to achieve the aim and objectives of the study. These expert interviews were conducted in a semi-structured format with 12 experts in the facility management and façade-maintenance sectors with more than 10 years of industry experience, selected using the judgmental sampling method. Experts interviews often provide in-depth and complex information that other techniques, including surveys or analyses of secondary data, may not be able to provide, and experts frequently provide insights based on their many years of expertise and specialist knowledge in their profession. The selection of experts is shown in Figure 1: 42% of the selected experts were belonged to the categories with 10–20 and 20–30 years of experience; 8% of the selected experts were belonged to the categories with 30–40 and more than 40 years of experience. Moreover, 45% of experts used the ropes-façade-access method and 27% of experts used a gondola-façade-access method. Furthermore, 14% of experts used scaffoldings and boom trucks as a façade-access method. Semi-structured interviews were conducted with experts to gather data with the aid of questionnaires.

Figure 1. Selection of experts.

A literature review is an in-depth examination of the available literature in a research study [48]. It is a critical phase of the research procedure because it offers a comprehensive summary of the topic's current knowledge base and identifies future research directions and variations in the literature. A comprehensive literature review was conducted in this research to obtain an overview of climate, climate change, the impacts of climate change in global and Sri Lankan contexts, an overview of the façade and its maintenance, OHS and its importance, and the impacts of climate change on façade maintenance workers. The literature review was performed after referring to journal articles, periodicals, books, research papers, conference proceedings, government reports, official websites, etc., to collect the required secondary data. Through a comprehensive literature review, a summarization and evaluation of previous studies' research findings could be used to respond to research inquiries and lay the groundwork for future research, as well as assisting researchers in identifying the key conceptual and methodological methodologies that were implemented in previous studies.

Data analysis should be performed soon after the completion of the data collection process [48]. Editing, tabulation, statistical analysis, and coding are some of the methods that can be used in the data analysis process [48]. The data analysis technique used in the research is limited by the applied data collection techniques [51]. Moreover, the way in which the data analysis process is performed depends on two factors, namely information type (qualitative or quantitative) and the way in which findings are presented to others [52]. Thus, content analysis can be identified as a technique that helps in the creation of valid inferences, including the use of visual, written, or verbal data to quantify and explain specific steps [53]. Content analysis refers to replicable and systematic techniques that can be used to compress texts with words into various content types [54]. The collected data were analyzed using software-aided thematic content analysis with the aid of NVivo software, as the collected data related to the research problem can be analyzed systematically in a more reliable manner within a shorter period. The inferential quality of the findings can be enhanced by integrating categories with the context of the produced data through content analysis, as this helps to summarize and reduce the data by identifying various correlation patterns in the observed variables.

4. Results

4.1. Climate Change Impacts on Façade-Maintenance Workers

In Sri Lanka, according to the experts, scaffoldings, gondolas, ropes and boom trucks are used for façade access in Sri Lanka. Moreover, as per the findings of the expert interviews, a considerable impact of climate change on almost all the façade access methods can be identified. Extreme weather conditions including storms, hurricanes, and floods may become more common as a result of climate change, which can make accessing building façades, particularly those at height, more difficult and riskier. For example, high winds are likely to render it impossible for workers to safely use suspended-access equipment such as cradles or platforms. Precipitation and temperature trends can also alter as a result of climate change. Warmer temperatures, for example, may cause more frequent and extreme heat waves, making it more challenging for employees to safely access façades. Heavy rain and snowfall may additionally render façade-maintenance workers' jobs dangerous. Accordingly, all the experts who used scaffoldings, gondolas and boom trucks stated that their façade-access methods are impacted by climate change. However, different perceptions were identified by experts who used rope access, as one expert stated that any certain forecast cannot be made regarding the impacts of climate change on the OHS of façade-maintenance workers using rope access.

