Underpinning the Resilience Flexibility for Critical Asset Risk Management

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ABSTRACT

Managing critical assets is crucial as it supports a country's economic and social growth. Besides, the functions and operations of critical assets are irreplaceable. These assets need to comply with comprehensive protection, excellent risk management and a mitigation plan to protect their physicality and functions. Thus, the main issue in managing the risk for critical assets is to manage and minimise the impacts of any threats (natural, man-made or technological threats) that can occur. The elements of resilience adaptability are the focus of this research as a strategic approach to risk management for critical assets. The research objective is to identify and analyse the resilience elements for critical asset risk management, particularly of port terminals. The methodology adopted in this research is based on a quantitative approach by distributing questionnaires to 75 respondents who engaged within the port terminal industry. The data are analysed using the Relative Importance Index (RII) and Cronbach's Alpha to detail the resilience elements according to their significance level. Thus, this research contributes to the critical asset stakeholders and management in prioritising their action plan towards strengthening the resilience adaptability for effective critical asset risk management.

Keywords: Risk management, critical assets, port terminal, resilience elements, Malaysia.

INTRODUCTION

In recent years, the world has experienced numerous disastrous events from natural, man-made and technological defects. These events significantly impact communities, economy, infrastructure and the environment. Critical asset refers to a physical asset or system that is important for the function of the country's important sectors, such as economy, government, telecommunications, energy, banking and finance, transportation, water system and emergency services [23][28]. Other research has also highlighted that these sectors could impact security, the economy, and national public health if they are not recognised as critical assets essential to national strategic security [7]. According to [29], at the global level, critical assets include energy resources, finance, food, health, government services, manufacturing, law and legislation, national icons, people and education, transportation, and intellectual property. An efficient risk management is very essential to ensure comprehensive protection for the critical asset. Traditional risk management strategies often lack the adaptability and flexibility needed to respond to rapidly evolving threats. Thus, there is a pressing need to enhance the resilience and flexibility of these assets to ensure continuous functionality during and after disruptions. However, current frameworks often operate in silos, are reactive rather than proactive, and fail to incorporate cross-sectoral risk interdependencies. The lack of integrated, dynamic risk assessment models also impedes timely decision-making for asset protection and recovery.

In the era of globalisation, as economic growth fluctuates, so does risk probability. Therefore, awareness of the consequences must always be kept in mind. Risk exists when the element of uncertainty emerges in any

situation. Resilience is related to the capacity of a system to reorganise itself to absorb stress and maintain its function and form [5]. Priorities for critical asset protection must be established, which includes analysing how threats might affect asset systems in various scenarios [28]. Critical asset risk management requires the critical assets to be maintained through analysis and planning towards the provided services and facilities. Thus, this research fills the gap by identifying and analysing the resilience elements for critical asset risk management.

Critical Asset Risk Management: Resilience

Critical asset requires comprehensive and further protection as the asset is fragile and vulnerable to threats. The functionality of the critical asset must remain stable with adequate backup to absorb stress and remain in its best condition. This is to safeguard the operation and function of critical assets, as finding suitable substitutes for them is difficult once they are destroyed. Resilience is proposed as an applicable strategy to be used when facing difficulty and uncertainty-induced risk problems. It is a suitable tool to cope with unanticipated actions or uncertainty [14]. Further understandings of resilience definitions are presented in Table 1.

Based on Table 1, resilience enhances safety and security by encompassing technical infrastructure, an organisation's ability to counter contingent threats, as well as human knowledge and experience in responding to and implementing mitigation plans to minimise impact [14]. It aims to maintain the stability of the asset [25] and the capability to return to its original condition [25][33][15]. This is because a critical asset, especially with high-security level categorisation, is very critical in terms of asset functions and is not replaceable with another asset. Managing critical asset protection requires resilience, which involves adapting to changes in technical asset functions and human responses to contingent threats. Other research also supported that resilience reduces human vulnerability towards threats [17][31].

