THE IMPACT OF POWER INTERRUPTIONS ON MULTI-STOREY COMMERCIAL BUILDINGS IN SRI LANKA

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Abstract. The recent Sri Lankan economic crisis has led to fuel shortages, affecting power supply in multi-storey commercial buildings. The consequences of power interruption vary by facility type and consumer categories. Thus, comprehensive studies are required to assess the cost of unserved energy. Recently, high-rise commercial buildings have been increasingly studied, due to the shown variations in energy use. Considering this energy usage variation and the requirement of further studies, this study aims to explore the impacts of power interruption on multi-storey commercial buildings in Sri Lanka. Under a qualitative research approach, five multi-storey commercial buildings were selected for the case studies. Document reviews and semi-structured interviews with two respondents in each selected building were executed to data collection, and data were analysed using manual content analysis. The findings revealed that power interruption significantly affects commercial activities, business operations, building systems, maintenance and customer service. Also, the power interruption impacts are varied across the core business activities of the building. As the current solutions, generators and uninterruptible power supply are widely used. Fuel shortage, lack of skilled personnel, and lack of experience in sudden power outages are key barriers to implementing the identified solutions. To overcome the impacts of power interruption, strategies such as remote working, shift scheduling, work prioritisation, limiting the number of operational floors, limited usage of unnecessary systems and equipment, entering into the fuel supplier agreements and conducting routine maintenance to reduce power dependency during outages were suggested.

Keywords. Commercial Building, Electricity, Power Interruptions, Power Supply

1. Introduction

Multi-storey buildings have been rapidly increasing worldwide, due to restricted land availability in popular places and their fundamental role as vital buildings in modern cities and capitals(Amadi & Okafor, 2015). A multi-storey building is a structure with a total height of more than 36 meters or more than 12 floors, with a variety of uses such as residential, administrative, or hotel (Farouk, 2011). The concept of a multi-storey building is generally understood as a structure with multiple floors above ground level. While there is no explicit minimum number of floors defined, research often focuses on buildings with more than four floors (Zohair & Reddy, 2018). Multi-storey buildings appear to be the more environmentally friendly solution to urban density and enable larger urban density than lower buildings and occupy a small area (Weidner et al., 2018). Multi-storey commercial buildings are designed to accommodate a large number of people and businesses, and include amenities such as elevators, escalators, and parking facilities. Multi-storey commercial buildings are common in urban areas where space is limited and the demand for commercial space is high (Levine et al., 2007). However, a closer inspection reveals that multi-storey buildings consume more resources than low-rise buildings due to increased requirements for structure, façade, vertical transit, and foundations (Hall, 2013). Also, multi-storey office buildings reveals that the intensity of electricity and fossil fuel usage has been increased in multi-storey office buildings (Godoy-Shimizu et al., 2018).

The power supply is an important aspect to the multi-storey commercial buildings. For a multi-storey hospital building, continues power supply is required to run the emergency equipment whereas, multi-storey warehouse buildings require continues power supply to carry out continuous production in their daily operations. Power distribution has a more concentrated view at the operational level since power interruptions negatively influence key services, business, public life, productivity, resource utilization, and overall customer satisfaction and service level (Al-Aomar et al., 2017). Frequent power outages are also expected to cause direct damage to electrical appliances such as refrigerators, televisions, and other electronics (Cissokho & Seck, 2013).Increased energy consumption, particularly commercial energy like electricity, has

