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Developing an emerging risk model for airport management

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ABSTRACT

Air transport is a key contributor to the global economy and supports the United Nations Sustainable Development Goals (SDGs). Airports are central to this system, but increasingly face emerging risks that are uncertain and difficult to predict. This study proposes a model for managing emerging risks in airport management, using airports in Thailand as a case study. Data were collected through a questionnaire survey of airport risk management personnel and analyzed using Exploratory Factor Analysis (EFA) to identify major risk factors. The results identify four groups of emerging risks: environmental and operational risks, information and economic risks, social and governance risks, and technology-related risks. The model is based on 28 indicators. Validity was confirmed through expert evaluation and factor analysis, while reliability was assessed using Cronbach's alpha. The findings demonstrate the novelty of systematically incorporating emerging risk management into airport operations, an area that has received limited attention in previous research. The proposed framework offers both theoretical and practical contributions by providing a useful tool to support airport risk management policies, operational guidelines, and strategic planning. It enables airports to reduce potential losses, enhance competitiveness, and align with international standards to support long-term sustainability.

1. Introduction

Logistics and supply chain management are strategic actions that manage the flow of goods and services to minimize total costs and maximize value within the supply chain. By getting the right products to the right places. At the right time and lower prices. This strategy is widely popular worldwide. However, the primary activity of the logistics and supply chain management system is transportation, which plays a crucial role in economic development for businesses worldwide. This encompasses all activities related to efficiently moving products or raw materials from origin to end consumption, thereby reducing total costs. Trade in the current world is characterized by globalized international trade, which significantly enhances the movement of products and services through improved transportation infrastructure (Eachus and Keim, 2019).

Transportation balances supply and demand in all businesses. It is an international relationship that creates a market for goods and services, as the distribution of income, employment, urban expansion, time stability, and equal prosperity all affect the country's economic and social development. Air transport is a vital and widely used form of transportation worldwide. Such growth has led to the creation of modern and sufficient commercial airports that meet the demand for freight transport, which can be operated conveniently and quickly. The airport business is a crucial part of the air transport process and is one of the key logistics and supply chain management processes that drive the transport and logistics system. The role of airports and logistics services is crucial for economic growth, contributing to global, national, regional, and international connectivity. However, such opportunities may pose a risk to the entire supply chain because the air transport industry is one of the essential services for overall transport, including airport and air transport services. In addition, the global Sustainable Development Goals (SDGs) are also necessary principles of the United Nations and are incorporated into the Organization's missions. Sustainable development in Thailand aims to

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become a high-income country, encompassing both sustainable development and the capacity to cope with crises. According to Thailand's 20-year national strategy and the 13th National Economic and Social Development Plan, air transport is a key goal of sustainable development. For Thailand, Airports of Thailand (AOT) is the leader in the airport business. Six international airports are responsible for all of them: Don Mueang Airport, Phuket Airport, Chiang Mai Airport, Hat Yai Airport, Chiang Rai Airport, and Suvarnabhumi Airport, which support both domestic and international flights.

Furthermore, the COVID-19 outbreak is affecting the world's aviation industry. This rapid change has significantly reduced passenger travel patterns and behaviors due to various restrictions. Moreover, the economic crisis that governments around the world are facing (Gössling et al., 2020). Therefore, identifying and assessing potential risks is a crucial part of the risk management process for airport operations. This is evident from AOT's sustainability report, which outlines a risk management policy that addresses various risks, including strategic, operational, financial, IT, compliance, and emerging risks. To lead to the formulation of strategies or risk management plans to reduce the chances of risks or impacts from risks that may occur in the future. Respond to various situations promptly and maintain competitiveness, which may result in loss of income, lost marketing opportunities, and inability to meet the needs and expectations of customers and other stakeholders

The above information indicates that the airport business is an integral part of the air transport process. It is one of the critical logistics and supply chain management processes in driving the transportation and logistics system. However, it was found that emerging risks are essential risks that the government emphasizes. Airports have policies and risk management plans in place. Although various areas are specified, there is no approach to managing emerging risks in airports. It is a significant risk that cannot be predicted and has high uncertainty. Moreover, if it were to occur, it would have a severe impact. Therefore, it is necessary to develop an emerging risk model using the Thai airports case study, which presents the factors and indicators of emerging risk management. To lead to the proposal of new risk management guidelines for airports in Thailand as a case study. The development and improvement of airports must reduce the risk of income loss and maintain business competitiveness in various situations.

2. Methodology

2.1. Research design and approach

This study employed a mixed-methods research design comprising three research phases. The first phase of research was qualitative research by reviewing both academic and practical literature and using qualitative research tools by conducting content analysis to study emerging risk indicators of airports in Thailand. The second phase involved quantitative research, where the study aimed to design a questionnaire to identify emerging risk factors in airports using a factor analysis of airports in Thailand. The third phase involved synthesizing models by creating relationships between emerging risk factors. The data were collected, analyzed, and synthesized to draw conclusions and propose guidelines for managing emerging risks at airports in Thailand. The research design is shown in Fig. 1.

2.2. Data collection and data analysis

Research Phase 1: A study of emerging risk indicators that the review covers academic and practical literature, consisting of two stages. Firstly, academic aspects, including a literature review of international journals examined by a qualified person (peer-reviewed Journal) published between 2013-2024 (12 years in the past) which are the keyword searches include ‘Emerging Risk for the airport, Emergency Response Planning’ and ‘Airport Emergency Plan’ by Burapha University databases sourcing in Emerald, Springer Link, and Science Direct. Secondary, practical secondary data synthesizes data from the airport sustainability reports and emergency plans of the world's top 10 airports and Thai airports that are published on the airport website. Data analysis: tools analysis is a social science method. This technique reduces the bulk of the original content and puts it in a smaller category. These include understanding the semantics of complex text and data relationships. This tool is for discussions, and results are extended to action.

Research Phase 2: Data collection by collecting data from survey questionnaires with the sample groups, including the Risk Management Committee, AOT Risk Management Working Group, Risk Management and Internal Control Working Group of the Department, Office and Airport, Internal Control and Risk Management Working Group of the Risk Management Department and the AOT Internal Control Evaluation Working Group, which are directly responsible for AOT's risk management, covering six international airports under the responsibility of Airports of Thailand. To ensure the quality of the research instrument, the content validity of the questionnaire was examined by a panel of experts in risk management and airport operations, who reviewed and confirmed that the items were comprehensive and aligned with the research objectives. Construct validity was further supported with exploratory factor analysis (EFA), which confirmed that the observed variables appropriately represented the underlying constructs. Reliability of the questionnaire was tested using Cronbach’s alpha coefficient, with values above 0.70 considered acceptable, thereby indicating satisfactory internal consistency of the measurement items. Data analysis: Data analysis using exploratory factor analysis (EFA) statistics with indicators to determine the components, factors

and indicators of emerging risks of airports in Thailand. Data analysis by considering the KMO value is close to 1, so it can be concluded that the variables are related. An eigenvalue is a value used to consider how many elements (groups) can be extracted (grouped) from the variables entered into this analysis, using a criterion of 1.0 or higher. If the grouping has an eigenvalue of 1 or higher, the entry is accepted. And the Factor loading, which should have a value of 0.3 or more. However, when working, it will be found that a weight of only 0.3 is considered very little. It should be 0.5 or 0.7 or more.

