Koralage, S.P., Rajini, P.A.D. and Samarakoon, W.K.U.R.M.K.P.K., 2025. A conceptual framework for capacity building in physical asset resilience. In: Waidyasekara, K.G.A.S., Jayasena, H.S., Wimalaratne, P.L.I. and Tennakoon, G.A. (eds). *Proceedings of the 13th World Construction Symposium*, 15-16 August 2025, Sri Lanka. pp. 14-28. DOI: https://doi.org/10.31705/WCS.2025.2. Available from: https://ciobwcs.com/papers/

A CONCEPTUAL FRAMEWORK FOR CAPACITY BUILDING IN PHYSICAL ASSET RESILIENCE

S.P. Koralage[1], P.A.D. Rajini[2] and W.K.U.R.M.K.P.K. Samarakoon[3]

ABSTRACT

Physical assets, defined as tangible resources with intrinsic value, play a major role in organisations. The concept of Physical Asset Resilience (PAR) is a physical asset's ability to prepare for, absorb, recover from, and adapt to disruptions. The resilience of physical assets is increasingly recognised as important for maintaining operational continuity and allowing long-term sustainability in the face of disruptions within the organisation. For capacity building in PAR required to develop or strengthen the four capacity building elements, including skills, resources, policies, and practices needed to enhance physical asset resilience capacities. However, the extant literature does not provide a clear picture of how capacity-building elements interactively contribute to capacity building in the PAR or how organisations currently approach PAR. Accordingly, by adopting a comprehensive literature review, this study proposes a conceptual framework for capacity building in PAR, focusing on four capacities: anticipative, absorptive, restorative, and adaptive, with their sub-elements. For instance, sub-elements in policies include the maintenance policy, communication policy, practices, including conducting physical assets risk assessments, resources, including backups, physical assets, financial resources, and finally, skills, are technical skills, maintenance skills. This proposed framework provides a structured foundation for future researchers who are in the field of PAR, and for practitioners, offering guidance for improving PAR in organisations.

Keywords: *Capacity Building; Physical Asset; Physical Asset Resilience; Physical Asset Resilience Capacity.*

1. INTRODUCTION

Physical Asset Resilience (PAR) is becoming a popular pillar of organisations. The resilience of physical assets is significant for ensuring continuous operations and minimising the impact of different disruptions, whether the disruption has arisen internally or externally (Aruväli et al., 2023). PAR is characterised by four capacities: anticipative capacity, absorptive capacity, adaptive capacity, and restorative capacity. Capacity building in PAR can be identified as a promising approach for developing these

[1] Undergraduate, Department of Facilities Management, University of Moratuwa, Sri Lanka, koralagesp.20@uom.lk
[2] Lecturer, Department of Facilities Management, University of Moratuwa, Sri Lanka, damithar@uom.lk
[3] Lecturer, Department of Facilities Management, University of Moratuwa, Sri Lanka, samarakoonk@uom.lk

capacities. In the context of PAR, capacity building refers to the development or strengthening of the skills, resources, policies, and practices to enhance PAR capacities. Despite the growing recognition of PAR's importance, the role of capacity building for the four PAR capacities remains underexplored. Existing literature does not clearly understand how skills, resources, policies, and practices contribute to strengthening PAR in business organisations. Therefore, this paper addresses this gap by proposing a conceptual framework with capacity building and four capacities of PAR. The paper is structured as follows. The next section discusses the research method, while the third and fourth sections present a thorough review of the literature and the development of the conceptual framework, respectively. Finally, the paper concludes with implications of the findings and future directions of the study.

2. RESEARCH METHODOLOGY

This study adopts a literature review to explore the existing studies related to PAR and capacity building. A literature review serves as a foundation for understanding prior work, identifying research gaps, and synthesising key concepts (Saunders et al., 2009). This study used a non-systematic literature review, which allows flexible integration of diverse studies to support conceptual development (Lilley et al., 2020). Compared to the structured systematic reviews (Snyder, 2019; Lame, 2019), this method is more suitable for exploratory research while improving the conceptual insights needed for framework development. The review focused on literature from the past 10–15 years to include both foundational and recent insights. Sources were selected based on their relevance to capacity building and physical asset resilience. It was based on a structured search of academic databases such as Scopus, ScienceDirect, along with professional platforms like Google Scholar and ResearchGate for supplementary sources. The sources included peer-reviewed journal articles, conference papers, and industry reports. The following search string was used to guide the review. "Physical Asset Resilience", “Capacity Building Elements”, “Capacity Building in PAR”. In addition, a manual content analysis technique was employed to analyse and synthesise the literature relevant to the development of the conceptual framework. The process of development of the conceptual framework for capacity building in PAR involved: (1) identifying key concepts related to PAR and capacity building from the literature, (2) identifying the relationships between these concepts, (3) organising the concepts and their relationships into a coherent conceptual structure and (4) developing the conceptual framework in a way that capacity building in PAR is easily understood. Hence, it developed solely through literature synthesis and is intended to guide future research.

3. LITERATURE REVIEW

3.1 PHYSICAL ASSET RESILIENCE

The word resilience originated from the word “resiliere”, a Latin word that denotes the bounce back (Hosseini et al., 2016; Rose, 2009). Wu et al. (2013) defined resilience as the ability to withstand in the face of disruptions, whereas Fleming and Ledogar (2008) mentioned it as the process and outcome of successfully adapting to disruptions. A physical asset is a tangible item with economic or operational value to an organisation, such as equipment, machinery, tools, infrastructure, or inventory (Hayes, 2022). These assets form the backbone of organisation operations, supporting efficiency, productivity,