Almost all the experts who used scaffoldings, gondolas and boom trucks stated that climate change impacts the OHS of façade-maintenance workers. However, 90% of experts using the rope façade-access method stated that climate change is impacting the OHS of façade-maintenance workers, and 10% of the experts elaborated that the forecasting of climate change's impacts on the OHS of façade-maintenance workers cannot be predicted, because most of them have had real-life experiences, including accidents in the industry, caused by climate change when using ropes to access façades. Various reasons for the occurrence of accidents among façade-maintenance workers were given, namely animals, climate change, cracks in glasses, damage to ropes, falling equipment, maintenance malpractice, the malfunctioning of gondolas, and poor training and inspections. However, almost all the experts, irrespective of their method of façade-access, stated that climate change made a more significant contribution to the occurrence of accidents among façade-maintenance workers. All the experts validated the above statement with their real-time experience in the industry, as they have faced various hardships from climate change that have caused accidents.

As per the findings from the expert interviews, a considerable impact of climate change on the OHS of façade-maintenance employees can be identified, and 27 significant OHS risks were also identified. Various OHS risks for façade-maintenance workers in general and in the Sri Lankan context were identified in the current study; these can have catastrophic impacts, even leading to death, for the façade-maintenance workers due to their higher exposure to various climate-change scenarios when working at height outside buildings for a prolonged period. Moreover, some of the existing OHS risks are considerably increased by climate change, and the possibility of the occurrence of new OHS risks caused by climate change is also significantly high.

The interview responses identified various existing OHS risks for façade-maintenance workers, and climate change was shown to impact those risks, as shown in Table 4.

Thus, as per the experts' findings, the façade-maintenance employees in Sri Lanka are considerably impacted by various climate change scenarios, namely, extreme wind, temperature, thundering and rain conditions, irrespective of the façade-access method used. Moreover, the slipperiness of the façades and the possibility of lightning and thunder during heavy rains cause difficulties in the performance of façade-maintenance activities. Furthermore, prolonged exposure to heavy rains may lead to injuries, deaths, and various sicknesses, such as cold and coughs, for the façade-maintenance employees, irrespective of the façade-access method used. When global temperatures increase, heat waves become more intense and frequent, increasing the risk of heat stroke along with other heat-related ailments for employees conducting maintenance chores on building façades. This may impact the risk of equipment falling, as employees could faint, causing equipment to fall. Furthermore, severe weather conditions such as thunderstorms or hurricanes produce strong winds, making it hard for workers to keep their balance and potentially causing them and their equipment to fall from the façade. Whether the existing OHS risks for façade-maintenance workers in Sri Lanka, as shown in Table 4, are increased, decreased or unchanged due to climate change can be denoted as follows.

Table 4. Identifying whether climate change impacts existing OHS risks.

Facade Access Method	OHS Risks	Impacts by Climate Change Yes	No	May Be	References
Scaffoldings	Risks from falling equipment	√			EI-8, EI-9, EI-10
	Risk of workers' falling	√			EI-8, EI-9, EI-10
	Risks caused by scaffolding becoming slippery	√			EI-9, EI-10
	Risk of employees fainting, becoming sick, being injured, or death	√			EI-8, EI-9, EI-10
Gondolas	Risk of workers dropping or throwing the from the bucket	√			EI-3, EI-5, EI-8, EI-9, EI-10, EI-11, EI-12,
	Risk of employees fainting, becoming sick or injured (eg: bruises and cuts) or dying while carrying out façade maintenance at height	√			EI-3, EI-5, EI-8, EI-9, EI-10, EI-11
	Risk of employees being caught in thunderstorms	√			EI-5, EI-12
	Risks caused by falling gondolas	√			EI-3, EI-12
	Risks caused by the collision of the gondola bucket with the façade due to the vibration of the bucket	√			EI-5, EI-8, EI-10, EI-12
	Risks caused by falling equipment	√			EI-3
	Risks caused by fraying or damage to the wire ropes of gondolas	√			EI-3
	Risk of heatstroke	√			EI-5
	Risks caused by not wearing PPE	√			EI-8
Ropes	Risks caused by façades becoming slippery	√			EI-1, EI-7
	Risks caused by not wearing PPE	√			EI-1
	Risk of employees fainting, becoming sick (examples: common cold and cough) or severely injured or dying while carrying out façade maintenance at height	√			EI-2, EI-4, EI-7, EI-9, EI-10, EI-12
	Risk of employees falling	√			EI-9, EI-10, EI-12
	Risks caused by falling equipment	√			EI-12
	Risk of employees being caught in thunderstorms	√			EI-7, EI-12
	Risks causd by the difficulty of working with ropes for hours	√			EI-7
	Risks caused by the swaying of ropes, resulting in the collision of workers with the façade	√			EI-7, EI-9
	Risks caused by ropes breaking	√			EI-4, EI-8
	Risks caused by dust and other particles getting in workers' eyes	√			EI-4
Boom Trucks	Risk of workers falling	√			EI-8, EI-9, EI-10
	Risk of employee injury or death	√			EI-8, EI-9, EI-10
	Risk of employees being hit by thunderstorms	√			EI-9, EI-10
	Risks caused by the collision of the bucket with the façade due to swaying	√			EI-8, EI-9, EI-10

