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OPERATIONAL RISK EVALUATION IN SUPPORT OF THE SUSTAINABILITY OF THE RAMMANG-RAMMANG KARST AREA AS A NATURE TOURISM DESTINATION IN SOUTH SULAWESI

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Abstract

The Rammang-Rammang Karst is one of Indonesia's prominent nature-based tourism destinations with significant geological, ecological, and tourism values, requiring effective operational risk management to ensure its sustainability. The increasing number of tourism activities has the potential to generate operational risks that may affect service quality, visitor safety, comfort, and environmental conservation if not properly managed. This study aimed to evaluate the performance and importance levels of operational risk attributes and to formulate operational risk mitigation strategies to support the sustainability of the Rammang-Rammang Karst Area in South Sulawesi. A quantitative approach was employed using purposive sampling involving 190 visitors. Data were analyzed using the Risk Evaluation Matrix (REM) to assess risk levels based on frequency and impact, and Importance Performance Analysis (IPA) to identify the priority of operational risk attributes according to visitors' perceptions. The findings revealed that Operational Risk Management Strategy were classified into retain risk, transfer risk, reduce risk, and avoid risk categories. The IPA results indicated that most operational attributes were positioned in Quadrant IV (Possible Overkill), while three attributes toilets, waste bins, and directional signage were located in Quadrant I (Concentrate Here), indicating that they require immediate improvement. Accordingly, the proposed mitigation strategies emphasize improving supporting facilities and infrastructure through regular toilet maintenance, strengthening waste management systems, and providing more informative directional signage. These strategies are expected to reduce operational risks, improve service quality, enhance visitor satisfaction, and support the sustainable management of the Rammang-Rammang Karst as a nature-based tourism destination.

Keywords: Operational Risk, Risk Evaluation Matrix, Importance Performance Analysis, Rammang-Rammang Karst

INTRODUCTION

Tourism is a strategic sector that contributes significantly to economic growth, employment creation, and regional development (Fadilla, 2024). One destination with considerable potential for nature-based tourism development is the Rammang-Rammang

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Karst Area in Maros Regency, South Sulawesi. The area is characterized by distinctive karst landscapes, including ancient limestone formations, natural rivers, karst caves, and the cultural richness and daily activities of local communities. These features make Rammang-Rammang an attractive destination for both domestic and international tourists while demonstrating strong potential for ecotourism development that integrates economic, environmental, and social dimensions.

Despite its economic and social benefits, tourism activities can also generate environmental and social pressures when they are not properly managed. The *World Tourism Organization* (UNWTO, 2018) emphasizes that poorly managed tourism development may create ecological pressures, environmental degradation, declining natural resource quality, and social conflicts within local communities. This situation indicates that the success of tourism development cannot be assessed solely through increased tourist arrivals but must also consider the destination's ability to maintain environmental sustainability and community well-being. Sustainable tourism has emerged as an important approach to addressing these challenges. UNWTO (2004) defines sustainable tourism as tourism development that meets the needs of present tourists and host communities while protecting and enhancing opportunities for future generations. This principle is consistent with the concept of sustainable development proposed by the *Brundtland Commission* (1987), which emphasizes meeting present needs without compromising the ability of future generations to meet their own needs.

Tourism sustainability encompasses interconnected environmental, social, cultural, and economic dimensions. Hunter (1997) argues that sustainable tourism should maintain the quality of natural and cultural resources while ensuring that local communities receive equitable economic benefits. Fennell (1999) emphasizes the importance of maintaining the long-term ecological, cultural, and economic viability of destinations. Similarly, Butler (1999), Sharpley (2000), and Weaver (2006) highlight that successful tourism development requires a balance among the interests of tourists, local communities, and environmental conservation. Therefore, destination sustainability depends not only on the attractiveness of tourism resources but also on the capacity of destination managers to anticipate and control various risks that may threaten the continuity of tourism activities.

Risk management is an important instrument in sustainable tourism management because tourism destinations face multidimensional risks. Lesmana (2022) states that sustainable tourism management depends on the ability of destinations to maintain a balance between economic benefits, tourist experience quality, and environmental conservation. However, such a balance is difficult to achieve without effective risk management (Ariyachandra, 2023). Risks in tourism destinations are not limited to natural disasters but also include operational, social, economic, and environmental risks that may affect destination sustainability (Wijianto, 2023). Sugiarto (2023) explains that risk management is a systematic process involving risk identification, analysis, evaluation, and control to minimize negative impacts while maximizing opportunities for destination development. Therefore, preventive, adaptive, and participatory risk management is essential to enable destination managers and stakeholders to respond appropriately to environmental and social changes (Sugiarto, 2023).

The importance of risk management becomes even more pronounced in destinations located within karst environments. Karst areas possess unique ecological characteristics while

being highly vulnerable to environmental changes resulting from human activities. Gunawan (2018) explains that karst landscapes have a high level of environmental sensitivity, including vulnerability to hydrological and geomorphological degradation. Ford and Williams (2007) state that increasing tourism activities without adequate control mechanisms can accelerate the degradation of karst landscapes and disrupt ecosystem balance. Gillieson (1996) further emphasizes that karst areas require rigorous risk management systems because tourism pressures can affect cave stability, underground water systems, and biodiversity. These characteristics make risk management an integral component of efforts to maintain the sustainability of karst tourism destinations.