and organisational success (Schuman & Brent, 2005; Trojanowski, 2015). However, physical assets are also faced with various disruptions, such as breakdowns, natural disasters, deterioration, operational disruptions, and unexpected external conditions (Gardoni et al., 2021; Heckmann et al., 2015; Linkov et al., 2013), and therefore, PAR has become a fundamental component in a business organisation's operations (Madni et al., 2020). The concept of PAR has been defined by researchers from different perspectives, reflecting several ranges of characteristics. The primary focus of the PAR is emphasising the ability of physical assets to withstand disruptions. For instance, a return to the previously designed condition or state of the physical assets after a disruption can be made by PAR (Norris et al., 2007). PAR refers to the ability of these systems to withstand, adapt to, and recover from disruptions, including natural disasters and other adverse events. In contrast, Ayyub (2013) demonstrated that the "PAR notionally means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions". These retrievals, PAR, is beyond the bounce back or return to their original state. A broader perspective incorporates preparedness and adaptability. On the other hand, recognising that PAR involves absorbing potential disruptions. Further, highlights the importance of not only withstanding disruptions but also needing efficient restoration of functionality. Hence, the above definitions highlight the common and distinct characteristics of PAR, which can be defined as the capacity of a physical asset to anticipate, absorb, recover, and adapt from disruptions. PAR helps organisations to maintain operations continuously even within disruptive conditions. Correspondingly, PAR allows organisations to adapt to external disruptions like economic fluctuations, ensuring that assets continue to support operational continuity. Besides, PAR can lead to financial achievements (Beemsterboer, 2023). Simultaneously, resilient physical assets can recover more quickly after disruptions, minimising downtime and associated financial losses (Coffee, 2019). On the other hand, resilient physical assets can enhance the overall value of physical assets, thus, organisations often willing to pay a premium for physical assets that are less likely to incur damage from disruptions, thereby increasing the market value of these physical assets (Coffee, 2019). Monitoring physical assets before disruptions and understanding their impacts helps identify vulnerabilities and inform measures for improving resilience (Asia Pacific Economic Cooperation [APEC], 2009). Accordingly, by understanding the potential risks, business organisations can introduce mitigation strategies such as maintenance, repair, retrofitting, and recovery activities (Gardoni et al., 2021; Silva et al., 2024). Similarly, PAR also facilitates effective risk management by supporting the implementation of appropriate mitigation techniques. These actions reduce the vulnerability of physical assets to future disruptions and enhance their ability to recover from disruptions (Gardoni et al., 2021). On the other hand, organisations increasingly needed to adhere to standards and regulations based on physical asset resilience (Costella et al., 2017). Therefore, by incorporating resilience into the physical asset management, organisations can ensure compliance with these regulations while also indicating transparency and accountability to the organisation's stakeholders.

3.2 PHYSICAL ASSET RESILIENCE CAPACITY OF AN ORGANISATION

According to Brown et al. (2001), capacity is the ability to obtain the stated objectives. Simultaneously, capacity can be defined as the combination of resources, skills, and abilities that allow organisations to effectively respond to and recover from disruptions (Albright & Crow, 2021). Further, it is an exclusive concept (Brown et al., 2001).

However, prior research has identified and explored various capacities associated with PAR, highlighting their significance in the ability of assets to withstand, adapt, absorb, and recover from disruptions (Braynt, 2021; Manyena et al., 2019). As mentioned by Yarveisy et al. (2020), absorptive, adaptive, and restorative capacities are the capacities associated with PAR. In addition to these capacities, Kozine et al. (2018) noted that anticipative, adaptive, absorptive, and restorative capacities achieve PAR. Simultaneously, Rathnayaka et al. (2024) demonstrated that anticipative or planning capacity is necessary for PAR with the other capacities. A thorough probe into the available literature found four main capacities which determine the PAR of an organisation. In other words, the PAR capacity of an organisation is composed of four capacities, which can be named as anticipative capacity, absorptive capacity, restorative capacity, and adaptive capacity. According to Kozine et al. (2018), anticipative capacity refers to the capacity of physical assets to foresee potential disruptions and provide proactive measures to reduce their impacts. Anticipative capacity provides preparedness for future disruptions, including environmental disruptions. As Vugrin and Camphouse (2011) mentioned, absorptive capacity is the extent to which a system can absorb shocks from different disruptions. On the other hand, 20 it refers to the capability or inherent ability of the system to minimise the negative impacts caused by disruptions. Further, absorptive capacity is the degree to which a system can absorb the negative impact of system disturbances and minimise consequences with much effort (Richter, 2015). According to Mottahedi et al. (2021), restorative capacity is the degree to which the system can effectively restore its damaged performance. Similarly, this capacity incorporates the vital ability to restore complete functionality efficiently and effectively based on disruptions (Rahi, 2019; Yang et al., 2023). Finally, adaptive capacity expresses the ability to adapt (Engle, 2011). Adaptive capacity is considered the ability to quickly and effectively adapt to changing conditions and respond to disruptions that could impact its functionality (Comes & Van De Walle, 2014; Kim et al., 2024).

3.3 CAPACITY BUILDING IN PHYSICAL ASSET RESILIENCE

Capacity building is a concept that rose to provide practices, policies, and thoughts for the management of disruptions (Tadele & Manyena, 2009). As mentioned by Brown et al. (2001), capacity building is an ongoing process that is continued through several levels, including individuals, groups, and organisations, to improve their capabilities to identify and achieve improvement obstacles (Brown et al., 2001). Therefore, to perform major activities effectively and to enhance and strengthen over time, capacity building provides the evidence-based process of building abilities of any context (Brown et al., 2001). Specifically, capacity building strengthens an organisation's ability to achieve its objectives by developing effective practices, resources, policies, and skills (Lammert et al., 2015). Through reviewing existing literature, four key elements of capacity building have been identified. They are policies, practices, resources, and skills. Accordingly, capacity building in the context of PAR refers to the systematic process of developing or strengthening the skills, resources, policies, and practices needed to enhance physical assets' ability to anticipate, absorb, adapt to, and recover from disruptions. The following explains how these elements collectively contribute to capacity building in the PAR in an organisation.