Note that EI refers to expert interview.

Expert interview (EI)-8, EI-9, and EI-10 show that the risk of falling equipment, risk of falling workers, risk of scaffolding becoming slippery, and risk of employees fainting, becoming sick or injured, or dying are faced by façade-maintenance workers who use scaffoldings for façade access. These are increased by climate change, including extreme weather conditions such as wind or rain and temperature variations, as indicated in Figure 2.

As per EI-3, EI-5, EI-8, EI-9, EI-10, EI-11 and EI-12, the risks of workers being thrown or falling out of the bucket, risk of employees fainting, becoming sick or injured (e.g., bruises and cuts) or dying while carrying out façade maintenance at height, risk of employees being hit by thunderstorms, risk of falling gondolas, risks of gondola bucket colliding with the façade due to bucket vibrations, risk of falling equipment, risks of frayed or damaged wire gondola ropes, risk of heat stroke, and risk of not wearing PPE for façade-maintenance workers who used gondolas for façade access are increased by the climate change impacts, including extreme weather conditions such as wind or rain and temperature variations, as indicated in Figure 3.

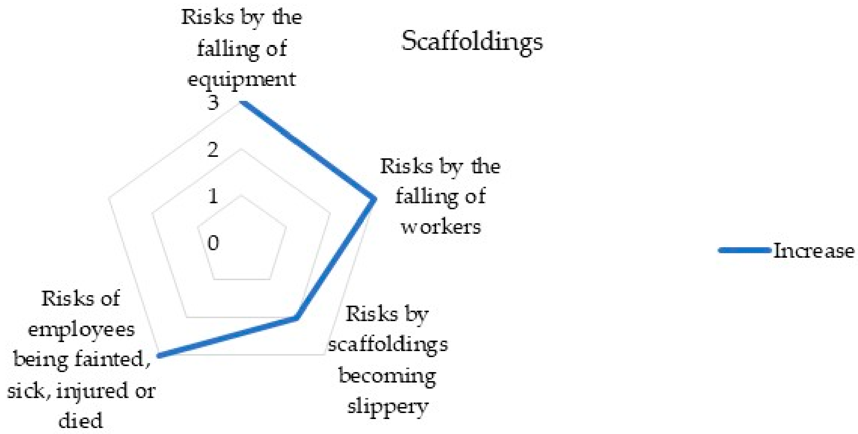

Figure 2. Increase, decrease or no change in OHS risks caused by climate change for façade-maintenance workers' access through scaffolding.