Research Phase 3: Using the new risk factors and indicators of airports in Thailand to synthesize the model by creating the relationship of the new risk factors of airports in Thailand from the data collection, leading to analysis and synthesis to obtain the conclusion to propose the guidelines for managing the emerging risks of airports in Thailand. (Keeves, 1997)

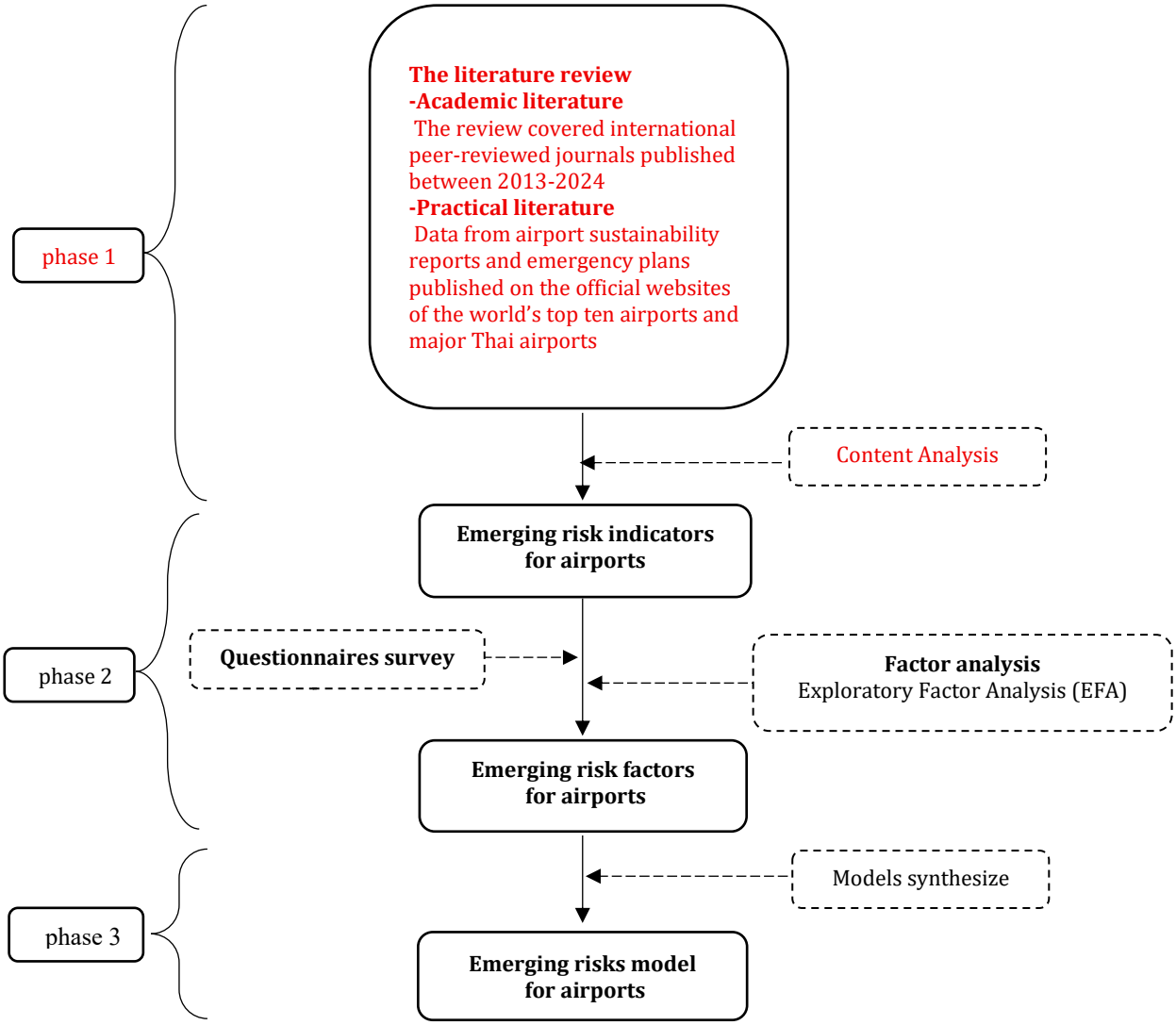

Fig. 1: Research method design

2.3. Population and sample

The population consists of the Risk Management Committee, AOT Risk Management Working Group, Risk Management and Internal Control Working Groups of the Departments, Offices, and Airports, the Internal Control and Risk Management Working Group of the Risk Management Department, and the Internal Control Evaluation Working Group of the six international airports under the control of Airports of Thailand Public Company Limited (AOT), comprising Suvarnabhumi, Don Mueang, Phuket, Chiang Mai, Hat Yai, and Mae Fah Luang Chiang Rai Airports. The total number of members is 228. In this research, the sample was the entire population.

General Information of Respondents This section presents personal data of the study sample, consisting of 228 respondents: 5 in the Risk Management Committee, 21 in the AOT Risk Management Working Group, 186 in the Risk Management and Internal Control Working Group of the Office and Airports, 7 in the Internal Control and Risk Management Working Group of the Risk Management Department, and 9 in the AOT Internal Control Evaluation Working Group. 14% of the respondents were senior executives (levels 10-11), 75% were middle executives (levels 8-9), and 11% were junior executives (levels 6-7). The questionnaire responses revealed that 61% of the respondents had worked for more than 20 years,

28% had worked for 15-20 years, 6% had worked for 10-15 years, 4% had worked for 5-10 years, and 1% had worked for less than 5 years. According to the data, most of the respondents were middle executives and had worked for more than 20 years.

3. Finding the emerging risk model

3.1. Emerging risk patterns from data analysis

This study synthesizes emerging risk indicators by integrating findings from both the literature review and secondary data analysis. The literature review covered publications from 2013 to 2024, distributed across three leading academic databases: Emerald Insight (65 articles), SpringerLink (23 articles), and ScienceDirect (15 articles)—a total of 103 peer-reviewed studies.

The analysis of these sources provided a comprehensive overview of the scholarly landscape and research trends related to emerging risks in airport management. The selected databases were intentionally chosen for their extensive coverage of aviation, logistics, and risk management disciplines, ensuring methodological consistency and conceptual reliability. The synthesis revealed that most studies emphasized emerging risks as evolving and interdependent phenomena that require continuous monitoring and adaptive management strategies.