3.3.1 Establishing Policies for Capacity Building in PAR

As mentioned by Moteff (2013), policy is a deliberate combination of principles to guide decisions and achieve rational outcomes, serving as a foundation for making consistent decisions and can be applied in various contexts. Simultaneously, in this context, policies underlie the other three elements. i.e., practices, resources, and skills depend upon the organisation's PAR policy. Accordingly, regular maintenance helps prevent asset failures by addressing potential issues before they become major problems (Organisation for Economic Co-operation and Development [OECD], 2021). However, this can be allowed through the maintenance policy, and it ensures that physical assets are regularly maintained to prevent disruptions and improve their ability to withstand disruptions. The maintenance policy incorporates the preventive and predictive maintenance strategies that can significantly improve PAR (Aspell, 2024). Regularly scheduled maintenance tasks based on manufacturer recommendations and organisation standards help maintain physical asset functionality and prevent unexpected failures. On the other hand, utilising data analytics and technology can help to forecast when maintenance should occur, preventing failures before they happen (Aspell, 2024). Another significant aspect of policies is employee training. This policy should be developed to allow employees to be trained in all aspects of the physical assets, including emergency procedures, asset management, and business continuity planning (Tadele & Manyena, 2009). For instance, regular fire drills and emergency preparedness training should be incorporated into the organisation's overall training policy, certifying that employees are familiar with procedures for managing various types of disruptions (Robertson et al., 2015). Thus, this revealed, these policies should outline the frequency of training and the types of scenarios that employees should be prepared. On the other hand, by having physical assets procedures for disruptions management and a clear plan in place, business organisations can minimise downtime and ensure business continuity, which is essential for maintaining resilience (Australian Capital Territory [ACT], 2024). While a disruption management policy is important, effective communication is equally essential for enabling PAR. It facilitates coordination, risk management, and stakeholder engagement throughout the resilience-building process. This revealed the requirement of the communication policy. It not only affects immediate response but also supports long-term restorative efforts. For instance, assessing the effectiveness of communication precautions post-event can inform future improvements and adaptations, ensuring that lessons learned are integrated into ongoing PAR planning. Therefore, a robust communication policy is essential in this context. In addition, worker preparation involves maintaining physical assets effectively, ensuring they can withstand and recover from disruption (Robertson et al., 2015). Therefore, this preparation can be introduced as a policy in PAR. The operator preparation policy is an essential aspect of a commitment to continuous improvement. Organisations must regularly review their resilience strategies, learn from past disruptions, and adapt their approaches based on new insights and emerging disruptions.

3.3.2 Implementing Practices for Capacity Building in PAR

Practice is generally referred to as repeated activity for acquiring or maintaining proficiency in it (Esmalian et al., 2022). It includes the working methods and approaches that improve the efficiency and effectiveness of an organisation (Luenendonk, 2017). According to Bukowski and Werbińska-Wojciechowska (2020), the implementation of maintenance protocols aimed at ensuring the continued functionality, efficiency, and

safety of physical assets throughout their lifecycle and having the proper maintenance recovery approaches can enhance resilience in the physical asset. This highlights that improving the maintainability of physical assets can contribute to it. Continuous monitoring can detect potential disruptions before they increase into severe failures or other interruptions. However, by analysing real-time data, predictive maintenance can be implemented to address disruptions before they cause disruptions. Monitoring physical assets before disruptions and understanding their impacts helps identify vulnerabilities and inform measures for improving resilience (APEC, 2009). Thus, conducting post-event damage assessment as a practice helps to take recovery planning by highlighting areas where physical assets can be restored with enhanced resilience characteristics. On the other hand, post-event damage assessments for physical assets involve rapid and comprehensive evaluations of disruption impacts on infrastructure, buildings, and critical physical assets to inform recovery and disruption impact reduction. These assessments combine hazard modelling, exposure data, structural vulnerability analysis, and advanced technologies to quantify damage and prioritise reconstruction (Johnston et al., 2024). The development and implementation of standard operating procedures (SOPs) for routine operations, maintenance, and emergency response are essential in allowing consistent, efficient, and safe practices (Harwood & Nieto-Gomez, 2017). Consequently, it provides structured processes for maintaining and repairing physical assets, as well as responding to disruptions, including natural disasters, fires, and physical asset failures (Harwood & Nieto-Gomez, 2017). According to Borg et al. (2022), allowing staff to be well-trained in the SOPs and emergency response protocols allows quicker recovery from disruptions. The regular conducting of fire drills and ensuring staff are trained in emergency procedures helps maintain preparedness for all disruptions (Robertson et al., 2015). On the other hand, Tracey et al. (2017) pointed out that business continuity planning allows an organisation can continue to operate their physical assets during and after disruptions. Further, it emphasised, organisations to identify and map their physical assets, which is essential for understanding what resources are available during a disruption. This asset-mapping process helps organisations recognise the strengths they possess. In addition to these practices, physical asset risk assessments help identify vulnerabilities in physical assets, allowing for the mitigation of the impacts of disruptions (Klerk, 2024). Along with conducting risk assessments, it supports continuous development by aligning with goals that focus on building resilience capacity in physical asset investments (Cassottana, 2023). Hence, conducting the physical assets risk assessments is essential for this context. On the other hand, business organisations are concerned about the continuous business process within the organisation (Zhang et al., 2021). Therefore, companies need to require their physical assets to be properly repaired. So that they can optimise the inventory of spare parts. Further, an optimised inventory spare parts system ensures that critical spare parts are readily available, consequently reducing unplanned downtime and associated costs (Ajayat, 2024). Another one is scenario planning for disruptions. As pointed out by Bullis (2024), scenario planning is a strategic practice that enhances resilience by preparing for potential future disruptions. For instance, by developing strategies for various scenarios, organisations can enhance their resilience and adaptability, ensuring they remain operational even during disruptions (Harris, 2024). Further, this can involve exploring a range of potential disruptions in the future. Utilising this practice, organisations can create flexible plans that allow them to respond effectively to unforeseen disruptions (Skemp et al., 2020). Hence, this adaptability is essential for this context.