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become a symbol of a country's high economic status (Meles, 2020). Frequent power interruptions adversely affect output in productive sectors and discourage new firms from locating or investing in a country (Fakih et al., 2020). The consequences of power outages are depending on whether it is occurring in manufacturing plants, commercial service firms, or households (Suman et al., 2021). Power outages have significant economic and health impacts, particularly in high-rise commercial buildings. These outages can disrupt critical infrastructure, hinder emergency responses, and affect business operations (Mangat & Singh, 2015).
The economic impact of electricity interruptions varies across consumer categories such as domestic, industrial and commercial, requiring comprehensive studies to assess the cost of unserved energy (Colambage, 2022). High-rise commercial buildings receiving more attention in recent studies, due to shown variations in energy use and emissions between high-rise and low-rise structures (Bahramian & Yetilmezsoy, 2020). In Sri Lanka, commercial sector consumers consume substantial energy to meet modern client expectations, and revealed that unexpected short outages generally incur higher costs than longer ones, while costs for expected outages increase with duration (Alahakoon et al., 2022; Balasooriya et al., 2023). Thus, it is notable that energy usage varies among different consumer categories with high-rise commercial buildings receiving particular attention. Also, rising costs associated with Sri Lankan commercial buildings emphasise the requirement of further studies on impact of power outages. Therefore, this study aims to examine the impacts of power interruption on multi-storey commercial buildings in Sri Lanka. In Section 1, the literature review explores multi-storey commercial buildings, their operations, the importance of power supply, sources of power, and the causes and im-pacts of power interruptions on such buildings. Sections 3, 4, 5, and 6 present the methodology, results, discussion, and conclusion, respectively.

2. Literature Review

Due to limited land supply in commercial zones of metropolitan cities multi-storey buildings are rapidly expanding throughout the world (Al-Janabi et al., 2021). Multi-storey commercial buildings have ability to accommodate a large number of businesses in a relatively small footprint (Rodrigues et al., 2019). Commercial buildings are utilized for commercial uses, including offices, shops, restaurants, and other establishments(Zuo, 2015).Multi-storey commercial buildings are significant element of urban landscapes, offering a variety of commercial spaces for enterprises and enhancing the life and energy of metropolitan regions (Jayasinghe et al., 2016). According to Yoo et al. (2013), these buildings require more complex mechanical, electrical, and plumbing systems to provide services to multiple floors.

2.1. OPERATION OF MULTI-STOREY COMMERCIAL BUILDING

The operation of a multi-storey building refers to the processes and activities involved in the day-to-day functioning of the building, such as its maintenance, security, management, and use by occupants (Cahvan et al., 2018). Smith et al.(2013) stated that building services are essential for the smooth operation of a commercial building and are required to ensure the safety, comfort, and functionality of the building for its occupants. In multi-storey buildings, air conditioning systems are equipped with variable speed drives since the cooling load varies throughout the day and season (Lopatin, 2016). Modern multi-storey structures frequently have a large interior space that is not naturally lit by sunlight and must be illuminated by artificial light and the lighting systems are responsible for at least one-third of a building's overall electrical energy costs (Jonas, 2024). Alarms and control units, fire safety control devices, annunciators, power supply, and wiring can all be found in building’s fire alarm systems (Nadeem et al., 2012). There are numerous staircases, elevator shafts, pipe shafts, air passageways, cable shafts, and other vertical shafts in multi-storey buildings are caused to quick fire spreads s (Liu et al., 2012). The

capacity to construct buildings that are taller and taller depends on the availability of efficient vertical transportation, and current developments in elevator design promise to drastically cut energy usage. The provision of electrical power to commercial buildings is referred to as "power supply," as it is necessary for the building's numerous electrical systems and equipment to function (Hossain et al., 2023).

2.1.1 importance of power supply to a commercial building

Power supplies are utilized in multi-storey commercial structures to provide electricity to different electrical loads under diverse building conditions (Rahman et al., 2018). It is anticipated that a dependable power supply service will improve business performance in terms of availability, quality, and pricing (Arnold et al., 2008). The productivity and welfare of a multi-storey structure are directly impacted by the availability and accessibility of energy supply (Nyanzu & Adarkwah, 2016). Power supply plays a significant role in enhancing the productivity of human capital and almost all corporate operations, particularly those involving industrial facilities (Scott et al., 2014). Power supply availability often plays a crucial role in keeping finished items on hand ahead of demand, which increases consumer satisfaction by ensuring that they are accessible when needed (Moyo, 2012). Commercial buildings use majority of its electricity for lighting (Muhamad et al., 2010). In addition, most energy is used for maintaining comfortable interior environment, including thermal comfort and air quality, as well as household appliances(Kamilaris et al., 2014). Operation of the building services in a commercial building depends on a continuous power supply (Sha & Qi, 2020). A reliable and efficient power supply system is crucial for ensuring the safety and convenience of a commercial building (Basak, 2015).