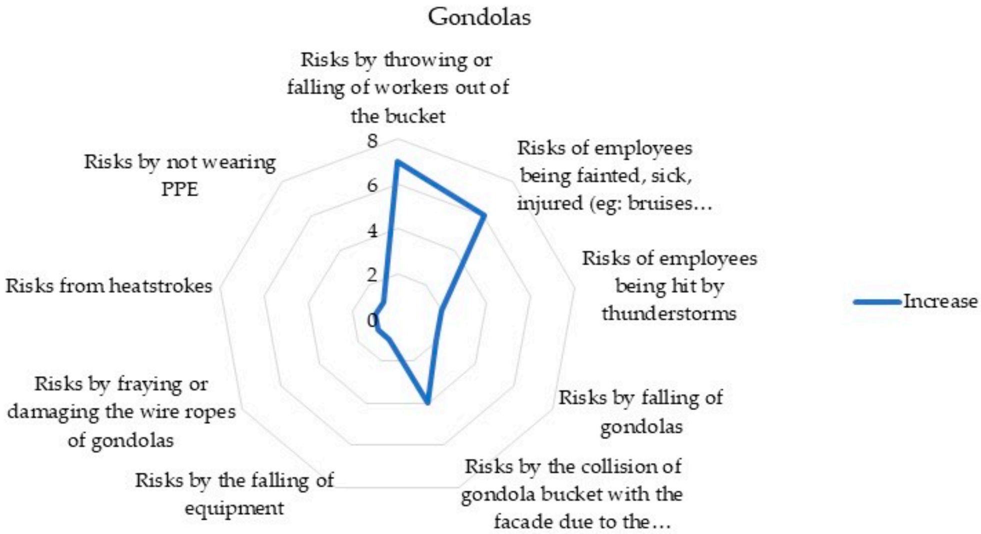

Figure 3. Increase, decrease or no change in OHS risks caused by climate change for façade-maintenance workers' access through gondolas.

As per EI-1, EI-2, EI-4, EI-7, EI-8, EI-9, EI-10 and EI-12, the risks of façades becoming slippery, risks caused by not wearing PPE, risks of employees fainting, becoming sick (examples: common cold and cough) or severely injured, or dying while carrying out façade maintenance at height, risk of employees falling, risk of equipment falling, risk of employees being hit by thunderstorms, risks caused by the difficulty of working with ropes for hours, risks caused by the swaying of ropes, resulting in workers colliding with façade, risk of ropes breaking, and risk of dust and other particles falling in the eyes of workers for the façade-maintenance workers who use ropes for façade access are increased by the climate change impacts, including extreme weather conditions such as wind or rain and temperature variations, as indicated in Figure 4.

As per EI-8, EI-9, and EI-10 the risk of workers falling, risk of employees becoming injured or dying, risk of employees being hit by thunderstorms, and risk of the bucket colliding with the façade due to swaying for the façade-maintenance workers who use boom trucks for façade access are increased by the impacts of climate change, including extreme weather conditions such as wind or rain and temperature variations, as indicated in Figure 5.

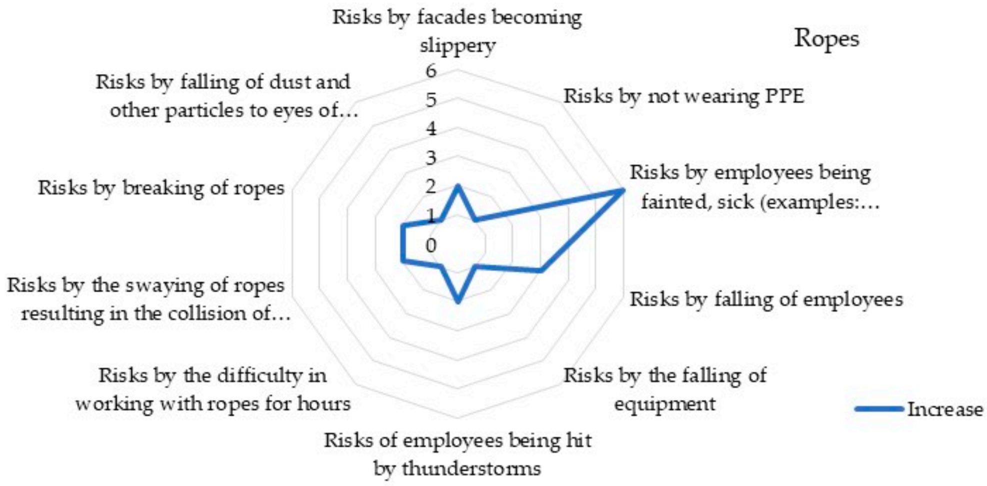

Figure 4. Increase, decrease or no change in OHS risks caused by climate change for façade-maintenance workers' access through ropes.