3.3.3 Enhancing Resources for Capacity Building in PAR

Resources refer to anything that can be available within a community, society, or organisation that can be utilised to achieve specific goals related to a particular field (Dharmadasa et al., 2023). One key resource in building PAR is having a backup physical asset that can maintain the operation even in disruptive conditions (Alberti, 1999; Kusumastuti et al., 2014; Pant et al., 2014). Consequently, by having physical backups, business organisations can minimise downtime and the impact of unexpected disruptions. This helps in safeguarding against potential financial losses associated with physical asset breakdowns (Crudu, 2024). Simultaneously, this is essential for maintaining service delivery and customer trust (Todd, 2024). Warehouses and evacuation centres are also important resources. Warehouses serve as storage facilities for major spare parts and backup physical assets, ensuring that essential resources are readily available when needed (Ciriaco & Wong, 2022). On the other hand, during disruptions, evacuation centres provide safeguarding personnel and shelter, and supplies. Similarly, supportive equipment and vehicles are also significant for physical asset resilience. Reliable, supportive equipment and vehicles for maintaining service delivery, as they support operations and confirm the smooth functioning of major physical assets. For instance, vehicles provide mobility during disruptions, allowing organisations to move resources efficiently. Another one is that the incorporation of new technology can allow more advanced users to access physical assets. Physical asset monitoring systems, which include IoT devices and sensors, provide real-time data on the condition and performance of physical assets. For instance, IoT sensors play a key role in real-time physical asset condition monitoring, predictive maintenance, and the reduction of risk from unexpected failures. On the other hand, simulation and modelling Platforms, including a physical assets risk model network, allow for wide effects of disaster-induced failures and post-disaster restoration. Renger et al. (2002) noted that Geographic Information Systems (GIS) provide visualisation of disruption impacts and resilience challenges, and support to scenario analysis and strategic planning for disaster preparedness and recovery. In addition, adequate financial resources increase physical asset performance against disruptions. Besides, many business organisations face a backlog of deferred maintenance, which can increase vulnerabilities to disruptions. However, investing in resilience is critical to prevent minor issues from escalating into significant problems that compromise physical asset integrity. This retrieval, developing comprehensive capital plans that prioritise resilience, can be more cost-effective than reactive measures post-disaster. It is important to separate them into specific categories. Firstly, capital investments refer to long-term financial allocations aimed at upgrading or acquiring physical assets with enhanced resilience features, such as climate-proof physical assets or sensor-based monitoring systems (Corti et al., 2022). Secondly, operational budgets support routine maintenance activities and daily operational needs that contribute to resilience through consistent performance and early problem detection (Karamouz & Hojjat-Ansari, 2020). Thirdly, contingency funds are significant for answering sudden disruptions, allowing for rapid repairs or temporary replacements to maintain continuity. In addition, pre-arranged financial mechanisms, including insurance, reserve funds, or pre-approved emergency financing, allow organisations to act swiftly when early warning systems indicate a potential disruption (Azadegan et al., 2021). Moreover, reliable physical assets are a crucial resource for enhancing PAR (OECD, 2024). Along with this, reliable physical assets allow operations to continue smoothly, even in the face of disruptions such as natural disasters or mechanical breakdowns. On the other hand, this

resource is important for maintaining stakeholder trust during turbulent situations (Beemboster, 2023). Another significant resource is a skilled workforce. According to Sam (2021), a skilled workforce ensures timely inspection, maintenance, and repair activities, which are critical for managing physical asset life and mitigating risks. The training and development of this workforce are significant for building capacity in PAR (Madrigano et al., 2017). The workers need to be regularly trained on the latest practices within their work and new technologies, and emergency procedures (Madrigano et al., 2017). On the other hand, leadership and governance structures affect fostering a skilled workforce by setting clear policies, providing ongoing support, and aligning human resources with the organisation's strategic goals in asset management (Helmrich & Chester, 2022). Consequently, they ensure that the workforce is adequately prepared for both routine operations and emergency response (Helmrich & Chester, 2022). In addition to internal resources, external resources are involved in this context. One such major external resource is having a proper supply chain, which ensures the continuity of material, equipment, and service flows required for physical asset resileince (Trucco et al., 2018). Additionally, the stakeholder network includes partnerships with local authorities, emergency responders, service contractors, community groups, and professional bodies that provide valuable resources such as technical expertise, regulatory support, and emergency coordination (Li & Ji, 2021). This revealed, these networks strengthen PAR by facilitating information sharing, mutual aid, and coordinated responses.

3.3.4 Enhancing Skills for Capacity Building in PAR

According to Perera et al. (2017), skills are the abilities that individuals or groups possess. Further emphasised that they significantly contributed to overcoming the desired outcomes effectively. Skills refer to the abilities and expertise that people can build through knowledge, training, and experience. Particularity in the context of PAR requires a combination of technical skills that can support human behaviour and physical assets (Thomas et al., 2019). For instance, having familiarity with specific tools and technologies that support resilience, such as simulation software and monitoring systems, is important (Woods, 2015). Thus, these skills can help in modelling scenarios and evaluating the resilience of physical assets. Similarly, as a technical skill, utilising Internet of Things (IoT) sensors allows continuous monitoring of physical asset conditions (Klerk, 2024). Therefore, these skills allow for proactive maintenance and rapid response to potential disruptions, significantly enhancing PAR during disruptions. On the other hand, community engagement skills require engaging with local parties to understand their needs and involve them in planning and decision-making processes. These include skills in public outreach, education, and participatory