2.1.2 Sources of power supply for multi-storey commercial buildings in Sri Lanka

The energy demand for commercial buildings in Sri Lanka have increased due to modernized building facilities and current economic practices (Alahakoon et al., 2022). There are several sources of power supply for a multi-storey commercial building, including Grid power, generators, and solar panels. Commercial buildings in Sri Lanka primarily rely on fossil fuels for power supply, with thermal oil and coal and hydroelectricity is second energy source (Fernando et al., 2019). Approximately 160 nations worldwide currently generate electricity using hydropower technology (Kaygusuz, 2016). There is growing interest in diversifying power sources to include more renewable options such as solar and biomass (Nanayakkara et al., 2021).Even though the price is higher than grid electricity, it is vital to use diesel generators in hybrid energy systems of commercial buildings to provide reliable electricity (Kolhe, 2014). Hydropower, wind, solar, and biomass are renewable energy sources that can be used to reduce greenhouse gas emissions and regional air pollutants brought on by the combustion of fossil fuels. The reliability of electricity sources is crucial to the development of future energy systems and environmental sustainability (Müller et al., 2011).

2.1.3 Power interruption in Sri Lankan context

Power interruptions can be divided as planned and unexpected power. Utility companies use planned outages to do maintenance work. Customers are told well ahead of time when an interruption is coming (Colambage, 2022). Power supply in developing countries has been generally characterized by unreliability and inefficiency, resulting adverse impacts on the economic performance of firms (Cissokho & Seck, 2013; Moyo, 2012). Sri Lanka had power shortages due to generating capacity shortfalls and the incapacity of hydropower facilities to fully compensate during periods of major storms (Wijayatunga & Jayalath, 2004). The availability

of electricity from micro hydropower plants that have already been built is difficult to anticipate for a number of reasons, including climatic fluctuations (Hasan & Wyseure, 2018). Since the Russia-Ukraine war has already increased global oil prices, making it more expensive for Sri Lanka to import gasoline for daily necessities, the country is implementing rolling power cuts to save energy (Bobadilla, 2024). All of Sri Lanka's crude oil and refined petroleum products needed for transportation and electricity production must be imported at the current time since the nation has no confirmed fossil fuel resources (Colambage, 2022). Sri Lanka is in the midst of a severe economic crisis as a result of the country's depletion of foreign reserves, which has resulted in food, gasoline, pharmaceutical, cement, and other essential supplies shortages (Sharma, 2022). Long lines of fuel stations are a direct effect of a lack of foreign reserves needed to replenish depleted supplies. The acute scarcity of fuel has forced the closure of many thermal power facilities, causing widespread blackouts throughout the nation (Colambage, 2022). According to Ceylon Electricity Board (2025), entire Sri Lanka faced blackout due to sudden failure in grid and until restore the system, CEB had to limit the electricity generation and disconnect the power according to a schedule.

2.1.4 Impact of Power interruption to the commercial buildings

Power interruptions typically have both direct and indirect effects on the performance of businesses, increasing economic expenses, reducing production quantities, and ultimately lowering sales and productivity (Arnold et al., 2008). Power outages can have a negative impact on corporate operations which ultimately lowers productivity (Bernstein & Hegazy, 1988). Additional costs are incurred to hire or own alternative energy sources such as generators (Yeaple & Golub, 2007). As a result of power outages, expenditures may arise that are both proportional to the length of the outage and to the lost files and programs and idle labor and machinery (de Nooij et al., 2007).

With related to the building operation and maintenance, the machineries and buildings systems are breakdown due to frequent power interruptions. Also, the building performance aspects such as standard lighting levels and indoor air quality are affected due to power interruptions (Meles, 2020).Power interruptions cause to building safety and security related impacts on operations of emergency lighting and access control systems (Sharma, 2022). Due to equipment shutdowns, this will effect on emergency evacuation and increase the risks to the occupants in building (Yasin & Jan, 2021). Customer service and care is getting problematic during the power outage as inability to full fill the requirements of the customer within the time (Ivanov, 2022). To mitigate the impacts of power interruptions, buildings can be adapted with different strategies such as using generators, laying off workers, changing the location of enterprise, obtain insurance policy and reduced shifts (Abeberese et al., 2019). Smart grid technology has potential to enhance grid stability, reduce fossil fuel dependence, and address power interruption challenges in Sri Lanka (Rajapaksha et al., 2024).