By combining literature synthesis with institutional data (including AOT Annual Reports and ICAO guidelines), the study established a preliminary foundation for identifying indicators that reflect multidimensional risk domains—technological, environmental, social, economic, and geopolitical. These patterns collectively highlight how emerging risks increasingly shape the operational resilience of airports in both developed and developing contexts.

3.2. Indicators of emerging risk for airport management

The emerging risk indicators identified in this study are summarized in Table 1. The findings indicate that these indicators are directly linked to the broader dimensions of airport risk management and operational sustainability. Emerging risks tend to materialize gradually and infrequently, yet they can generate profound disruptions when they occur. Their identification typically relies on event analyses, longitudinal studies, and empirical evidence drawn from both academic and operational contexts. The results classified emerging risks into five primary dimensions as follows:

1. Environmental and Natural Risks: These stem from environmental or climatic changes such as natural disasters, severe storms, or long-term climate variability. Such events can disrupt airport operations, damage infrastructure, and affect logistics systems. These risks evolve progressively and are influenced by global ecological transitions.
2. Social Risks: Emerging social risks arise from demographic transitions, workforce constraints, or shifts in societal behavior. Examples include labor shortages, aging workforces, or changing travel patterns following the COVID-19 pandemic. These conditions can alter demand patterns, service expectations, and workforce dynamics in airport management.
3. Technological Risks: Advancements in digital technologies introduce both opportunities and vulnerabilities. Issues such as cybersecurity breaches, automation failures, or system outages constitute key technological risks that threaten operational reliability. These risks are typically identified through post-incident reviews and analyses of digital transformation challenges.
4. Economic Risks: Economic instability—manifesting through inflation, fuel price volatility, or market downturns—affects airport revenues, passenger volumes, and long-term profitability. Although these risks develop gradually, they impose sustained financial and strategic pressures on airport operations.
5. Geopolitical Risks: Geopolitical tensions, regulatory changes, or conflicts between nations represent complex, cross-border threats to aviation networks. These can lead to flight cancellations, route restrictions, or disruptions in international coordination (WEF, 2024; 2023).

In summary, the results confirm that airport risk management is increasingly confronted with interconnected and transboundary emerging risks originating from political, legal, social, technological, and environmental domains. Although these risks may occur infrequently, their cumulative impacts can be severe if not systematically managed. Thus, recognizing, classifying, and continuously monitoring these indicators form the cornerstone of a sustainable and resilient airport risk management framework, ensuring long-term stability and operational continuity.

3.3. Exploratory factor analysis

The 28 indicators of emerging risks were identified at airports in Thailand. The researchers used the indicators to create a questionnaire for analyzing the data through Exploratory Factor Analysis. The analysis can be displayed as in Table 2 and Table 3.

Table 2, the KMO value = .949 is close to 1, so it can be concluded that the variables are related. Using Bartlett's Test, which has an approximate Chi-Square distribution, we obtain a Chi-Square value of 5,117.884 and a Sig value of .000, which is less than .05. Therefore, it can be concluded that the variables are significantly related. Next, we analyzed the factors using Principal Component Analysis, which yielded the results shown in Table 3.

Table 1: Emerging risk indicators for airport management

Indicators		Description/examples	References
ID	Name		
ERM1	Violent misinformation and disinformation in the airports	1. The concept of misinformation may be used as an online resource to communicate meaning 2. Online users may receive messages that are misinformed 3. Some responses may become an aid to misinformation 4. The spread of misinformation may cause division and cannot change the original idea	WEF (2024), Chomintra (2023), and Davis and Beck (2023)
ERM2	Extreme weather events affecting airports	1. Extreme weather conditions, extreme temperatures, severe droughts, heavy rains, and severe tropical cyclones 2. Heavy rain and floods 3. Wildfires 4. The impact of severe weather conditions on flight delays and cancellations	Chung et al. (2015), Sawalha (2020), Fardnia et al. (2021), Ngo and Tian (2021), Dinh (2021), Bateman and Majumdar (2020), Poo et al. (2021), and Ioannou et al. (2022)
ERM3	Protests and social conflicts in the airports	1. The use of the internet to communicate political conflicts in Thailand 2. The behavior of political representatives 3. Distorted information and misperceptions during social conflicts 4. Social attitudes 5. People's political dissatisfaction 6. The suppression of freedom of expression 7. Protest activities	WEF (2024), Meyer et al. (2021), and Shen et al. (2022)
ERM4	Cybercrime in the airports	1. Number of virus programs released to destroy important data files 2. Cyberbullying 3. A large number of visits caused the website to be down	WEF (2024), Sawalha (2020), Taibah et al. (2018), and Panda and Bower (2020)
ERM5	International war on airport management	1. Use of weapons in interstate conflicts, events of violence, conflict between states, the inefficiency of multilateral organizations, and international cooperation	WEF (2024), Chung et al. (2015), Dinh (2021), Bateman and Majumdar (2020), Ioannou et al. (2022), Shen et al. (2022), and Caro (2016)
ERM6	Loss of economic opportunity for airport management	1. In the event of an emergency, accident, or incident involving an aircraft 2. Changes to codeshare agreements with other airlines 3. Intense competition in the aviation industry and competition from other forms of transport 4. Significant decline in demand for air travel in the Thai and Southeast Asian tourism markets 5. Obtaining concessions to provide airport-related services	WEF (2024), Sawalha (2020), Ngo and Tian (2021), Poo et al. (2021), Ioannou et al. (2022), and Panda and Bower (2020)
ERM7	Rapidly increasing airport services cost due to inflation	1. Current inequality in living standards 2. The price of consumer goods is increasing rapidly	WEF (2024), Ngo and Tian (2021), Dinh (2021), Ioannou et al. (2022), Shen et al. (2022), Pani (2024), and Caro (2016)
ERM8	In terms of airport income from the continued economic downturn	1. Gross domestic product continues to decrease 2. The number of imports and exports of goods continues to decrease 3. Rising interest rates influence inflation	WEF (2024), Ngo and Tian (2021), Boccalatte (2022), and Pani (2024)
ERM9	Increased pollution from airports	1. Greenhouse gas emissions 2. Noise pollution from aircraft	WEF (2024), Chung et al. (2015), Dinh (2021), Ngo and Tian (2021), Poo et al. (2021), and Ioannou et al. (2022)
ERM10	Changes in the global aviation industry at airports	1. Airline business adjustments from the COVID-19 outbreak 2. Jet fuel prices are more volatile 3. Liberalization and competition in the airline business	WEF (2024), Chung et al. (2015), Dinh (2021), Sawalha (2020), and Ngo and Tian (2021)
ERM11	Technology that changes the global economic and social structure affects airports	1. Medical and public health technology make people live longer as the number of elderly people increases, resulting in society entering an aging society 2. It causes unemployment because robots and automation systems replace humans in heavy industries, which may result in other social problems, such as crime 3. Countries with high technological development are often superpowers that play an important role in the global economy 4. High-tech businesses may create monopolies. This means that other manufacturers cannot produce the same type of product to compete in the market	WEF (2024), Ngo and Tian (2021), Ioannou et al. (2022), and Shen et al. (2022)
ERM12	Lack of resources used in the aviation industry	1. Rapid and continuous population growth rate 2. The rate of resource utilization as necessities of life has increased unnecessarily due to technological advances, leading to environmental crises	WEF (2024), Sawalha (2020), Ngo and Tian (2021), Dinh (2021), Bateman and Majumdar (2020), Poo et al. (2021), and Ranta et al. (2023)
ERM13	State boycott and control of airport administration	1. The division of international economic interactions. 2. Currency measures	WEF (2024), Chung et al. (2015), Dinh (2021), Bateman and Majumdar (2020), Ioannou et al.