Resilience Element in Critical Asset Risk Management

Based on the previous research, the resilience elements are categorised into 6: Emotional competence, social competence, futures oriented, planning, adaptive capacity and minimisation of impact. Further elaborations of each element are in the following sub-topic.

Emotional Competence

The first resilience element for the port terminal is emotional competence, which is the ability to handle emotion when facing an emergency. Hence, it involves positive self-concept [16][33][27][17][2], internal locus of control [16][31][2], autonomous [16][33][30][2] and sense of humor [16][14][31][2]. A positive self-concept is calming and acting positively in an emergency. This includes finding a solution or at least able of doing something to minimise the event's seriousness. Second is the internal locus of control, which results from the control of attributions and decisions. Next is autonomous, which is self-contained and has the right or power to handle the situation without outside control. Autonomous, as mentioned by [30], is a self-reliant personality essential to overcoming reliance and vulnerability. Finally, there is a sense of humour, which is the trait of appreciating or being able to express feelings. A positive self-concept is a characteristic of an individual who survives in contrary or unsafe situations. Locus of control includes protective factors by always considering resilience [2]. A person's capacity for resilience is determined by the way they respond to an adverse incident, and their internal sense of control is apparent when they regard the occurrence as a result of their actions. Sense of humour is related to safety and security culture [31] among individuals. A sense of uneasiness should be developed among individuals to increase awareness of threats [14].

Table 1 Resilience Definition

No.	Resilience definition	Reference
1	Resilience is a strategy to enhance risk assessment's quality of service, safety, and security.	[14]
2	Resilience is reliant on technological infrastructure, aptitude	[14]

	for organisation, human expertise and experience.	
3	Resilience engineering is a safety management paradigm that can deal with complexity under pressure and generate stability and consistency.	[14][25]
4	The concept of resilience is studied in greater detail in risk management and assessments.	[14]
5	Awareness of connections and dependencies can be enhanced by resilience.	[14][33]
6	Resilience reduces people's vulnerability to threats.	[31][17]
7	Resilience is the situation of structures that endure pressure and can recuperate and revert to their initial condition.	[25][33][15]
8	The new philosophy inspired by resilience adherents is to learn "to manage by change".	[22][25]
9	Resilience is the social ability to triumph over severe trauma and deprivation and to exhibit adaptive behaviour in the face of difficulty.	[25][17][35]
10	Resilience is the system's and the community's capacity to struggle or adapt to reach an adequate level of structure and functioning. This implies that the social structure can organise and grow itself to learn and adapt, including the ability to rebuild itself after a calamity.	[25][17][37][15][24]
11	The ability to endure, adjust and recover is known as resilience, which can be freely applied to a wide range of contexts, including businesses, ecosystems, families and international communities.	[25][17][32][37][1]
12	Resilience is abstracted as a dynamic process consisting of a series of constants and associated with positive outcomes in the context of risk. It is also conceptualised as adaptability rather than as stability.	[33]
13	Resilience links a collection of adaptive capacities to a successful course for functioning and adaption following a disturbance.	[33][17][1][20]
14	The inherent capacity of a system to modify its operation before or after changes and disruptions is known as resilience. This ability allows a system to continue operating even in the wake of a significant accident or under constant stress.	[13][17]

Social Competence

Social competence is the second resilience element for the port terminal. Social competence includes the elements of communication [4][5][12][18][14][8][33][27][16][10], relationships [4][18][33][27][16][19], emphaty [2][18][33][16] and benelovence [2][33][16]. Social competence and its methodological potentiality to cope and respond to threats can enhance people's social and individual capacities to respond to contingent threats if they occur [18].