3. Methodology

To analyse the impacts of power interruption in Sri Lanka, a comprehensive literature review was conducted focusing on importance of power supply to a commercial building, power interruptions in Sri Lankan context and impact of power interruptions to operations of the commercial buildings. Under qualitative research approach case studies were selected as the research strategy to achieve the aim of the study. Case studies are more suitable for this study, where require to explore real-life specific situation and to gain more holistic understanding (Rahi, 2017). Considering the depth of study, five commercial buildings in the Colombo district were selected through random sampling. Three bank buildings, one software company and one telecommunication building were selected for the case studies. Data collection was conducted using semi-structured interviews and document reviewing. Semi-structured interviews were

conducted with two (02) respondents in managerial level and non-executive level in each selected building. The details of selected case studies and interviewers are listed in Table 1. To obtain the data of building details including building size, number of employees and other special characteristics, document reviewing process were conducted and work schedules and power interruption time, were reviewed under this. The types of documents that were considered for reviewing include work schedules (WS), power interruption schedules (PIS), book of business (BOB) and Impact on cases (IPI). In order to analyse the collected data, manual content analysis was conducted as it allows to accurately identify the information gathered and highlight the crucial viewpoints, characteristics, or conclusions (Hsieh & Shannon, 2005).

Table 1: Selected case studies and respondents' details

Case	Description	Respondent	Description
A	Banking and financing	A1	Facility Manager with 10 years of work experience.
		A2	Senior Maintenance Technician with 08 years of work experience.
B	Software Development	B1	Director of Compliance with 08 years of work experience.
		B2	Maintenance Officer with 06 years of work experience
C	Banking and financing	C1	Maintenance manager with 09 years of work experience.
		C2	Maintenance Supervisor with 08 years of work experience
D	Banking and financing	D1	Senior Maintenance Executive with 10 years of work experience
		D2	Engineering Executive with 08 years of work experience
E	Telecommunication	E1	Electrical Engineer with 15 years of work experience.
		E2	Maintenance supervisor with 06 years of work experience.

4. Results

Data collection was executed under two stages, document reviewing and semi-structured interviews. This section is discussed the analysis of collected data and research findings.

4.1 STAGE 1- DOCUMENT REVIEWING

The commercial characteristics of selected buildings was identified through BOB, given in Table 2. Work schedule data was gathered to identify the impacts of power interruption during work time. According to the reviewed WS, similar type of working patterns was identified in A, C and D. In contrast cases B and E contained different type of data in their WS. Also, those two cases are operated even on the weekend. According to Zohari and Reddy (2018) this study also considered the multi-storey buildings more than four floors.

Table 2, Commercial characteristics of selected buildings

Case	Number of floors	Number of occupants	Primary commercial activity	Working schedule weekdays	Working schedule weekends
A	35	1550	Banking and financing	08.30 - 03.00	Closed
B	06	400	Software development	09.00 - 3.00	09.00 – 1.00
C	07	250-300	Banking and financing	09.00 - 3.00	Closed
D	25	1500	Banking and financing	08.00 – 6.00	Closed
E	10	500	Telecommunication	07.30 – 6.00	07.30 – 6.00

4.1.1 Power interruption period

During the economic crisis period CEB imposed power cuts by dividing the country into several zones and PIS documents provide details about the power cut periods. From March to June 2022, the country experienced a power cut for more than ten hours, and later from July to September, it has reduced to 4 hours. Then during the period of September to December power cuts were reduced to 2.30 hours. This power interruption period was significantly reduced after August 2022, as government was capable to resolve the issue after importing the fuel.