		3. Sanctions by government measures 4. Control of energy and technology trade	(2022), and Shen et al. (2022)
ERM14	Using violence to control conflicts at airports	1. Obstructing traffic, causing traffic congestion 2. Damage to property 3. Illegal acts	WEF (2024), Dinh (2021), Meyer et al. (2021), Shen et al. (2022), and Caro (2016)
ERM15	Insufficient infrastructure and public services at airports	1. The passenger terminal needs to be expanded to accommodate passengers during peak hours 2. Public transport vehicles need to be able to respond to passenger demand during peak hours more efficiently	WEF (2024) and Ngo and Tian (2021)
ERM16	Disruption of the aviation industry supply chains to airports	1. Supply chain failures 2. Non-renewable raw materials run out 3. Unpredictable market demand 4. Hoarding during shortages 5. Supply chain disruptions	WEF (2024), Ngo and Tian (2021), Dinh (2021), Ioannou et al. (2022), Shen et al. (2022), Boccalatte (2022), and Caro (2016)
ERM17	Collapse of the aviation industry ecosystem to airports	1. Unclear management system for aviation industry development policy 2. Improving the law to be consistent with the aviation industry context	WEF (2024), Chung et al. (2015), and Shen et al. (2022)
ERM18	Detection of illegal activities at airports	1. Illegal smuggling at checkpoints or checked baggage screenings 2. Dissatisfaction with being investigated for violating the law	WEF (2024), Chung et al. (2015), and Shen et al. (2022)
ERM19	The poor performance of the labor market for airport workers	1. Passenger confidence in the service has decreased 2. Staff must be more efficient in their work	WEF (2024) and Ioannou et al. (2022)
ERM20	Spread of emerging infectious diseases	1. Public health service infrastructure is insufficient 2. Preparation for the prevention of emerging infectious diseases	WEF (2024), Dinh (2021), Ioannou et al. (2022), Meyer et al. (2021), and Oliphant et al. (2022)
ERM21	Utilization of airport resources that are not achieving their goals and creating competitive opportunities in the aviation industry	1. Lack of understanding of how to use resources to create competitive opportunities in the aviation industry 2. Control of access and discretionary pricing by officials	WEF (2024) and Ioannou et al. (2022)
ERM22	Infrastructure conditions need to be created for airport operators	1. Infrastructure is an obstacle to operations 2. Infrastructure hinders passenger service, causing inconvenience	WEF (2024) and Poo et al. (2021)
ERM23	The rapidly expanding illegal business at airports	1. Transport of illegal goods that are dangerous to passengers 2. Escape of offenders at the airport	WEF (2024) and Ioannou et al. (2022)
ERM24	Adverse outcomes of AI technologies in the airport	1. Rapidly changing innovation patterns/processes 2. Rapidly changing human behaviors with digital systems	WEF (2024), Sawalha (2020), and Panda and Bower (2020)
ERM25	Effects of biological weapons on airports	1. Prevention of infectious disease outbreaks spread by passengers 2. Medical capability to deal with biological threats at airports 3. Biological pathogens that are dangerous sources of infectious disease outbreaks can be spread by criminals and terrorists to wage biological warfare 4. Outbreaks of diseases that pose a real threat to national defense that may harm national sovereignty, territorial integrity, and national security	WEF (2024), Chung et al. (2015), Dinh (2021), Bateman and Majumdar (2020), Ioannou et al. (2022), and Subiakto (2020)
ERM26	Terrorist seizure of the airport	1. Patterns of terrorism such as car bombing, hand bombing, and single-person operations 2. Development of equipment used to make improvised explosive devices 3. Knowledge of explosive assembly	WEF (2024), Chung et al. (2015), Bateman and Majumdar (2020), and Ioannou et al. (2022)
ERM27	non-weather-related natural disasters affecting airports	1. Events that result in a large loss of human life 2. Events that result in damage to the ecosystem 3. An earthquake or volcanic eruption in an area that has never happened before or has not happened for a long time	WEF (2024), Chung et al. (2015), Sawalha (2020), Fardnia et al. (2021), Ngo and Tian (2021), Dinh (2021), Bateman and Majumdar (2020), Poo et al. (2021), and Ioannou et al. (2022)
ERM28	The rapid development of airport technology	1. Cyber threats 2. Security of the personal data of those involved in the airport	WEF (2024), Sawalha (2020), Ioannou et al. (2022), Meyer et al. (2021), and Panda and Bower (2020)

Factor loading represents the correlation coefficient between each observed variable and its underlying factor, indicating the degree to which a variable contributes to a given component. In general, a loading value of 0.30 or higher is considered minimally acceptable; however, loadings below 0.50 are typically regarded as weak and may not provide sufficient interpretive strength (Hair et al., 2019).

Table 2: KMO and Bartlett's test

Kaiser-Meyer-Olkin measure of sampling adequacy		0.949
Bartlett's test of sphericity	Approx. Chi–square	5117.884
	df	378
	Sig	0.000

Table 3: Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	14.475	51.696	51.696	14.475	51.696	51.696
2	2.137	7.632	59.328	2.137	7.632	59.328
3	1.333	4.760	64.088	1.333	4.760	64.088
4	1.164	4.156	68.243	1.164	4.156	68.243
5	0.894	3.191	71.435			
6	0.741	2.645	74.080			
7	0.661	2.362	76.442			
8	0.597	2.131	78.573			

Extraction method: Principal component analysis

From Table 4, an examination of the factor loading values for each ERM indicator across the extracted components reveals clear and consistent clustering patterns. Indicators ERM12, ERM13, ERM15, ERM16, ERM17, ERM20, ERM25, ERM26, and ERM27 exhibit high loadings on Factor 1 (ERM-EnvOpr), representing Environmental and Operational Risks. Indicators ERM1, ERM2, ERM3, ERM4, ERM5, ERM6, and ERM8 load strongly on Factor 2 (ERM-InfEco), corresponding to Information and Economic Risks. Indicators ERM7, ERM9, ERM14, ERM18, ERM19, ERM21, ERM22, and ERM23 show high loadings on Factor 3 (ERM-SocGov), denoting Social and Governance Risks. Lastly, indicators ERM10, ERM11, ERM24, and ERM28 load primarily on Factor 4 (ERM-Tech), associated with Technology Risks.