The first element is communication, which is to spread information and news. Communication facilities for seismic events are important [33]. Information is the primary resource in technical and organisational systems, enabling adaptive performance. Effective communication ensures the rapid dissemination of accurate

information, especially during emergencies when people need reliable details about the danger and available response options. Effective communication must be present within an organisation so that staff can understand the information from other parties [4][18]. Next is relationships, which relate to having a good networking relationship. Warning communication and the importance of a network is the flow of information circulating among the community within the area. Warning communication is a sort of disaster resilience preventive and planning actions with first responder's activities [18]. Other than that, empathy is the ability to understand and share the feelings of one another. Finally, benevolence refers to kindheartedness.

Futures-Oriented

The third resilience element in the port terminal is future-oriented, the ability to look forward and be positive in problem-solving and handling social and emotional competence during an emergency. Firstly, optimism [2][33][16] refers to hopefulness and confidence in facing an emergency. The problem-solving process [12][33][16] will be more accessible by looking forward with positive critical thinking in solving problems. Other than that, there is a spiritual element [26][33][16] that refers to the nonmaterial soul.

Next, a sense of purpose [26][16] is the quality of having a definite purpose, focus and ability to overcome the seriousness during an emergency. Critical thinking [3][16] is the ability to think clearly and rationally about what to do and believe. Flexible and adaptive [28][33][16] refer to the asset systems that minimise the impact of any contingent threats; most asset systems nowadays are designed with adaptive capacity [28]. Being flexible is the capability of being able to modify and cope when things change. Besides, being proactive [26][33][16] and having a proactive plan are the best measures for controlling a situation before contingent threats occur.

Planning

The fourth resilience element in risk management is planning. It is the responsibility of the decision-maker to engage in proactive planning before contingent threats occur, whereas reactive planning involves developing an action plan for a harmful event. Based on previous studies, proactive postures [34][14][35]; recovery priorities, planning strategies [11][9][36][35]; participation in exercises [18][14][32][35][19] and capability and capacity of external resources [21][35] are the elements in planning.

Proactive postures are the ability to think ahead, anticipating and planning for change before contingent threats occur. Proactive postures require a level of awareness of any threats to react and minimise the risk. Next is recovery priorities [21][18][14][35], which is to make decisions and strategies to prioritise the recovery process. This includes planning strategies and contingency plans for risk reduction. Planning mitigation activities before a seismic event and emergency and response management after the occurrence of the seismic event is essential [9]. Other than that, exercise participation can be done by conducting a scheduled exercise to practice [18]. [14] added that increased scenario training of a set of defined crises, such as loss of communication, loss of power or communication equipment enhances resilience and improves the organisation's ability to handle contingent threats with greater competence and skill. The exercise involves every emergency team unit, staff beyond the port area and port user. To increase awareness regarding risk threat prevention and preparedness, conducting a scheduled exercise is a good practice that enhances knowledge and awareness. In dealing with emergency team units, port users and other ports around the vicinity area, there is a need for capability and capacity of external resources by establishing good networking cooperation in addition to external resources.

Adaptive Capacity

Several threat impact scenarios can be considered under key criteria, especially critical assets [28]. The resilience approach includes vulnerability research, ecological economics, sustainability and managing a transition toward more sustainable development paths [25]. The adaptive capacity term captures the combination of resilience, robustness, redundancy and rapidity [20][33]. The key criteria related to critical asset resilience are as follows:

- Vulnerability: It refers to the exposure and sensitivity of asset systems that can affect their ability to adapt.
- Survivability: The capability of asset systems to maintain their functions in the face of various threats, including natural disasters, technological failures and intentional human actions.
- Dependability: The reliance on the services provided by asset systems even when they are vulnerable to different threats.
- Complexity: The potential for cascading failures within complex asset system networks when facing threats from nature, technology or intentional human actions.
- Uncertainty: The lack of knowledge regarding unknown or unidentified risks that could render asset systems vulnerable to threats from nature, technology or intentional human actions.
- Adaptability: The policies and practices in place to manage and reduce risks to asset systems from threats posed by nature, technology or intentional human actions.
- Sustainability: The long-term ability of asset systems to adapt and mitigate risks from threats posed by nature, technology and intentional human actions.