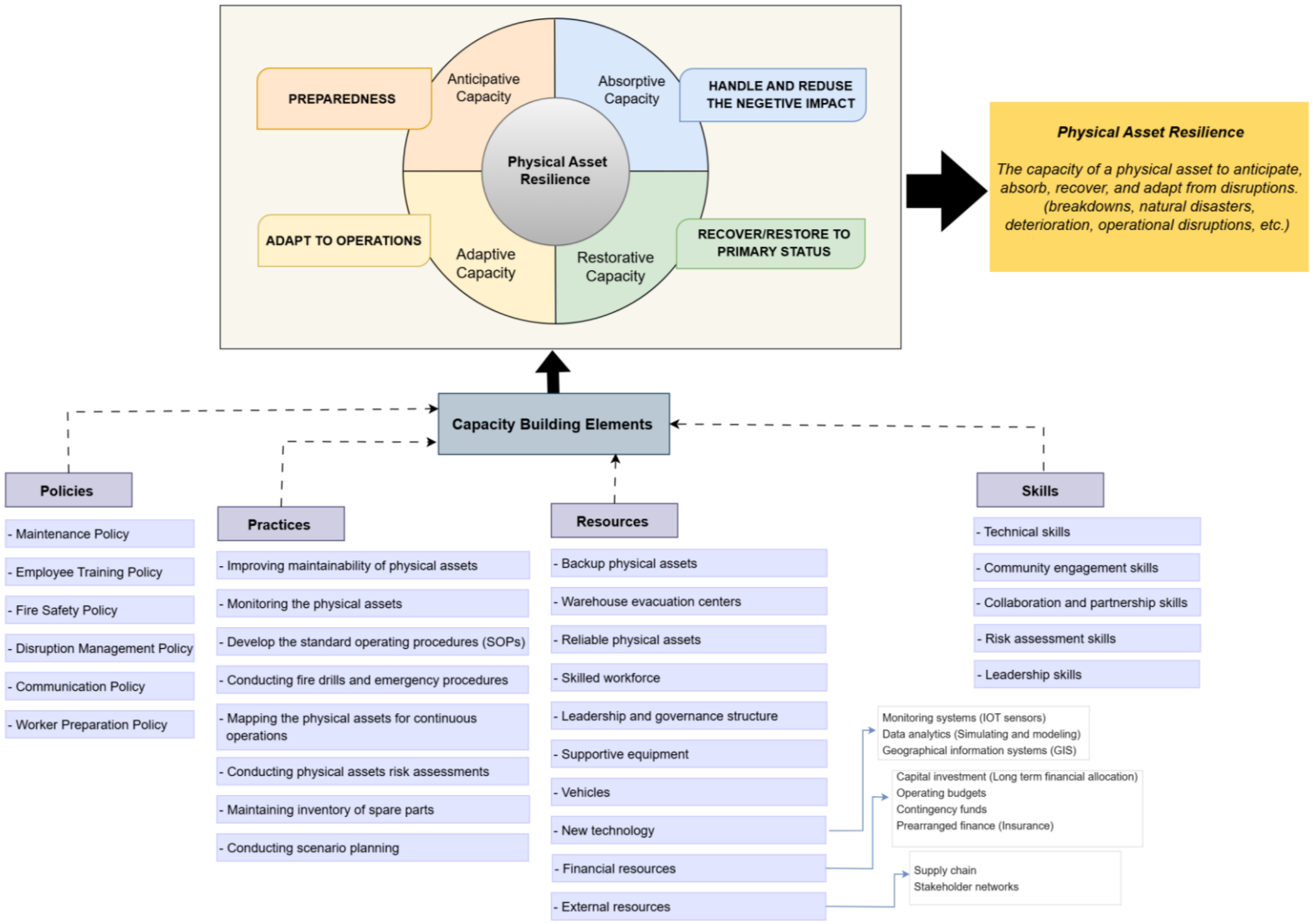

Figure 1: Conceptual Framework for Capacity Building in PAR

planning stages (Danaher et al., 2014). Moreover, community engagement should assist combined efforts among various stakeholders (Johnston et al., 2024). Thus, collaboration helps develop effective emergency plans. Strong community engagement and partnership skills are essential, as coordination among stakeholders, such as the government and private sector, enables knowledge sharing (Wieszczeczynska et al., 2024). Another one is understanding and addressing vulnerabilities, which is a contribution to developing resilience strategies. This involves skills in data collection, analysis, and interpretation to identify vulnerabilities and identify measures (Fleming & Ledogar, 2008). This emphasises that risk assessment skills are essential for capacity building in PAR. Moreover, having properly structured leadership skills is significant for coordinating disruption response efforts and managing resources efficiently (Danaher et al., 2014). In addition, leaders or top managers need to adjust strategies and operations in response to changing circumstances. This adoption is crucial in environments characterised by volatility, uncertainty, and ambiguity (Zamani & Ait Soudane, 2022).

4. CONCEPTUAL FRAMEWORK FOR CAPACITY BUILDING IN PAR

The conceptual framework developed in this study (Figure 1) integrates four key PAR capacities with essential capacity-building elements: policies, practices, resources, and skills. It serves as a guide to understanding how this works together to strengthen PAR in organisations. Anticipative capacity involves preparedness and the ability to foresee disruptions. Absorptive capacity refers to minimising the impact of disruptions, while restorative capacity focuses on the quick recovery of physical asset functionality. Adaptive capacity allows long-term improvement by adjusting operations. Capacity-building elements support these capacities through policies (e.g., maintenance, disruption, and fire safety), practices (such as risk assessments and monitoring), resources (financial, technological, and network-based), and skills (technical and community engagement). Together, these aspects contribute holistically to building resilience in physical assets. The legend of the conceptual framework (Figure 01) is as follows,

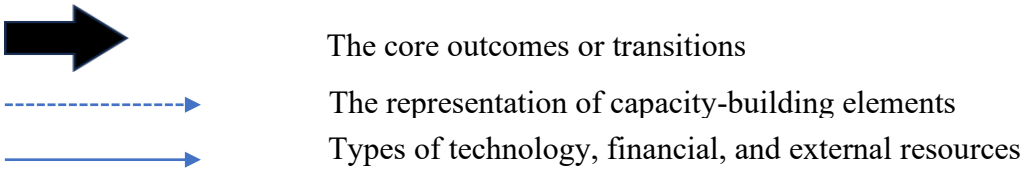

Figure 2: Guide to the conceptual framework

5. CONCLUSION

This study emphasises that the capacity building (PAR) in business organisations strongly depends on four key capacity-building elements. This review of literature aimed to identify the key capacity-building elements that contribute to strengthening PAR in business organisations. By reviewing existing studies, it was established that PAR is characterised by four capacities: anticipative, absorptive, restorative, and adaptive. The review further emphasised that policies, practices, resources, and skills are significant elements of capacity building, each allowing a critical place in improving PAR within business organisations. The findings identified six policies, eight practices, ten resources, and five skills that collectively allow physical assets to anticipate potential disruptions,

absorb their impact, recover or restore efficiently, and adapt to operations Thus, this study fills a gap in the existing literature by proposing a conceptual framework that includes the key elements of capacity building with the four capacities of PAR. However, in this study, it was not examined separately for each PAR capacity. Instead, a general approach to capacity building was considered to support the overall PAR. The need for capacity building in PAR is particularly critical for the apparel manufacturing sector. Which is one of the key economic contributors in Sri Lanka, and these organisations are highly reliant on their physical assets when driving their business, hence capacity building in this sector becomes an essential need. The conceptual framework developed through this study is intended to be explored further in apparel manufacturing organisations in Sri Lanka, and a more detailed analysis of how capacity building in individual PAR capacities will be conducted.

6. REFERENCES

Ajayat, A. (2025, July 30). *Managing spare parts inventory in manufacturing with Odoo*. SDLC Corp. https://sdlccorp.com/post/managing-spare-parts-inventory-in-manufacturing-with-odoo/

Alberti, M. (1999). Urban patterns and environmental performance: What do we know? *Journal of Planning Education and Research*, *19*(2), 151–163. https://doi.org/10.1177/0739456x9901900205

Albright, E. A., & Crow, D. A. (2021). Capacity building toward resilience: How communities recover, learn, and change in the aftermath of extreme events. *Policy Studies Journal*, *49*(1), 89–122. https://doi.org/10.1111/psj.12364

Aruväli, T., De Marchi, M., & Rauch, E. (2023). Analysis of quantitative metrics for assessing resilience of human-centered CPPS workstations. *Scientific Reports*, *13*, 2914. https://doi.org/10.1038/s41598-023-29735-1

Asia Pacific Economic Cooperation (APEC, 2009). *Guidelines and best practices for post-disaster damage and loss assessment*. https://www.apec.org/docs/default-source/Publications/2011/1/Guidelines-and-best-practices-for-post-disaster-damage-and-loss-assessment/211_epwg_damage-rpt.pdf