Table 4: Rotated component matrix

ID	Component			
	1	2	3	4
ERM12	0.514			
ERM13	0.665			
ERM15	0.509			
ERM16	0.741			
ERM17	0.773			
ERM20	0.651			
ERM25	0.772			
ERM26	0.777			
ERM27	0.710			
ERM1		0.682		
ERM2		0.740		
ERM3		0.758		
ERM4		0.750		
ERM5		0.634		
ERM6		0.513		
ERM8		0.403		
ERM7			0.541	
ERM9			0.552	
ERM14			0.636	
ERM18			0.751	
ERM19			0.591	
ERM21			0.625	
ERM22			0.632	
ERM23			0.674	
ERM10				0.537
ERM11				0.716
ERM24				0.719
ERM28				0.793

A conservative loading threshold of ≥ 0.50 was adopted to ensure that each indicator demonstrated a strong and meaningful association with its respective factors. This threshold enhanced the interpretability and robustness of the factor structure. Variables with loadings below 0.50 or those exhibiting substantial cross-loadings were excluded to preserve discriminant validity and ensure a clear conceptual distinction among the four components. The analysis revealed distinct and well-defined groupings of variables under each factor, summarized as follows:

- Factor 1: Environmental and Operational Risks (ERM-EnvOpr) — Indicators ERM12, ERM13, ERM15, ERM16, ERM17, ERM20, ERM25, ERM26, and ERM27 demonstrated strong loadings, highlighting their relevance to environmental variability, operational resilience, and physical infrastructure management within airports.
- Factor 2: Information and Economic Risks (ERM-InfEco) — Indicators ERM1, ERM2, ERM3, ERM4, ERM5, ERM6, and ERM8 loaded highly, emphasizing the interdependence between information management, cybersecurity, and financial stability in sustaining airport operations.
- Factor 3: Social and Governance Risks (ERM-SocGov) — Indicators ERM7, ERM9, ERM14, ERM18, ERM19, ERM21, ERM22, and ERM23 loaded significantly on this component, representing dimensions of social responsibility, employee relations, and governance accountability in airport management.
- Factor 4: Technology Risks (ERM-Tech) — Indicators ERM10, ERM11, ERM24, and ERM28 showed the strongest association with this factor, capturing technological challenges, digital system vulnerabilities, and the growing importance of automation reliability and cybersecurity readiness.

These findings confirm that each variable is clearly aligned with a primary factor, thereby reinforcing the four-factor structure of emerging risk indicators proposed in this study. The results also demonstrate that environmental, operational, and information–economic risks form the core operational challenges for airports, while social–

governance and technology risks represent strategic adaptation dimensions that require long-term organizational planning and investment. The conceptual grouping derived from the EFA is presented in Fig. 2, which visually depicts the interrelationships among the four factors and their collective contribution to airport risk resilience. Fig. 2 illustrates that the four components interact dynamically to support a comprehensive emerging risk management framework that aligns with global aviation governance standards (WEF, 2024).The EFA results thus provide robust empirical evidence validating the conceptual classification of emerging risk indicators. Together, the statistical and conceptual findings establish a theoretically grounded and empirically supported framework for emerging risk management in airports—one that enhances predictive capability, improves preparedness, and contributes to the advancement of sustainable and resilient airport operations.

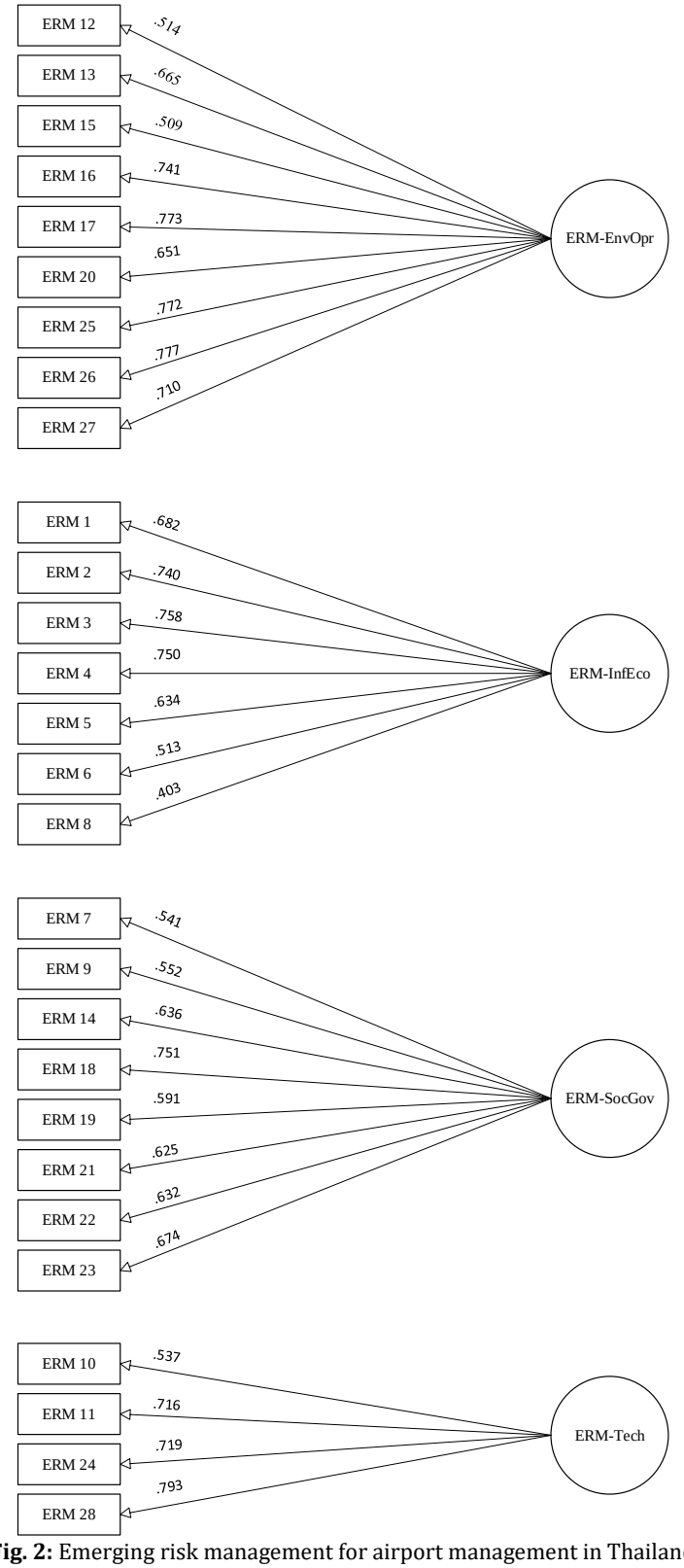

Fig. 2: Emerging risk management for airport management in Thailand

From Fig. 2, the findings indicate that the four factors correspond to the risk management dimensions previously proposed in the conceptual model. Environmental and operational risks exhibited the strongest factor loadings, suggesting that physical and operational stability remains the most critical concern for Thai airports. The identified factor structure provides empirical evidence supporting the conceptual framework of emerging risk management for airport operations in Thailand.