The capability to adapt allows ongoing growth in conjunction with and through change [25], which is the fifth resilience element in the port terminal. Adaptive capacity is the ability of the asset to mitigate asset risks.

Minimising Impact

Finally, the sixth resilience element in the port terminal is minimising impact in terms of response time [9] and loss of life [30][33]. Response time is reacting quickly and minimising impacts on critical assets. Other than that, there is a loss of life that requires activating an evacuation plan to minimise loss of life and injury. [33] mentioned that minimising impacts is essential to protect lives, reduce injuries and minimise damage, especially to public utilities.

In emergency management, the transportation network is a lifeline system and is very vulnerable and fundamental. Major damage to the transport network can inhibit and significantly delay and affect the resilience response to contingent threats [9]. In emergencies, evacuation is the only available strategy to save lives and reduce personal injuries. Further elaborations by [33] indicate that evacuation decisions are highly related to social support. The impact of contingent threats can be reduced through readiness training and infrastructure improvements. The event of an earthquake is a natural disaster that brings serious major effects and damage to the community [6][30]. Following the contingent threats, national and international disaster assistance efforts are needed to provide some temporary housing. Most importantly, the infrastructure needs to be improved with more resilient elements for further protection to minimise the impact of loss of life if an unwanted event occurs [30]. Furthermore, adequate and effective proactive planning for infrastructure resilience can shorten the response time to react upon contingent threats.

RESEARCH METHODOLOGY

This research aims to identify and analyse the resilience elements for critical asset risk management focusing on port terminals. The indicators were determined based on a literature review, a preliminary interview to validate the variables and a questionnaire. After validating the variables, 29 elements related to resilience for critical asset risk management were identified. Next, the indicators were analysed based on the significant level. Relative Importance Index (RII) was used to analyse the significant level for each indicator. It was expected that the analysed elements would be presented according to the significance level. These data were also entered into the Statistical Package for Social Science (SPSS 21), and the data was analysed using SPSS 21 to achieve frequency and mean analysis. Frequency analysis was carried out to obtain the results from respondents' answers regarding the 29 resilience elements. The choice of answers given was 1 = Not Significant; 2 = Less Significant; 3 = Moderate; 4 = Significant; 5 = Very Significant. The questionnaires were distributed to 75 respondents engaged within the port terminal industry. As a critical asset with a high-security level, this research adopted specified random sampling in data collection to obtain reliable data from respondents who are exposed and have adequate knowledge related to the port terminal. In applying RII, the

significance level was multiplied to the point for each category from not significant to very significant. The significant point is classified in Table 2.

Table 2. Classification of significant point

No.	Significant level	Significant point
1	Very Significant	5
2	Significant	4
3	Moderate	3
4	Less Significant	2
5	Not Significant	1

Thus, if the respondent answers 5, which is 'Very Significant', this question will carry 5 points in contributing to the total point. In completing the RII calculation, the total point was divided into *(A*N)*, as illustrated in the following formula:

$$\text{Relative Importance Index (RII)} = \frac{\text{Total Point}}{(A*N)} \quad (1)$$

Finishing the formula calculation results in the value of the relative importance index, the closer the index number is to 1, the more important the elements are.

FINDINGS AND DISCUSSIONS

SPSS 21 was used to conduct the data analysis. Descriptive statistics was used to analyse means, standard deviations and percentages of variables [37]. Besides using frequency analysis, mean analysis was adopted to obtain the mean score, standard deviation, and frequency of answering the answers given. Out of 29 elements, 19 elements were agreed based on the mean score from the respondents' answers. Thus, 65.52% of the resilience elements were agreed by the respondents. Based on Cronbach's Alpha analysis, all 29 resilience elements met the reliability value above 0.7 for Cronbach's Alpha analysis. The final value of Cronbach's Alpha was 0.980. The overall value of Cronbach's Alpha for all resilience elements ranged from 0.979 -0.980. The analysis results proved that the resilience elements, as indicated in this research, have a high value of reliability due to each element being linked to another and very significant.