4.1.2 Impact of power interruption

Based on the commercial characteristics of buildings in Table 2, the impact of power interruptions was identified separately for banking and financing buildings. Case A, C and D had consequences in service availability, making it difficult for customers to access their accounts or perform transactions. The ATMs and digital banking platforms are declined. Power interruptions in banks lead to data loss, and improper backup systems cause delays, transaction difficulties, and customer issues. Case C had difficulties in the processing of loans and credit applications. Additionally, power cuts make it more difficult to financial institutions for risk management. However, based on the reviewed documents none of the banking building was identified difficulties in fraud detection as banking facilities are using backup powers in security systems. Power interruption negatively impacted on customer care services by disrupting telephone lines and internet connectivity, preventing customers from contacting the customer care service. Considering case B and E, case B only supported with IPI documents and case E was not maintained any relevant document to obtain the impacts of power interruptions. As a software company, Case B heavily rely on servers and cloud services. Power outages are caused to server breakdowns, resulting in service disruptions and lost revenue. Also, caused data loss or corruption, resulting in costly data recovery efforts and damaging the company's reputation. It was notable that power interruption impact on business continuity, which can result in lost revenue and damage to the company's reputation.

4.2. STAGE 2- SEMI-STRUCTURED INTERVIEWS

The impacts of the power interruption that identified in the literature review were examined related to the selected case studies. Further, the impact on building services by the power interruptions, the solutions for the identified impacts and barriers in implementing proposed solutions were identified in this stage. The impact of power interruptions was identified from each case study as listed in Table 3.

Table 3: Impact on power interruption in commercial buildings in SL

Criteria	**Impact of power interruption in commercial buildings in Sri Lanka**	**A**	**B**	**C**	**D**	**E**
Impact on commercial activities and productivity	Data and inventory losses	✓	✓	✓	✓	✓
	Loss of revenue		✓	✓		
	Employees are unable to undertake their tasks	✓	✓	✓	✓	✓
	Decreases in sales and productivity		✓			✓
	Increases in production costs			✓		
	Firms will lose market opportunities					
	Communication problems	✓	✓	✓		✓
	Machinery breakdowns			✓		✓
	Effects on standard lighting levels	✓				✓

Impact on building system operations and maintenance	Effects on indoor air quality		✓	✓	✓	
	Effects on access control					
	Equipment shutdown and safe evacuation plans	✓				
	Emergency lighting	✓		✓	✓	
	Risk of workers	✓		✓	✓	
Impact on customer service	Inability to full fill the requirements of the customer within the time	✓		✓	✓	
	Getting negative reviews due to poor customer service					✓
	Bad reputation	✓		✓		✓

4.2.1 Impact of power interruptions on commercial activities and productivity

All the respondents highlighted the various factors affecting their commercial activities and productivity. A1, C1, and E1 mentioned that when there is a power loss, computers and other electronic equipment were rendered inoperable, inventory losses occurred and made it difficult to access data. All the respondents stated, power interruption caused decreases in sales and productivity due to disruption in operations. B1 and E2 highlighted that the increase in production costs caused to increase in the overall operating costs. Similarly, E1 mentioned that power outage made interfere with the production process, which reduced the productivity and quality. The site experienced no communication issues with team coordination, but the public addressing system was down due to a power cut. A1 mentioned that, the machinery breakdowns can be rectified quickly with proper vendor communication.

4.2.2 Impact on building system operation and maintenance

Considering the building system operation and maintenance, all most all the respondents mentioned that, long interruptions disrupted the operation of automated lighting systems.C1 stated that the power interruption caused significant damage to the electrical systems and other equipment, leads to expensive repairs and replacement. B1 stated that occasional power interruptions caused damage to lighting equipment, such as bulbs, ballasts, and fixtures. Respondents emphasized the importance of sufficient lighting for safe house-keeping services in a building, as failures can lead to navigation difficulties and increased accident risks.

All the respondents emphasized the importance of HVAC systems for the comfort and safety of building occupants. Power interruption caused poor indoor air quality (IAQ), which made negative health effects. C2 mentioned that workers are exposed to extreme temperatures during the power interruption and malfunctioning of the HVAC system leads to increase the humidity and caused a breeding ground for bacteria and other microorganisms and poor ventilation caused leads to the build-up carbon dioxide. In addition, the air conditioning system will need time to cool the building once power is restored. This results in occupant discomfort and higher energy consumption as the system compensates to restore the desired temperature. Power outages disrupt the operation of water treatment plants, leads to water shortages and automatic fire sprinkler system also will not work. All respondents stated that housekeeping services are carried out with manpower without using electrical equipment for this purpose. Respondents stated that without power system, security services such as intercoms, security cameras, and access control systems were unable to operate and caused risks to employees.