3.4. Emerging risk model

In determining the policy and risk management plan of airports around the world, there are international organizations to oversee and ensure that they comply with international standards, including the International Civil Aviation Organization (ICAO), the International Air Transport Association (IATA), the Federal Aviation Administration (FAA), the Airports Council International (ACI), and the European Union Aviation Safety Agency (EASA). In addition, Thailand has organizations that oversee and ensure compliance with various laws and regulations for risk management at airports, including the Department of Airports (DCA) and the Civil Aviation Authority of Thailand (CAAT). From the AOT Sustainability Report, which presents a risk management policy that focuses on managing various risks, six risk areas have been identified: 1) Strategic risk 2) Operational risk 3) Financial risk 4) IT risk 5) Compliance risk 6) Emerging risks And from researching airport risk management plans, Skytrax World Airport Awards announced The World's Top 10 Airports of 2022, which are the best airports in the world and airports in various regions, especially airports in the ASEAN region, it revealed the risk factors of airports around the world. Emerging risks have been ranked as crucial for airport risk management due to their high impact and severity.

The risks appear in WEF (2023), a risk resource from the World Economic Forum, and the Global Risks Perception Survey, which provides in-depth information on the changing global risk landscape, informed by experts from academia, the business sector, governments, the international community, and civil society. Risks are divided into five groups, and risks in each topic are interrelated and interconnected (WEF, 2023). This leads to the integration of risk management in each area. Emerging Risk Management in Airports (ERM in Airport), therefore involves four factors: factor 1: Airport Operations and Environment (ERM-EnvOpr), factor 2: Information and Economic Management (ERM-InfEco), factor 3: Social and Governance (ERM-SocGov), and factor 4: Technology (ERM-Tech).

Factor 1: Emerging Risk Management of airport in Environmental and airport Operations (ERM-EnvOpr).

Emerging Risk Management of airports in Environmental and Airport Operations (ERM-EnvOpr) involves managing the environmental and operational risks for Airports of Thailand. Impacting the management of emerging risks at airports of Thailand are nine indicators: Lack of resources used in the aviation industry (ERM12) stems from the rapid and continuous population growth and technological advancements, leading to increased resource utilization rates. This has unnecessarily increased the utilization rate of basic life resources, leading to resource crises affecting the aviation industry. State boycott and control of airport administration (ERM13) are a disruption of international economic interactions, using currency measures, various government sanctions, and controls on energy and technology trade. Insufficient infrastructure and public services at airports (ERM15) are associated with passenger capacity during peak flight periods or during high-traffic seasons, leading to congestion in terminals and vehicles, and public transport. Disruption of aviation industry supply chains to airports (ERM16) is a disruption in the supply chain, such as the depletion of irreplaceable raw materials or unpredictable market demand. Hoarding of goods during shortages. Collapse of the aviation industry ecosystem to airports (ERM17) due to the ambiguity of the aviation industry development policy management system and the amendment of laws to be consistent with the context of the aviation industry. Spread of emerging infectious diseases (ERM20) is a preparedness in response to preventing emerging infectious diseases that threaten national security. Effects of biological weapons on airports (ERM25) is an outbreak of disease that poses a real threat to national defense, potentially jeopardizing national sovereignty, territorial integrity, and national security. Prevention of infectious disease outbreaks spread by passengers, medical capacity to deal with biological weapon threats at airports, and biological pathogens that are dangerous sources of contagious diseases that can be spread by criminals and terrorists to use biological warfare. Terrorist seizure of airport (ERM26) is a form of terrorism, such as car bombings, hand bombings, and single-person operations. Non-weather-related natural disasters affecting airports (ERM27) are an event that results in massive loss of human life and causes damage to the ecosystem that is not caused by weather conditions, such as earthquakes and volcanic eruptions. It can be said that these are events that have never happened or have occurred for a long time in that area.

Factor 2: Emerging Risk Management of airport in Information and Economic (ERM-InfEco).

The emerging risk management of airports in information and economic has seven indicators: Violently Misinformation and disinformation in the

airports (ERM1) refers to false information that may be used as an online source for communication or may result in the receipt of false information, which may cause division and irreversible change in perceptions; Extreme weather events affecting airports (ERM2) refer to critical weather conditions, including extreme temperature changes, severe droughts, heavy rainfall, wildfires, and severe tropical cyclones; Protests and social conflicts in the airports (ERM3) refer to the use of the internet to communicate political conflicts; the behavior of political representatives; distorted information and misperceptions during social conflicts; social attitudes and public political dissatisfaction; the suppression of freedom of expression, including protest activities; Cybercrime in the airports (ERM4) refers to cyberbullying by releasing virus programs to destroy important data files; and massive visits that cause website downtime. International war on airport management (ERM5) refers to the use of weapons in interstate conflicts, particularly violent interstate conflicts. This is due to the ineffectiveness of multilateral organizations and international cooperation; Loss of economic opportunity for airport management (ERM6) in the event of emergencies, accidents or incidents involving aircraft, changes in code-share agreements with other airlines, intense competition in the aviation industry, a significant decrease in air travel demand in the Thai and Southeast Asian tourism markets, and the awarding of concessions for airport-related services; In terms of airport income from the continued economic downturn (ERM8) resulting from a continuous decline in gross domestic product, a continuous decrease in the volume of imports and exports of goods, and rising interest rates that affect inflation.

Factor 3: Emerging Risk Management of Airports in Social and Governance (ERM-SocGov).

Emerging risk management of airports in social and governance aspect consists of eight indicators: Rapidly increasing airport services cost with inflation (ERM7) which is the current inequality in living standards, leading to rapid increases in consumer goods prices in line with inflation; Increased pollution from airports (ERM9) as evidenced by increased greenhouse gas emissions from airports and noise pollution from aircraft; Using violence to control conflicts at airports (ERM14) when violence is used to control conflicts at airports, measures are taken to obstruct traffic flow, causing congestion to control incidents, which can result in property damage or illegal activity; Detection of unlawful activities at airports (ERM18) illegal smuggling detected at checkpoints or checked baggage screenings can lead to dissatisfaction with investigations for violations of the law; Declining efficiency of the airport labor market (ERM19) airport workers need to be efficient in their work to maintain passenger confidence in their services. Utilization of airport resources that are not achieving their goals and creating competitive opportunities in the aviation industry (ERM21) is a lack of understanding of how to utilize resources to create competitive opportunities in the aviation industry and may arise from access controls and discretionary pricing by officials that do not contribute to the achievement of competitive goals in the aviation industry. Infrastructure conditions need to be created to provide utility for airport operators (ERM22). The infrastructure hinders operations and obstructs passenger service, causing inconvenience. The rapidly expanding illegal business at airports (ERM23) involves a significant increase in the transportation of illicit goods that pose a danger to passengers, as well as the potential for increased escape of offenders at the airport.