Next, each resilience element was analysed using the RII to define the significance level of each element. This is to identify and analyse the resilience elements that must be prioritised. This research adopted the RII to produce a list of resilience elements based on the most significant to least significant elements. The purpose of getting to know the ranking is to help in enhancing the awareness of the elements. Table 3 presents an RII analysis of resilience elements. Based on Table 3, the most significant element compared to the other resilience elements was SCE1, which is communication (RII = 0.837). Meanwhile, the second most significant element in resilience was SCE2 with an RII value of 0.819. The third most significant element was PNG3 (planning strategies) with an RII value of 0.819. The RII mean value for this analysis was 0.778. Out of 29 elements analysed, 17 elements demonstrated higher values than the RII mean value.

The analysis resulted in three resilience elements being categorised as very significant: Communication, relationship and planning strategies. The other five resilience elements were classified as significant, while 21 other elements were moderate and less significant. Thus, the less significant elements were identified as being more related to individual conflicts. Since the case study of this research is a port terminal, the experts agreed that individual conflicts are not a big issue since they will move and act together as a team during an emergency.

Communication, relationship management and planning strategies are crucial in effective risk management across various domains, including business, project management and finance. Firstly, communication involves

information flow and transparency, fostering risk awareness through effective dialogue. It ensures timely updates with regular and clear messaging to keep stakeholders informed about any changes. Strong communication also facilitates stakeholder engagement and is crucial for managing critical situations, minimising damage, and maintaining reputation. Communication serves as a cornerstone of resilience in critical asset risk management. Effective communication channels ensure that information regarding potential risks, disruptions, and response plans is conveyed accurately and in a timely manner. According to [7a], resilient systems exhibit proactive communication behaviours that help organisations anticipate disturbances and coordinate adaptive responses. Clear internal communication fosters cohesion among asset managers, while transparent external communication enhances stakeholder trust, especially during crises. Without robust communication protocols, even well-designed contingency plans may fail due to misinformation or misalignment across decision-making levels.

Relationship management relates to trust and collaboration by maintaining positive relationships with stakeholders, including clients, partners, regulators and employers. Other than that, risk-sharing arrangements with partners are part of the risk management strategy and conflict resolution, where effective relationships can resolve conflicts related to risk perception, risk tolerance or risk responsibility. Knowledge sharing is also another collaborative relationship that often involves the exchange of knowledge and best practices, which can enhance an organisation's risk management capabilities. Relationship is another resilience element deemed highly significant, particularly in fostering collaboration across sectors and institutions. Strong inter-organisational relationships create a supportive environment for knowledge sharing, resource pooling, and joint decision-making during disruptions [21a]. Trust-based relationships among stakeholders, including government agencies, private firms, and community groups, enable quicker mobilization and more cohesive responses. These networks act as social capital, enhancing adaptive capacity and providing a platform for innovation and collective problem-solving during crises.

Planning strategies involve systematic risk assessment processes by identifying potential risks, evaluating their impact and likelihood, and prioritising them for action. Risk mitigation is other planning strategies that include risk reduction, avoidance, transfer or acceptance based on the organisation's risk tolerance. Additionally, effective planning includes resource allocation, contingency planning, and, most importantly, ongoing monitoring and periodic review of risk management efforts. Incorporating planning strategies strengthens the flexibility and anticipatory capacity of asset management systems. Strategic planning that includes scenario modelling, risk simulations, and continuity frameworks enables stakeholders to prepare for diverse disruptions. As emphasized by [12a], resilience engineering demands foresight and adaptive planning, allowing systems not only to recover from shocks but also to evolve in response to them. Integrating resilience thinking into long-term infrastructure planning helps in prioritising investments and enhancing decision-making under uncertainty.