Respondents mentioned that the excess usage of generators caused overheating, shortening lifespan, exhaustion, battery drain, and air filter clogging. In addition, this leads to consume fuel at a high rate, which can lead to fuel exhaustion and cause the generator to shut down. Also, it

was difficult to carry out day to day activities due to the unavailability of fuel during the economic crisis. D2 explained the difficulties of accessing the building to authorized personnel during power interruption, which can delay response time in case of an emergency. The continuous power supply is required to complete maintenance activities in satisfactorily level. It has to be rescheduled due to power failure and delays in the completion of work. In summary, disruptions in building system operations and maintenance were identified, including failures in automated lighting systems, costly repairs to electrical equipment, safety issues due to less illumination, health issues due to poor indoor air quality, discom-fort from extreme temperatures, increased generator maintenance, restricted building access, and delays in both emergency response and routine maintenance activities.

4.2.3 Impact on customer service and care

Respondents stated that the interruptions of building services, delays in providing good customer service, and customer complaints reduced building productivity. Power interruptions reduced customer occupancy in the building premises, which led to a decrease sale. According to E1, the disruptions lead to loss of customer confidence, cause to decrease future revenues. Further, A1 specified that the inability to full fill the requirements of the customer within the time led to delays in meeting customer expectations. Additionally, customer dissatisfactions are occurred due to unavailability of essential services such as lights and air conditioning. As a result, customers made negative reviews about the building. Further B2 and E1 stated that during power interruption time businesses were closed temporarily, which caused inconvenience to customers who had planned to visit the building or use the services provided. Additionally, A1 mentioned, any equipment or technology that relies on electricity stops functioning, making it difficult for businesses to conduct transactions or provide services. This also be an inconvenience for customers who are in the middle of a transaction or service. According to A1, as elevators typically stop functioning it is difficult for people to move between floors within the building. This is especially problematic for people with mobility issues or disabilities, as they may not be able to use the stairs and also an inconvenience for people who need to move heavy items or equipment between floors.

4.2.4 Current practices to overcome power interruption impacts

Selected cases are followed up several strategies to minimize the impacts of power interruption. A1 mentioned that, there was some backup strategies applied according to the power cut duration. According to the respondents, generator is the common backup source in all cases. C2 and D2 mentioned that during the period when the power interruption is more than 10 hours, the usage of the generator was extremely high. It leads to the malfunction of generators. C1 stated that, maintaining proper maintenance checklist is possible to overcome this issue. All the respondents highlighted that one common solution for power interruption problems is the use of UPS. Moreover, respondents elaborated that a UPS acts as a backup power source for devices that require a consistent power supply, such as servers and computers. UPS automatically shuts down non-critical systems to conserve battery power, preventing data loss and preventing equipment and machinery damage during a power outage.

Respondents stated that daylighting also helped to reduce the need for artificial lighting during a power interruption, which can save energy and lower costs in the long term. Daylighting improved the visual comfort, productivity, and enhance overall building performance. C1 emphasized implementing solar panels as it is a renewable and clean energy source. This will help to reduce the building's carbon footprint and improve its overall sustainability. D2 deliberately mentioned that, installing solar panels on the commercial building contribute to increase property value, as it demonstrates that the building is energy efficient and sustainable.

C2 specifically mentioned that proper grounding of battery backup can help to prevent damage to machinery caused by voltage spikes caused by power outages. D2 highlighted the requirement of a plan to work in power outages, to minimize the impact and ensure a quick recovery.
Therefore, companies allow employees to work remotely in power interruptions. Remote working or telecommunicating helped workers to minimize the disruption caused by power interruptions and allow to continue working. However, E2 stated that both the nature of work from home and remote working are similarly same. Respondents suggested limiting operational floors during power outages in commercial buildings and designating backup power zones to housing essential personnel and equipment, to minimize disruption and allow the building to continue functioning at a reduced capacity. E1 and B2 stated that creating a schedule helped to stay on track, ensuring that tasks were completed on time. It included breaks throughout the day and prioritized tasks requiring more focus and energy. B2 also supported this by stating, prioritizing the work tasks is when the power is out. Additionally, E2 highlighted that technology usage such as using mobile apps and cloud computing helped during power outage, to store documents and manage projects. Also, emphasized the importance of time management during power outages for businesses, as it allows us to continue to operate and deliver services to their customers. In brief, to minimize the impacts of power interruptions, respondents emphasized strategies such as using generators, UPS systems, daylighting, solar panels, remote working, backup power zoning, task prioritization, and leveraging technology for continued operation and sustainability.