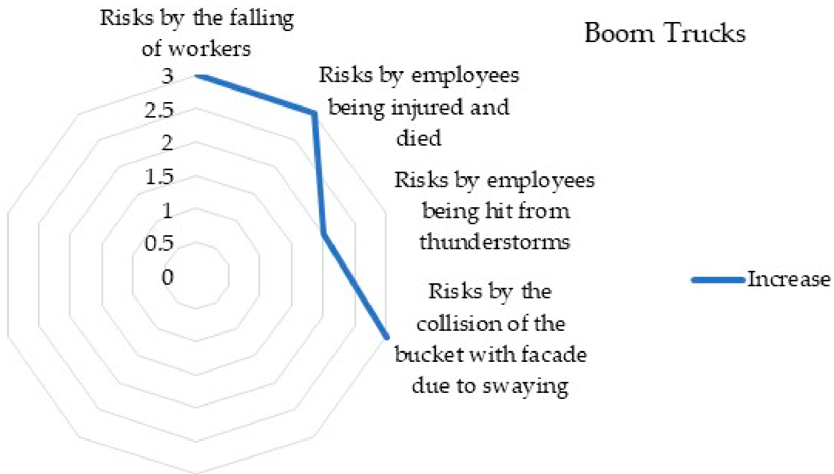

Figure 5. Increase, decrease or no change in OHS risks caused by climate change for façade-maintenance workers' access through boom trucks.

Therefore, climate change scenarios should be considered before and during the performance of façade-maintenance activities, irrespective of the façade-access method that is used. Moreover, necessary climate change adaptation measures should be practised to protect against unexpected incidents due to climate change. Thus, appropriate climate change adaptation measures should be adopted by practitioners for the identified climate-change-impacted OHS risks for façade-maintenance workers in Sri Lanka to provide a safer working environment in which to deliver façade maintenance activities. Thus, such measures will be beneficial for the façade-maintenance practitioners, allowing them to deliver their services productively with minimal or zero effects of climate change.

4.2. Climate Change Adaptation Measures

Thus, as façade maintenance is an essential activity, it is essential to perform periodic maintenance activities without any hindrances while ensuring the safety and security of the façade-maintenance workers. Therefore, façade-maintenance practitioners are considering the possibility of adopting various climate change scenarios experienced while carrying out façade maintenance activities. Almost all the experts stated that climate change is considered before or during the performance of façade-maintenance activities, irrespective of the façade-access method that they used, as climate change is capable of creating unexpected catastrophic incidents for façade-maintenance workers.

Table 5 presents an excerpt from the full list of climate change adaptation measures that are currently being practised and can be added to the current practices regarding the existing OHS risks faced by façade-maintenance workers in Sri Lanka, as follows.

Table 5. Adaptation measures that are currently being practised and can be added to the current practices for existing OHS risks caused by climate change that are faced by façade maintenance workers in the Sri Lankan context.

Facade Access Method	OHS Risks	Adaptation Measures	References
Scaffoldings	Risk of workers falling	• Inspecting the condition of scaffolding before the beginning of façade maintenance and fixing safety nets. • Anchoring scaffoldings properly to façades with the help of brackets and performing pull-out load tests at each anchoring point. • Personal protection equipment (PPE) is provided, including safety helmets, boots, face protection, belts, gloves and full-body harness kits. • Performance of visual inspections regarding weather conditions and referring to daily weather forecast reports before and during façade maintenance. • Works must not be performed under adverse weather conditions; wind speed is measured by a wind speedometer and workers are not allowed to work if the wind speed is above 20 km/h.	EI-6, EI-8, EI-9, EI-10
	Risks caused by scaffoldings becoming slippery	• Calling off work immediately and allowing the employees to safely land from the scaffoldings if heavy rain is going to occur. • Personal protection equipment (PPE) is provided, including safety helmets, boots, face protection, belts, gloves and full-body harness kits. • Performance of visual inspections regarding weather conditions and referring to daily weather forecast reports before and during façade maintenance. • Work must not be performed under adverse weather conditions; wind speed is measured by a wind speedometer and workers are not allowed to work if the wind speed is above 20 km/h.	EI-6, EI-9, EI-10
Gondolas	Risks caused by the collision of the gondola bucket with the façade due to the vibration of the bucket	• Not operating gondolas if heavy winds occur. • Application of rubber wheels to protect the façades if they are hit by the gondola buckets. • Fixing of gondola restrain hooks composed of tie wires. • Personal protection equipment (PPE) is provided, including safety helmets, boots, face protection, belts, gloves and full-body harness kits. • Performance of visual inspections regarding weather conditions and referring to daily weather forecast reports before and during façade maintenance. • Work must not be performed under adverse weather conditions; wind speed is measured by a wind speedometer and workers are not allowed to work if the wind speed is above 20 km/h.	EI-3, EI-5, EI-8, EI-9, EI-10, EI-11, EI-12
	Risk of heatstroke	• Carrying water bottles. • Provision of shade in the gondola to protect from sunlight.	EI-5, EI-12