The synergy between communication, relationships, and planning strategies creates a holistic approach to resilience. These elements reinforce one another effective communication supports relationship-building, which in turn facilitates coordinated planning. When embedded within the governance of critical asset systems, they ensure that risk management transitions from a reactive to a proactive paradigm. Consequently, these elements are not merely supportive but essential for resilience in the face of increasing global uncertainties. The following Table 3 shows the identified and analysed resilience elements findings.

Table 3. Identified and analysed resilience elements

Rank	Resilience Elements	Code	Mean	SD	(RII)	CA	Significant Level
1	Communication	SCE1	4.19	0.826	0.837	0.980	Very Significant
2	Relationships	SCE2	4.09	0.784	0.819	0.980	
3	Planning strategies	PNG3	4.09	0.807	0.819	0.980	
4	Recovery priorities	PNG2	4.04	0.931	0.807	0.979	Significant
5	Staff engagement and involvement	ACY3	4.02	0.812	0.804	0.980	
6	Loss of life	MNI2	4.00	0.824	0.800	0.979	

7	Information and knowledge	ACY5	3.98	0.901	0.796	0.979	
8	Problem-solving	FOD2	3.96	0.846	0.793	0.979	
9	Optimism	FOD1	3.96	0.856	0.789	0.979	Moderate
10	Critical thinking	FOD5	3.94	0.856	0.789	0.980	
11	Leadership, management and governance structures	ACY6	3.94	0.96	0.789	0.979	
12	Empathy	SCE3	3.94	0.843	0.785	0.979	
13	Devolved and responsive decision-making	ACY7	3.93	0.843	0.785	0.979	
14	Sense of purpose	FOD4	3.93	0.853	0.781	0.979	
15	Proactive	FOD7	3.91	0.875	0.781	0.979	
16	Proactive postures	PNG1	3.91	0.971	0.781	0.979	
17	Participation in exercises	PNG4	3.91	0.853	0.781	0.979	
18	Flexible and adaptive	FOD6	3.85	0.899	0.770	0.980	
19	Response time	MNI1	3.85	0.998	0.770	0.979	
20	Spiritual	FOD3	3.83	0.906	0.767	0.979	
21	Benevolence	SCE4	3.81	0.754	0.763	0.980	Less Significant
22	Internal and external situation monitoring and reporting	ACY1	3.81	0.826	0.763	0.979	
23	Positive self-concept	ECE1	3.80	0.786	0.759	0.980	
24	Internal locus of control	ECE2	3.76	0.823	0.752	0.980	
25	Capability and capacity of external resources	PNG5	3.76	0.95	0.752	0.980	
26	Capability and capacity of internal resources	ACY2	3.74	0.894	0.748	0.979	
27	Silo mentality	ACY4	3.72	0.834	0.744	0.979	
28	Autonomous	ECE3	3.63	0.996	0.726	0.980	Not Significant
29	Sense of humour	ECE4	3.59	0.813	0.719	0.980	

Source: Fieldwork Researcher (2016)