4.2.5 Barriers to implement the current practices

All respondents stated that companies heavily rely on fuel to operate the generator during power interruptions. During the economic crisis, the availability of fuel was limited due to the shortage of foreign currency. Other economic challenges, making it difficult for them to secure necessary fuel to power backup generators. E1 and E2 discussed the increased demand for backup generators due to power interruptions and fuel price increases, but also noted the high upfront cost and high upfront investment required for such solutions. A2 stated, the economic crisis impacted the availability of equipment such as backup generators, battery systems, and other power management solutions. A1 stated the technicians did not have the necessary knowledge or expertise to determine which solutions would be the most effective for building in this circumstance. Power interruption solutions can be complex and require specialized knowledge and skills to design, install, and maintain. E2 and E1 discussed the complexity of new technologies, requiring specialized knowledge and skills for installation and maintenance, and the potential for costly hiring of technicians. Also highlighted the challenge of compatibility with existing building systems, significant modifications to electrical infrastructure, and the need for staff training, which can be time-consuming and costly, and may require dedicated employees or external trainers.

4.2.6 Suggestions to overcome the impacts of power interruptions
Case A has a contract with the Indian Oil Company (IOC), ensuring a steady fuel supply even during shortages. Respondents B1, C1, and E2 also have contracts with the Ceylon Petroleum Corporation, but receive fuel on a limited basis. A2 mentioned that, IOC may have been able to purchase fuel when other suppliers were unable to meet their needs. All respondents mentioned that they maintained a daily maintenance checklist to ensure the condition of the backup sources. These checklists include checking the oil level, coolant level, air filter, fuel level, exhaust system, and control panel in daily routine. B2 stated that, to avoid overheating, a daily maintenance checklist is required for the long-life span of generators. A2 mentioned that, technicians working with generators and power systems require a thorough understanding of their operations, quick troubleshooting skills, and efficient repairs to ensure system recovery and quick system uptime.

Other than the identified current practices, respondents provided suggestions that can be implemented in commercial buildings in Sri Lanka. E2 suggested that changing the working shift period when power is available is also a suitable solution to overcome the impact. E1 elaborated on the statement by mentioning that this solution may not always be practical or feasible for all types of work. Additionally, shifting working hours may also have an impact on employee schedules and may require changes to transportation. B1 and B2 suggested that reducing shifts can be one solution to mitigate the impact of power interruptions. By reducing the number of staff during operating hours, the building's energy consumption can be decreased, which in turn reduces the demand for generators during the power interruption. A2 specifically mentioned mobile banking services was carried out as a temporary solution for the power interruption. C1 stated that, as lifts require a significant amount of energy to operate, limited usage during a power interruption can reduce the overall demand for power, and consequently, the fuel consumption of the generator. C2 mentioned it is important to consider the safety of people when limiting the use of lifts during a power interruption. If there is a medical emergency or a situation that requires evacuating people, operable lifts are essential to ensure their safety. D2 suggested to deploy temporary power generators or backup power systems to supply electricity to specific floors or areas, such as emergency lighting, elevators, security systems, and life safety equipment.

5. Discussion

Uninterrupted power supply is an important aspect in terms of improving business performance, productivity, operating industrial machineries, maintaining comfort indoor environment and working office appliances(Sha & Qi, 2020). In selected cases, the importance of power supply was depended on the commercial activities involved in. Sri Lanka faced power shortages due to generating capacity shortfalls and the incapacity of hydropower facilities (Wijayatunga & Jayalath, 2004). The fuel scarcity has forced the closure of thermal power facilities, causing widespread blackouts throughout the nation (Colambage, 2022). Based on document reviewing, it was identified that during the economic crisis period in Sri Lanka, the buildings experienced power outages more than ten hours and this duration was significantly reduced after resolving the issue of fuel importing.