Factor 4: Emerging Risk Management of Airports in Technology (ERM-Tech).

Emerging Risk Management of Airports in Technology (ERM-Tech) consists of four indicators: Changes in the global aviation industry to airports (ERM10) reflects airline business adaptation to changes such as the COVID-19 pandemic, increasingly volatile jet fuel prices, liberalization of competition in the aviation industry, and a global economic and trade slowdown; Technology that changes the international economic and social structure affects airports (ERM11) reflect improved medical and public health technology, which has led to longer lifespans, resulting in a growing elderly population and an increasingly aging society. Modern technology is causing unemployment as robots and automation replace humans in heavy industries, potentially leading to other social problems such as crime. Countries with high technological development are often major powers that play a key role in the global economy. High-tech businesses can create monopolies, meaning other manufacturers cannot produce the same products to compete in the market; Adverse outcomes of AI technologies in the airport (ERM24) demonstrates that airports' designs and processes are rapidly changing due to innovation, resulting in rapid digital transformation of human behavior; The rapid development of airport technology (ERM28) The leap in technology may create various threats such as cyber threats and the security of personal data of those involved in airports.

4. Discussions

4.1. Guidelines for emerging risks management for the airports in Thailand

In earlier practices, airport emergency management planning primarily focused on addressing operational risks through standardized procedures and regulatory compliance. However, emerging risks represent a distinct class of newly arising or evolving threats that may initially appear minor but can escalate into major disruptions

affecting airport operations and the wider aviation network. This study identified 28 emerging risk indicators that are crucial for supporting strategic and operational planning. These indicators offer new insights into the development of an airport's emerging risk management framework, emphasizing the need for proactive anticipation and preparedness. They serve as strategic instruments that assist airport managers in formulating policies, operational plans, and control mechanisms aligned with organizational objectives and sustainability goals. To ensure preparedness and business continuity, airports should conduct quarterly reviews and collaborative risk assessment sessions involving relevant departments—operations, safety, finance, and IT—to continuously refine and update their risk management strategies. Such a continuous improvement cycle minimizes potential disruptions and reinforces long-term resilience.

From a business management perspective, the findings underline that emerging risk management is integral to sustainable airport development. The 28 indicators identified form a foundation for operational measures that enhance risk anticipation and control across airport systems. Moreover, aligning these measures with international risk management frameworks—such as those recommended by WEF (2024) and Airports of Thailand—is essential for building globally resilient and sustainable airport operations. Following the qualitative synthesis and expert validation, 28 indicators were statistically confirmed through Exploratory Factor Analysis (EFA) to verify their internal consistency and conceptual grouping. These validated indicators now constitute the empirical basis for developing a comprehensive, integrated model of emerging risk management in airport operations, which bridges theoretical knowledge and practical application. In previous practices, airport emergency management planning was primarily developed to address operational risks through the implementation of standard emergency procedures and regulations. However, emerging risks represent a unique category of newly arising threats that may initially appear minor yet have the potential to cause severe consequences for airport operations and the wider aviation network.

This study identified 28 key emerging risk indicators that play a vital role in supporting operational planning. The findings provide new insights into the development of airport emerging risk management frameworks, highlighting the need for a proactive approach to prepare for future risks. These indicators serve as strategic tools that assist airport managers in formulating policy, operational, control, and improvement plans aligned with organizational goals. To ensure preparedness and business sustainability, it is essential that airports conduct regular reviews and brainstorming sessions each quarter to refine their risk management strategies. This continuous improvement process reduces potential operational disruptions and strengthens the airport's ability to maintain long-term resilience. From a business management perspective, the results emphasize that emerging risk management is integral to sustainable airport development. The 28 identified indicators provide a foundation for planning and implementing operational measures that enhance risk control across airport systems. Establishing international standards and frameworks for emerging risk management and sustainability reporting is therefore critical for developing resilient and sustainable airport operations (WEF, 2024). Following the identification of 28 statistically validated indicators through literature and document analysis, further confirmation was performed using Exploratory Factor Analysis (EFA) to verify the underlying structure and grouping of these emerging risk indicators.

The researcher, therefore proposed a guideline for emerging risk management for the airports in Thailand, which was derived from a study of emerging risk management indicators for the airports in Thailand, to be used as a guideline for developing and improving the management of airports in Thailand in assessing emerging risk management or as a guideline for reviewing policies, improving risk management manuals, preparing annual operational plans or annual strategic plans to reduce the risk of losing revenue and maintain business competitiveness in time for various situations and to upgrade airports to meet international standards. The researcher found that emerging risk management for the airports (ERM in Airports) consists of 4 aspects: 1) Emerging Risk Management of Airports in Environmental and airport operations (ERM-EnvOpr), 2) Emerging Risk Management of Airports in Information and Economic management (ERM-InfEco), 3) Emerging Risk Management of Airports in Social and Governance (ERM-SocGov), and 4) Emerging Risk Management of Airports in Technology (ERM-Tech), as shown in Fig. 3.

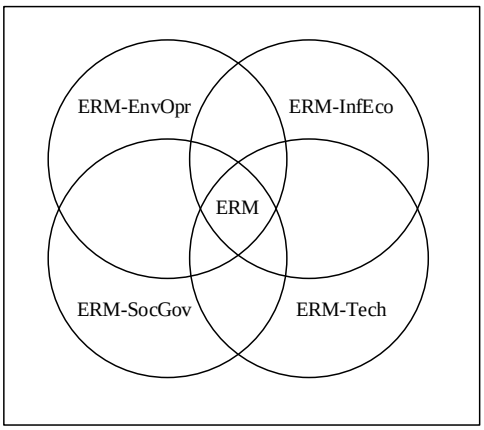

Fig. 3: Guidelines for emerging risks management for the airports in Thailand

Risk management is a process to prepare for, prevent, and adapt to various risks, as well as to seek business opportunities from these risks effectively. The Committee of Sponsoring Organizations of the