Aspell, R. (2024, March 18). *Crafting a resilient asset maintenance strategy: Best practices unveiled.* Facilities Management Group. https://www.rfm-group.com/crafting-a-resilient-asset-maintenance-strategy-best-practices-unveiled/

Australian Capital Territory Government. (ACT, 2024). *ACT disaster resilience strategy 2024-2030: Connection builds resilience*. https://www.act.gov.au/__data/assets/pdf_file/0004/2567128/Disaster-Resilience-Strategy.pdf#page=2.50

Ayyub, B. M. (2013). Systems resilience for multihazard environments: Definition, metrics, and valuation for decision making. *Risk Analysis*, *34*(2), 340–355. https://doi.org/10.1111/risa.12093

Azadegan, A., Modi, S., & Lucianetti, L. (2021). Surprising supply chain disruptions: mitigation effects of operational slack and supply redundancy. *International Journal of Production Economics*, *240*, 1–14. https://doi.org/10.1016/j.ijpe.2021.108218

Beemsterboer, B. (2023, February 14). *Adopting a resilient asset management strategy: Evolving to managing assets to meet business goals sustainability*. IFS Blog. https://blog.ifs.com/2023/02/adopting-a-resilient-asset-management-strategy-evolving-to-managing-assets-to-meet-business-goals-sustainably/

Borg, N., Naderpajouh, N., Scott-Young, C. M., & Borg, J. (2022). An interdisciplinary and multi-level review of resilience to inform training of human resources for critical infrastructure. *International Journal of Disaster Risk Reduction*, *78*, 103113. https://doi.org/10.1016/j.ijdrr.2022.103113

Brown, T., Lafound, A., & Macintyre, K. (2001). *Measuring capacity building*. Carolina Population Center, University of North Carolina at Chapel Hill. https://doi.org/10.5771/9781475873191-360

Bukowski, L., & Werbińska-Wojciechowska, S. (2020). Resilience based maintenance*:* A conceptual approach. In P. Baraldi, F. Di Maio, & E. Zio (Eds.), *Proceedings of the 30th european safety and reliability conference and the 15th probabilistic safety assessment and management conference,* Venice, Italy, (pp. 1–9). http://dx.doi.org/10.3850/978-981-14-8593-0_4450-cd

Bullis, J. (2024, May 22). *Scenario planning: strategies, techniques, & examples* [2024]. Scenario planning. https://www.cubesoftware.com/blog/scenario-planning

Cassottana, B. (2023, October 19). *The importance of building resilience and adaptive capacity in sustainable infrastructure investments*. Retrieved March 1, 2025, from https://www.fastinfralabel.org/news/the-importance-of-building-resilience-and-adaptive-capacity-in-sustainable-infrastructure-investments

Ciriaco, T. G., & Wong, S. D. (2022). Review of resilience hubs and associated transportation needs. *Transportation Research Interdisciplinary Perspectives*, *16*. https://doi.org/10.1016/j.trip.2022.100697

Coffee, J. (2019). Financing resilient infrastructure. In *Optimizing Community Infrastructure* (pp. 101–121). https://doi.org/10.1016/b978-0-12-816240-8.00006-9

Comes, T., & Van De Walle, B. (2014). Measuring disaster resilience: The impact of hurricane sandy on critical infrastructure systems. In S.R. Hiltz, M.S. Pfaff, L. Plotnick, & P.C. Shih (Eds.), *Proceedings of 11th International Conference on Information Systems for Crisis Response and Management,University Park, Pennsylvania, USA*, May 2014. (pp. 195–204). https://idl.iscram.org/files/comes/2014/408_Comes+VanDeWalle2014.pdf

Costella, C., Jaime, C., Arrighi, J., Perez, E. C. de, Suarez, P., & Aalst, M. van. (2017). Scalable and sustainable: How to build anticipatory capacity into social protection systems. *Courting Catastrophe? Humanitarian Policy and Practice in a Changing Climate*, *48*(4). https://doi.org/10.19088/1968-2017.158

Corti, F., Liscai, A., Ruiz, T., & Liscai, Alessandro. (2022). The recovery and resilience facility: Boosting investment in social infrastructure in europe? *Italian Labour Law*, *15*(1), 16–30. https://doi.org/10.6092/issn.1561-8048/15706

Crudu, A. (2024, March 23). *Enhancing IT resilience: The role of backup solutions in modern business*. Moldstud. https://moldstud.com/articles/p-enhancing-it-resilience-with-backup-solutions

Danaher, P. A., Davies, A., De George-Walker, L., Jones, J. K., Matthews, K. J., Midgley, W., Arden, C. H., & Baguley, M. (2014). *Contemporary capacity- Building in educational contexts* (1st ed.).. Palgrave Pivot London. https://doi.org/10.1057/9781137374578

Dharmadasa, K. H. K., Kulatunga, U., Thayaparan, M., & Keraminiyage, K. P. (2023). Review on the importance of capacity building for enhancing disaster resilience through the effective utilisation of resources. In Y.G. Sandanayake, K.G.A.S. Waidyasekara, T. Ramachandra, & K.A.T.O. Ranadewa (Eds.), *Proceedings of the 11th world construction symposium*, *Sri Lanka,* 21-22 July 2023. (pp. 920-929). https://doi.org/10.31705/WCS.2023.74

Engle, N. L. (2011). Adaptive capacity and its assessment. *Global Environmental Change*, *21*(2), 647–656. https://doi.org/10.1016/j.gloenvcha.2011.01.019

Esmalian, A., Yuan, F., Rajput, A. A., Farahmand, H., Dong, S., Li, Q., Gao, X., Fan, C., Lee, C., Hsu, C., Patrascu, F. I., & Mostafavi, A. (2022). Operationalizing resilience practices in transportation infrastructure planning and project development. *Transportation Research Part D Transport and Environment*, *104*, 103214. https://doi.org/10.1016/j.trd.2022.103214

Fleming, J., & J Ledogar, R. (2008). Resilience, an evolving concept: A review of literature relevant to aboriginal research. *Pimatisiwin, 6*(2), 7–23. https://pmc.ncbi.nlm.nih.gov/articles/PMC2956753/

Gardoni, P., Tabandeh, A., Sharma, N., & Nocera, F. (2021). *Risk analysis of physical assets: Addressing the current gaps in modeling hazards and structures / infrastructure*. MAE Center at the University of Illinois at Urbana-Champaign. https://ormir.giesbusiness.illinois.edu/docs/librariesprovider9/pdf/risk-analysis-of-physical-assets-.pdf?Status=Master&sfvrsn=ff8c644e_3