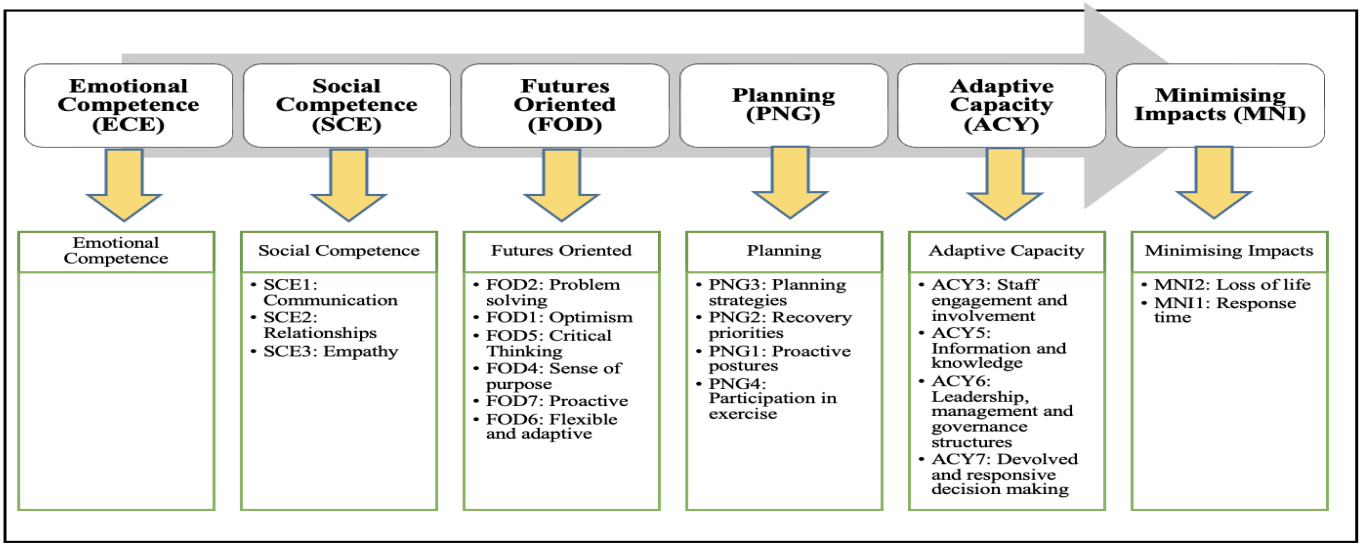

Figure 1 Framework Diagram of the research results based on Moderate, Significant and Very Significant of resilience elements

The research findings revealed that emotional competence was rated as the least significant among the resilience elements for port terminal risk management. While emotional intelligence plays a crucial role in individual stress management and interpersonal relations, its direct impact on the resilience of port terminal systems appears limited. Port terminals often operate within structured frameworks with predefined protocols, and resilience in this context tends to rely more heavily on operational coordination, communication, and planning mechanisms rather than personal emotional responses. The following Figure 1 extracts the research findings in a visual framework diagram of mainly six resilience elements as has been discussed in the literature review of the research.

Emergency responses at port terminals are usually trained and conducted in groups or teams**,** where collective action and coordination override individual emotional processing. Team members are trained to follow standard operating procedures and emergency guidelines, which are regularly briefed and reinforced through simulations or drills. This structured environment reduces the reliance on personal emotional regulation, instead promoting calm, decisive action based on rehearsed protocols. Furthermore, the presence of prior training and briefings equips employees with a sense of preparedness and confidence, mitigating emotional distress during real incidents. As noted in the field, employees who have undergone emergency response training exhibit less anxiety and more confidence in their roles, making individual emotional competence less critical in high-pressure situations. The procedural nature of terminal operations, especially during emergencies, thus minimizes the variability that emotional competence might otherwise introduce.

In summary, while emotional competence is undoubtedly valuable in many work settings, its role in port terminal resilience is less pronounced due to the nature of team-based emergency responses and the emphasis on procedural preparedness. The structured and collaborative environment, underpinned by regular training, ensures that resilience stems more from collective discipline and clear protocols than from individual emotional regulation.

CONCLUSION

This research has investigated the resilience indicators and assessed the indicators in minimising impacts. Thus, the relationship of resilience indicators in port risk management was analysed. Three types of analysis were adopted to achieve the research results. The analysis included the mean score in frequency analysis, Relative Importance Index (RII) and Cronbach's Alpha (CA). There were eight significant resilience indicators identified with three very significant elements, namely communication (SCE1), relationships (SCE2) and planning strategies (PNG3). It was concluded that the results regarding the significant resilience indicators in port risk management are essential. The enhanced improvement by adopting resilience in port risk management resulted in better risk management with adaptive capacity. In conclusion, communication, relationship management and planning strategies are integral to risk management as they facilitate identifying, assessing, mitigating and monitoring risks. They also enhance stakeholder engagement, trust and cooperation, ultimately contributing to an organisation's ability to navigate uncertainties and achieve its objectives while minimising potential negative outcomes.

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