Treadway Commission (COSO), an organization formed by the integration of major accounting and auditing agencies in the United States, in collaboration with the World Business Council for Sustainable Development (WBCSD), has developed an integrated draft of enterprise risk management or ERM (Enterprise Risk Management) based on the COSO-ERM 2017 risk management framework. This document provides guidelines for companies to understand the risks associated with their business operations and to manage and disclose the results of their risk management with the highest efficiency. This serves as a crucial foundation for driving organizations toward sustainable success. Therefore, guidelines for emerging risk management in airports (ERM in Airport) based on the COSO-ERM 2017 risk management framework have been established by identifying and analyzing emerging risks, Emerging Risk Assessment, Emerging Risk Response Planning, Emerging Risk Implementation, and Monitoring and Reviewing Emerging Risks to manage emerging risks that are new issues for the airport. Which will have a significant impact in the future, according to the changing environment. It is a risk that occurs slowly or at low frequency. But if it happens, it will have a severe impact. In dealing with risks that cannot be clearly predicted and have high uncertainty, there are guidelines for emerging risk management in airports. Which consists of 4 aspects: emerging risk management of airport environment and operations, emerging risk management of airport information and economy, emerging risk management of airport society and governance, and emerging risk management of airport technology, as shown in Fig. 4.

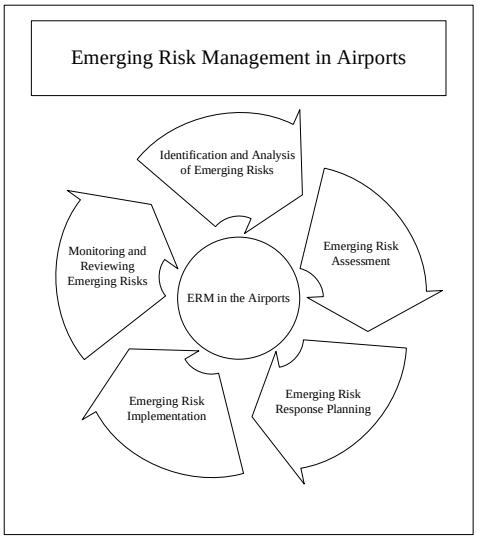

Fig. 4: Emerging risk management in airports

Each area will use the following steps to implement the approach:

1. Identification and Analysis of Emerging Risks: This involves identifying and analyzing emerging risks. This must cover both internal and external risks, considering the likelihood and impact of the risks.
2. Emerging Risk Assessment: It is an assessment of the probability of whether it is high or low, and whether the impact is high or low. Then, the risk is prioritized using a Risk Matrix to manage the risk to know the risk that should be managed immediately or is an acceptable risks. The risk assessment must be done at every step to be able to adjust the strategy quickly.
3. Emerging Risk Response Planning: It must be flexible and able to adapt quickly to situations. Strategies can be defined as follows:

- Emerging Risk Avoidance involves stopping or making unnecessary changes to plans or procedures that could lead to risk.
- Emerging Risk Mitigation involves designing control systems or implementing work improvements to prevent or limit impacts and reduce the likelihood of damage.
- Emerging Risk Acceptance involves accepting unavoidable risks because the costs of managing or establishing control systems may exceed the potential benefits. However, monitoring and oversight measures should be in place.
- Emerging Risk Transfer involves distributing or moving assets or processes to external parties or organizations to reduce the risk of loss.

4. Emerging Risk Implementation: Once strategies have been established to address emerging risks that are unpredictable and highly uncertain, the strategies should be implemented:

- Develop a plan to design or develop an operational or contingency plan to manage emerging risks.
- Develop preventative measures to address emerging risks.
- Conduct training to develop personnel's capabilities in managing emerging risks.
- Obtain insurance to reduce the risk of loss.
- Outsource emerging risk management.
- Foster a risk culture by creating awareness and training within the organization to address emerging risks.
- Use technology and innovation by using technology to anticipate emerging risks and develop innovative tools to manage emerging risks.

5. Monitoring and Reviewing Emerging Risks: To ensure that emerging risks are effectively managed and the strategic plan can be adjusted promptly to suit the situation, and are always ready.

This approach aims to develop and improve the management of Thailand's airports by assessing and managing emerging risks, or as a guideline for policy review, to mitigate the risk of lost revenue and maintain business competitiveness on time, and to elevate the organization to international standards.

5. Conclusion

The main finding regarding the emerging risk factors and twenty-eight indicators is the application of emerging risk management concepts for developing an emerging risk plan for airports, with a focus on a case study of airports in Thailand. Therefore, other airports need to consider their business factors, and these concepts apply to their airport management. This knowledge concept emphasizes the understanding of emerging risk management, including preparation and control, which serves as a guideline for developing and strengthening emerging risk management. This study develops an emerging risk model for airports using Thailand's international airports as a case study. The model identifies four main factors: environment and operations, information and economy, social and governance, and technology—supported by 28 indicators. The novelty of this research lies in its systematic integration of emerging risk management into airport operations, an area that previous studies do not explicitly emphasize.

The findings provide both theoretical and managerial contributions. Theoretically, the study advances literature by clarifying how emerging risks are categorized and operationalized within airport management. From a managerial perspective, the proposed model offers a structured framework that enables airport operators to identify, assess, and respond to emerging risks effectively. It also serves as a foundation for improving risk management policies, manuals, and strategic planning, which supports airports in minimizing revenue loss, enhancing competitiveness, and achieving compliance with international standards.

Future research broadens the scope beyond Thailand by applying and empirically testing these indicators in different airport contexts as well as international airports. Comparative studies refine and validate the model across diverse environments, which improves its generalizability and ensures its practical applicability for sustainable airport risk management.

List of abbreviations

AI	Artificial intelligence
ACI	Airports council international
AOT	Airports of Thailand
CAAT	Civil aviation authority of Thailand
CCRI	Climate change risk indicators
COSO	Committee of sponsoring organizations of the treadway commission
COSO-ERM	Committee of sponsoring organizations enterprise risk management framework
DCA	Department of airports
EASA	European union aviation safety agency
EFA	Exploratory factor analysis
ERM	Enterprise risk management
ERM-EnvOpr	Emerging risk management in environmental and operational risks
ERM-InfEco	Emerging risk management in information and economic risks
ERM-SocGov	Emerging risk management in social and governance risks
ERM-Tech	Emerging risk management in technology risks
FAA	Federal aviation administration
GDP	Gross domestic product
IATA	International air transport association
ICAO	International civil aviation organization
IRB	Institutional review board
IT	Information technology
KMO	Kaiser–Meyer–Olkin measure of sampling adequacy
SDGs	Sustainable development goals
WBCSD	World business council for sustainable development
WEF	World economic forum
WSR	Wu–Shi–Ren paradigm

Compliance with ethical standards

Ethical considerations

This study was approved by the Ethics Committee of Burapha University (Approval No. IRB4-124/2024). All participants were informed about the purpose of the study, and written informed consent was obtained prior to participation. Participation was voluntary, and all responses were collected anonymously and treated with strict confidentiality.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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