Harris, A. M. (2024, December 16). *Scenario planning and resilience: Strategies for navigating uncertainty*. Transformative Growth Solutions. Retrieved March 1, 2025, from https://www.transformativegrowthsolutionsllc.com/post/scenario-planning-and-resilience-strategies-for-navigating-uncertainty

Harwood, S. M., & Nieto-Gomez, R. (2017). *Adaptive standard operating procedures for complex disasters*.https://calhoun.nps.edu/bitstream/handle/10945/52987/17Mar_Harwood_Shawn.pdf?sequence=1&isAllowed=y

Hayes, A. (2022). *What is a physical asset: Definition, types, and how to account*. Investopedia. https://www.investopedia.com/terms/p/physicalasset.asp

Heckmann, I., Comes, T., & Nickel, S. (2015). A critical review on supply chain risk: Definition, measure and modeling. *Omega*, *52*, 119–132. https://doi.org/10.1016/j.omega.2014.10.004

Helmrich, A., & Chester, M. (2022). Navigating Exploitative and Explorative Leadership in Support of Infrastructure Resilience. *Frontiers in Sustainable Cities*, *4*(February). https://doi.org/10.3389/frsc.2022.791474

Hosseini, S., Barker, K., & Ramirez-Marquez, J. E. (2016). A review of definitions and measures of system resilience. *Reliability Engineering and System Safety*, *145*, 47–61. https://doi.org/10.1016/j.ress.2015.08.006

Johnston, K. A., Taylor, M., & Ryan, B. (2024). Evaluation of community engagement for resilience outcomes: A pre-engagement approach. *International Journal of Disaster Risk Reduction*, *110*,104613. https://doi.org/10.1016/j.ijdrr.2024.104613

Karamouz, M., & Hojjat-Ansari, A. (2020). Uncertainty based budget allocation of wastewater infrastructures' flood resiliency considering interdependencies. *Journal of Hydroinformatics*, *22*(4), 768–792. https://doi.org/10.2166/hydro.2020.145

Kim, J., Lee, S., Arigi, A. M., & Kim, J. (2024). Quantitative analysis of contributing factors to the resilience of emergency response organizations in nuclear power plants. *Progress in Nuclear Energy*, *172*, 105209. https://doi.org/10.1016/j.pnucene.2024.105209

Klerk, D. D. (2024, May 31). *Building asset resilience: Infrastructure strategies for a changing climate future.* Beca. Retrieved March 1, 2025, from https://www.beca.com/ignite-your-thinking/ignite-your-thinking/may-2024/building-asset-resilience-infrastructure-strategies-for-a-changing-climate-future

Kozine, I., Petrenj, B., & Trucco, P. (2018). Resilience capacities assessment for critical infrastructures disruption: The READ framework (part 1). *International Journal of Critical Infrastructures*, *14*(3), 199–220. https://doi.org/10.1504/IJCIS.2018.094405

Kusumastuti, R. D., Viverita, Husodo, Z. A., Suardi, L., & Danarsari, D. N. (2014). Developing a resilience index towards natural disasters in Indonesia. *International Journal of Disaster Risk Reduction*, *10*, 327–340. https://doi.org/10.1016/j.ijdrr.2014.10.007

Lame, G. (2019). Systematic literature reviews: An introduction. *Proceedings of the international conference on engineering design, ICED, 2019-August*, (pp. 1633–1642). Cambridge University Press. https://doi.org/10.1017/dsi.2019.169

Lammert, J. D., Johnson, L., & Fiore, T. A. (2015). *Conceptualizing capacity building*. Westat

Li, Y., & Ji, W. (2021). Robustness of stakeholder response networks for infrastructure system protection. *Journal of Management in Engineering*, *37*(6). https://doi.org/10.1061/(asce)me.1943-5479.0000960

Lilley, H., Payne, R., Fox, D., Brown, R. J., & Fountain, D. (2020). PMU68 Systematic vs. non-systematic literature review methodology for publication in leading journals. *Value in Health*, *23* (Suplement 2), S614. https://doi.org/10.1016/j.jval.2020.08.1280

Linkov, I., A. Eisenberg, D., E. Bates, M., Chang, D., Convertino, M., H. Allen, J., E. Flynn, S., & P. Seager, T. (2013). Measurable resilience for actionable policy. *Environmental Science and Technology*, *47*(18), 10108–10110. https://doi.org/10.1021/es403443n

Luenendonk, M. (2017, October 10). *Management practices*. Cleverism. https://cleverism.com/lexicon/management-practices/

Madni, A. M., Erwin, D., & Sievers, M. (2020). Constructing models for systems resilience: Challenges, concepts, and formal methods. *Systems*, *8*(1), 3. https://doi.org/10.3390/systems8010003

Madrigano, J., Chandra, A., Costigan, T., & Acosta, J. D. (2017). Beyond disaster preparedness: Building a resilience-orientedworkforce for the future. *International Journal of Environmental Research and Public Health*, *14*(12), 14. https://doi.org/10.3390/ijerph14121563

Manyena, B., Machingura, F., & O'Keefe, P. (2019). Disaster resilience integrated framework for transformation (DRIFT): A new approach to theorising and operationalising resilience. *World Development*, *123*, 104587. https://doi.org/10.1016/j.worlddev.2019.06.011

Moteff, J. D. (2013). *Critical infrastructure resilience: The evolution of policy and programs and issues for congress* (CRS Report for Congress). Congressional Research Service https://sgp.fas.org/crs/homesec/R42683.pdf

Mottahedi, A., Sereshki, F., Ataei, M., Qarahasanlou, A. N., & Barabadi, A. (2021). The resilience of critical infrastructure systems: A systematic literature review. *Energies*, *14*(6), 1571. https://doi.org/10.3390/en14061571

Norris, F. H., Stevens, S. P., Pfefferbaum, B., Wyche, K. F., & Pfefferbaum, R. L. (2007). Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology*, *41*, 127–150. https://doi.org/10.1007/s10464-007-9156-6

Organisation for Economic Co-operation and Development (OECD). (2021). *Building resilience: New strategies for strengthening infrastructure resilience and maintenance*. OECD Publishing. http://dx.doi.org/10.1787/354aa2aa-en OECD

Organisation for Economic Co-operation and Development (OECD). (2024). *Compendium of good practices on quality infrastructure 2024: Building resilience to natural disasters*. OECD Publishing, Paris. https://doi.org/10.1787/54d26e88-en