Power interruptions typically have effects on business performance, increasing economic expenses, reducing production quantities, and ultimately lowering sales and productivity (Arnold et al., 2008). Similarly, Semi-structured interviews were provided details on impacts related to business continuity and productivity. The malfunctioning of electronic equipment resulted in inventory losses and data access issues. Internal business communication was less affected. Damage to electrical systems led to costly repairs and replacements. Document reviewing of selected cases shows that power interruption impacts are vary across the core business activities of the building. Banking and financing related companies are facing issues related to ATMs and digital banking, data losses, service availabilities and difficulties in risk management. Software and telecommunication facilities are heavily impacted by issues with server uptime, data integrity, development of testing, cloud services, and business continuity. Literature further discussed the power interruption impacts on safety, security and customer service. Interviews proved this stating; the security systems and access control systems are unable to operate and caused risks to employees. Power interruption caused poor indoor air quality, negative health effects due to carbon dioxide buildup, bacteria and other microorganisms, and exposure to extreme temperatures due to absence of HVAC. People with mobility issues or disabilities are facing issues due to inability of using elevators and escalators.

To overcome the impact of power interruptions there were certain strategies are used (Abeberese et al., 2019). As the current practices, selected cases are adhering to the backup strategies such as using generators, UPS systems and Solar panels as a renewable energy

source. Daylighting reduces artificial lighting during power interruptions, while proper grounding of battery backups and preventive maintenance are necessary to prevent damage to machinery due to voltage spikes. In addition, remote working procedures are implementing in buildings to reduce the number of workers who are working inside the building premises and limit the number of operational floors during an outage. Respondents highlighted the importance of prioritizing the work tasks during the power is out. In selected cases, certain barriers were identified in implementing these strategies. Due to the increased demand for the backup generator, investing on backup solutions is not affordable. Also, during the economic crisis, limited fossil fuel availability is a barrier to operate backup generators. Designing, installing, and maintaining power interruption solutions can be complex and require specialized knowledge, while new technology integration can require costly electrical infrastructure modifications. To power interruption management training staff can take time and resources. To prevent the fuel shortages commercial buildings are tend to get into agreements with fuel suppliers. To ensure the reliability of the backup sources organization conduct the daily maintenance checklist and provide adequate training to the technicians. Other than the current practices, respondents suggested to limit the number of workers inside the building using strategies such as shift working, remote working and work prioritization, to reduce the required backup power load.

6. Conclusion

In conclusion, this study examined the impact of power interruption in multi-storey commercial buildings in Sri Lanka, revealing significant consequences on commercial activities, productivity, building systems and operation and customer service. Findings indicate that power outages significantly affect various commercial sectors differently, with banking and finance industries facing challenges in ATM operations and digital banking, while software and telecommunication companies struggle with server uptime and data integrity. Furthermore, power interruptions disrupt building services such as lighting, heating, cooling, and security systems, leading to reduced tenant satisfaction, financial losses, and health risks due to poor IAQ. To mitigate these impacts, commercial buildings rely on backup power solutions such as generators, UPS systems, solar panels and daylight utilization. Additionally, preventive maintenance of backup systems and proper grounding of battery backups were also identified as critical measures. However, economic constraints, fuel shortages, and technical complexities of new technologies such as smart grids, pose barriers to implementing effective power interruption management solutions. Thus, strategies such as remote working, shift scheduling, and work prioritization have been adopted to reduce power dependency during outages. Additionally, agreements with fuel suppliers and routine maintenance checks ensure the reliability of backup sources. This study contributes to minimize the impact of power interruption on multi-storey commercial buildings in Sri Lanka. Data collection and case studies were conducted within the limitation to multi-storey commercial buildings which have the building structure have more than four floors and located in Colombo, Sri Lanka. As the power impacts are de-pends on the core activities of building, analyse the power interruption impact on other types of consumer categories can be suggested for further studies.

7. References

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