Table 5. *Cont.*

Facade Access Method	OHS Risks	Adaptation Measures	References
Ropes	Risks caused by the difficulty of working with ropes for hours	• Stopping all work immediately and instructing workers to remove themselves from the ropes if heavy wind or rain is going to occur. • Taking water and other essentials. • Performance of visual inspections regarding weather conditions and referring to daily weather forecast reports before and during façade maintenance. • Work must not be performed under adverse weather conditions; wind speed is measured by a wind speedometer and not allowed to work if the wind speed is above 20 km/h.	EI-1, EI-2, EI-4, EI-6, EI-7, EI-8, EI-12
	Risks caused by the swaying or ropes, resulting in workers colliding with the façade	• Personal protection equipment (PPE) is provided, including safety helmets, boots, face protection, belts, gloves, glass shackles, and full-body harness kits. • Performance of visual inspections regarding weather conditions and referring to daily weather forecast reports before and during façade maintenance. • Work must not be performed under adverse weather conditions; wind speed is measured by a wind speedometer and workers are not allowed to work if the wind speed is above 20 km/h. • Stopping all work immediately and instructing workers to remove themselves from the ropes if heavy wind is going to occur.	EI-1, EI-2, EI-4, EI-6, EI-7, EI-12
Boom Trucks	Risk of employees being hit by thunderstorms	• Performance of visual inspections regarding weather conditions and referring to daily weather forecast reports before and during façade maintenance. • Work must not be performed under adverse weather conditions; wind speed is measured by a wind speedometer and workers are not allowed to work if the wind speed is above 20 km/h.	EI-9, EI-10
	Risks caused by the collision of the bucket with the façade due to swaying	• Performance of visual inspections regarding weather conditions and referring to daily weather forecast reports before and during façade maintenance. • Work must not be performed under adverse weather conditions; wind speed is measured by a wind speedometer and workers are not allowed to work if the wind speed is above 20 km/h.	EI-8, EI-9, EI-10

Note that EI refers to expert interview.

As per the experts' responses, various safety precautions should be taken against accidents due to climate change, namely checking the health condition of workers and providing life insurance, facilitating emergency communication, the application of glass shackles, rubber wheels, safety nets and gondola restrain hooks, measuring weather conditions, providing PPE, following safety guidelines, fixing signage, visual inspection of weather conditions, performing inspections and testing, etc. Thus, it is essential to follow these adaptation measures according to the situation to ensure the OSH of façade-maintenance workers, occupants, and nearby people and properties.

5. Discussion

This study discusses various impacts of climate change on the OHS of façade-maintenance workers while introducing appropriate climate change adaptation strategies. Outdoor workers can be regarded as the first group of people affected by climate change [18]. According to the experts, the OHS of façade-maintenance workers will be subjected to the significant effects of climate change during the upcoming period, as Sri Lanka is identified as a country that is highly subjected to the different climate change scenarios. Notably, a considerable number of negative consequences of climate change, which can affect the OHS of façade-maintenance workers either directly or indirectly, can be identified. Thus, employees should be more understanding of the situations that may arise regarding their OHS due to the effects of climate change. Workers will be exposed to both traditional and unidentified hazards due to climate change.

Thus, extreme weather conditions, namely droughts, floods, landslides, storms, and wildfires, caused by climate change, could considerably influence the OHS of outdoor workers, causing mental fatigue [32]. According to the experts, façade-maintenance workers are experiencing high risks due to the extreme wind and rain conditions. The severity and frequency of these risks could increase as a result of climate change. Moreover, the swaying of ropes and buckets on gondolas and boom trucks due to heavy winds results in these items colliding with the façades, causing severe injuries and even death. Furthermore, the scaffoldings and ropes will be operated under slippery conditions due to heavy rains, causing accidents for façade-maintenance workers.