Pant, R., Barker, K., & Zobel, C. W. (2014). Static and dynamic metrics of economic resilience for interdependent infrastructure and industry sectors. *Reliability Engineering and System Safety*, *125*, 92–102. https://doi.org/10.1016/j.ress.2013.09.007

Perera, S., Adeniyi, O., & Babatunde, S. O. (2017). Analysing community needs and skills for enhancing disaster resilience in the built environment. *International Journal of Disaster Resilience in the Built Environment, 8*(3), 292–305. https://doi.org/10.1108/IJDRBE-10-2015-0046

Rahi, K. (2019). Indicators to assess organizational resilience: A review of empirical literature. *International Journal of Disaster Resilience in the Built Environment*, *10*(23), 85–98. https://doi.org/10.1108/IJDRBE-11-2018-0046

Rathnayaka, B., Robert, D., Adikariwattage, V., Siriwardana, C., Meegahapola, L., Setunge, S., & Amaratunga, D. (2024). A unified framework for evaluating the resilience of critical infrastructure: Delphi survey approach. *International Journal of Disaster Risk Reduction*, *110*. https://doi.org/10.1016/j.ijdrr.2024.104598

Renger, R., Cimetta, A., Pettygrove, S., & Rogan, S. (2002). Geographic Information Systems (GIS) as an evaluation tool. *American Journal of Evaluation*, *23*(4), 469–479. https://doi.org/10.1177/109821400202300407

Ritcher, R. (2015). Resilience and critical infrastructure. *The Science for Population Protection*, *7*(1), 71–76. http://www.population-protection.eu/prilohy/casopis/29/201.pdf

Robertson, P., Moore, L., & Dempsey, A. (2015). Training employees for resilience in asset management. *Journal of Human Resources and Asset Management, 22*(4), 101-112.

Rose, A. (2009). *Economic resilience to disasters*. Community and Regional Resilience Institute. https://merid.org/wp-content/uploads/2019/09/Economic-Resilience-to-Disasters.pdf

Sam, G. K. (2021). The impact of asset management on company's operational performance: A case of Horizon Construction Ltd. *International Journal of Scientific Research and Management, 9*(10), 2465–2475. https://doi.org/10.18535/ijsrm/v9i10.em06

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research methods for business students* (5th ed.). Pearson Education Limited.

Schuman, C. A., & Brent, A. C. (2005). Asset life cycle management: Towards improving physical asset performance in the process industry. *International Journal of Operations & Production Management, 25*(6), 566–579. https://doi.org/10.1108/01443570510599728

Silva, R. F. D., Melani, A. H. D. A., Michalski, M. A. D. C., Souza, G. F. M. D., & Nabeta, S. I. (2024). Risk management of physical assets supported by maintenance performance indicators. *Sustainability (Switzerland), 16*(14). https://doi.org/10.3390/su16146132

Skemp, S., Boldenow, M., Holmes, S., & Voller, D. (2020). *Scenario planning: How to be resilient in design and operations*. BWBR. https://www.bwbr.com/wp-content/uploads/2023/11/Scenario-Planning_White-Paper_Final.pdf

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Tadele, F., & Manyena, S. B. (2009). Building disaster resilience through capacity building in Ethiopia:Disaster Prevention and Management. *An International Journal, 18*(3), 317–326. https://doi.org/10.1108/09653560910965664

Thomas, J. E., Eisenberg, D. A., Seager, T. P., & Fisher, E. (2019). A resilience engineering approach to integrating human and socio-technical system capacities and processes for national infrastructure resilience. *Journal of Homeland Security and Emergency Management, 16*(2), 1–17. https://doi.org/10.1515/jhsem-2017-0019

Todd, H. (2023, June 29). *The importance of backup systems in business continuity planning*. Yorb. https://www.yorb.tech/the-importance-of-backup-systems-in-business-continuity-planning

Tracey, S., O'Sullivan, T. L., Lane, D. E., Guy, E., & Courtemanche, J. (2017). Promoting resilience using an asset-based approach to business continuity planning. *SAGE Open*, *7*(2). https://doi.org/10.1177/2158244017706712

Trojanowski, M. R. (2015). Asset management determinants of polish universities. *Journal of Corporate Real Estate, 17*(3), 178-197.10.1108/JCRE-022015-0006

Trucco, P., Petrenj, B., & Birkie, S. E. (2018). Assessing supply chain resilience upon critical infrastructure disruptions: A multilevel simulation modelling approach. *Supply Chain Risk Management: Advanced Tools, Models, and Developments*, 311–334. https://doi.org/10.1007/978-981-10-4106-8_18

Vugrin, E. D., & Camphouse, R. C. (2011). Infrastructure resilience assessment through control design. *International Journal of Critical Infrastructures*, *7*(3), 243. https://doi.org/10.1504/ijcis.2011.042994

Wieszczeczynska, K. A., Tollin, N., & Spaliviero, M. (2024). Capacity building within urban climate resilience in the Global South: A literature review. *Frontiers in Sustainable Cities*, *6*. https://doi.org/10.3389/frsc.2024.1380936

Woods, D. D. (2015). Four concepts for resilience and the implications for the future of resilience engineering. *Reliability Engineering & System Safety, 141*, 5–9. https://doi.org/10.1016/j.ress.2015.03.018

Wu, G., Feder, A., Cohen, H., Kim, J. J., Calderon, S., Charney, D. S., & Mathé, A. A. (2013). Understanding resilience. *Frontiers in Behavioral Neuroscience*, *7*, 1–15. https://doi.org/10.3389/fnbeh.2013.00010

Yang, Z., Barroca, B., Weppe, A., Laffr, K., Daclin, N., Omrane, K., Kamissoko, D., & Benaben, F. (2023). Indicator-based resilience assessment for critical infrastructures : A review. *Safety Science*, *160*. https://doi.org/10.1016/j.ssci.2022.106049

Yarveisy, R., Gao, C., & Khan, F. (2020). A simple yet robust resilience assessment metrics. *Reliability Engineering and System Safety*, *197*. https://doi.org/10.1016/j.ress.2020.106810

Zhang, S., Huang, K., & Yuan, Y. (2021). Spare parts inventory management: A literature review. *Sustainability,13*(5), 2460. https://doi.org/10.3390/su13052460

Zamani, M. H., & Ait Soudane, J. (2022). Strategic Leadership and VUCA environment. *Revue Internationale Des Sciences de Gestion*, *5*(1), 479–505