The increase in average global surface air temperature over the past 100 years has resulted in heat-related effects for workers, which can be fatal [32]. According to the experts, these direct effects could increase injuries due to exposure to extreme heat conditions. Heat exposure can lead to fatal or severe non-fatal risks to workers [17]. According to experts, façade-maintenance workers are also experiencing various physical and mental health issues due to the extreme temperatures. Most workers have to perform their entire job in a hot working environment, which has become hotter due to the increase in ambient temperatures or increase in extreme heat events.

Thus, outdoor workers are at high risk due to the adverse OHS impacts in recent decades and exposure to UV radiation [32]. UV radiation can considerably affect façade-maintenance workers; overexposure to UV radiation can lead to severe immune suppression, sunburn, eye damage, and skin and other cancers. Climate change will also cause most outdoor workers to be frequently exposed to various environmental pollutants [12]. Façade-maintenance workers are also working outside, and allergic disorders, strokes, respiratory illnesses, irritations, and ischemic heart illnesses can occur due to exposure to air pollution.

Climate change impacts related to the health of the workers can be reduced through three broad approaches, namely; prevention of the production of GHGs, the implementation of various approaches to overcome the impacts of climate change, and the implementation of proper actions to ensure the OHS of workers [12]. The severity of OHS injuries and risks due to climate change is increasing each day while people are searching for climate change management models [32]. Adaptation strategies are key to overcoming the challenges generated by climate change. Therefore, adequate financial and human resources should be available for the implementation of these adaptation plans, allowing for organizations to counteract the effects of climate change [55]. Accordingly, the preparedness of both employers and employees regarding climate change should consist of a well-organized set of actions for controlling and monitoring [7]. Thus, realistic models should be used for the development of these adaptation plans [56]. Moreover, maintenance activities and technical works should be developed, establishing an appropriate climate adaptation strategy [15]. Hence, the development of or change in traditional job roles could also be identified as a remedy for climate change [20]. The job roles of workers who are affected by climate change should be characterized [19]. Reducing the application of physical labour during peak heat hours, providing adequate training regarding climate change responses, and increasing resting time intervals during work shifts are simple techniques that can be applied to prevent the occurrence of the above-stated hazards for façade-maintenance workers. More attention should be paid to the strategic planning of actions for the mitigation of or reduction in OHS injuries and risks due to climate change and awareness programs regarding climate change [32]. In addition, experts stated that identification of the severity, frequency, and likelihood of hazards will also help in the proper implementation of mitigation processes.

Hence, the findings of the current study are beneficial for the future of the FM industry in Sri Lanka, as well as other tropical countries with similar climatic backgrounds, allowing for them to deliver maintenance services effectively and efficiently by adopting the appropriate measures to protect against the unexpected accidents and hindrances caused by climate change. Climate change will soon be a considerable threat to almost all the countries in the world, with catastrophic impacts on the façade-maintenance industry. Thus, more attention should be given paid to combatting the varying climate change scenarios and improving the lives of façade-maintenance workers.

6. Conclusions

Considerable attention should be paid to identifying the impacts that climate change has on different façade-access methods and façade-maintenance workers to develop building-level adaptation measures. A scarcity of such findings in the existing literature was identified, which we aimed to address in the current study. When developing such adaptation measures, the case of façade-maintenance workers was selected. Façade-maintenance activities have become more complicated due to the construction of sophisticated façades with advanced technologies, as well as due to the impacts of climate change, as asserted in the current study. Therefore, the identification of climate change's impacts and appropriate climate change adaptation measures will be help to effectively and efficiently perform façade-maintenance activities, removing any hindrances to the performance of these activities. This is necessary, as the façade is an essential building component that directly affects the performance of the building. Moreover, these measures will pave the way to protect not only façade-maintenance employees, but other, similarly vulnerable groups of workers from unanticipated accidents and various other difficulties caused by climate change. Thus, the findings of this research will be invaluable to the enhancement of the facilities management (FM) industry. Moreover, while the current study focuses on Sri Lanka, these findings will make significant contributions to the development of climate change adaptation measures in the building and facilities' management industries in tropical countries the world-over.

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