These conditions are particularly relevant to the Rammang-Rammang Karst Area in Maros Regency, South Sulawesi, which possesses significant ecological, geological, social, and tourism value. UNESCO Global Geopark (2017) and Sukamto and Suryadi (2019) identify Rammang-Rammang as a highly significant karst landscape with substantial ecotourism potential. Its limestone formations, rivers, caves, and local community activities contribute to the destination's distinctive tourism character. However, increasing tourism activities may also generate pressures that threaten the sustainability of the area. Maulana (2020) warns that uncontrolled tourism pressure can contribute to environmental degradation when it is not accompanied by adequate mitigation mechanisms. Rahman (2021) also identified several management challenges in Rammang-Rammang, including weak environmental monitoring, suboptimal zoning systems, increasing tourist pressure, and conflicts of interest regarding the utilization of tourism space. These conditions indicate that the development of Rammang-Rammang as a tourism destination should not focus solely on increasing its attractiveness and tourist arrivals but should also strengthen risk management to maintain a balance between tourism activities and environmental conservation.

In addition to ecological pressures, external environmental changes and digital technological developments have increased the complexity of destination management. Darsana (2023) explains that climate change, technological developments, and global tourism market dynamics have altered tourists' expectations regarding destination quality. Duan (2022) notes that destinations that fail to manage operational risks effectively may experience declining competitiveness. In the digital era, Satpathy (2025) further emphasizes that tourists' perceptions can be rapidly shaped through social media and online reviews, making destination management weaknesses more visible and potentially affecting the image of tourism areas. Consequently, operational risk management requires greater attention because aspects such as safety, cleanliness, facilities, service quality, accessibility, and destination monitoring can directly influence tourist experiences while also affecting destination sustainability.

Although studies on sustainable tourism and karst area management have continued to develop, research specifically examining the relationship between the performance and importance of operational risk attributes in supporting the sustainability of karst tourism destinations, particularly in the Rammang-Rammang Karst Area, remains limited. This gap indicates the need to identify operational risk attributes that are performing adequately as well as those requiring immediate improvement. The *Importance Performance Analysis* (IPA) approach provides a useful framework for comparing the perceived importance and performance of various attributes and determining which attributes should receive priority for

improvement. This approach is particularly relevant because not all operational risks have the same level of urgency, and limited management resources need to be directed toward attributes considered highly important by tourists but perceived as inadequately performed.

Based on these conditions, this study focuses on evaluating operational risk management in supporting the sustainability of the Rammang-Rammang Karst Area as a nature-based tourism destination in South Sulawesi. Specifically, the study analyzes the importance and performance levels of operational risk attributes and identifies the attributes requiring priority improvement using the *Importance Performance Analysis* (IPA) approach. The novelty of this study lies in its effort to integrate operational risk management and destination sustainability perspectives within the context of a karst tourism area characterized by high ecological vulnerability. The findings are expected to contribute to the development of sustainable tourism studies and provide practical recommendations for destination managers and stakeholders in determining risk management priorities to maintain tourist experience quality and the long-term sustainability of the Rammang-Rammang Karst Area.

IMPLEMENTATION METHOD

This study employed a quantitative research design to evaluate operational risk management in supporting the sustainability of the Rammang-Rammang Karst Area as a nature-based tourism destination in Maros Regency, South Sulawesi, Indonesia. The study was conducted from January to June 2026, covering field observations, questionnaire distribution, data collection, data processing, analysis, and interpretation. A quantitative approach was selected because the study aimed to obtain measurable and objective information regarding tourists' perceptions of operational risk attributes, particularly their perceived importance and performance. The population consisted of tourists who had visited the Rammang-Rammang Karst Area, as tourists directly experience the quality of destination management, tourism services, facilities, accessibility, safety, and environmental conditions.

A non-probability sampling technique using purposive sampling was applied because the number of tourists visiting the destination could not be determined precisely and a complete sampling frame was unavailable (Sugiarto et al., 2023). Respondents were required to have visited Rammang-Rammang at least once, be at least 17 years old, and have visited the destination within the previous 12 months. The sample size was determined based on the guideline proposed by Hair et al. (2022), which recommends approximately 5–10 respondents for each indicator in quantitative research. Since this study involved 19 operational risk attributes, the sample size was calculated using the upper multiplier of 10, resulting in 190 respondents. Primary data were collected using a structured questionnaire administered to eligible tourists.

The questionnaire was developed based on the operational risk management concept and translated into observable and measurable attributes (Kubina, 2024; Vandekan, 2025). The 19 attributes were grouped into four dimensions: internal processes, human resources, software systems, and supporting facilities and infrastructure. The attributes included a safe tourism environment, availability of safety information, environmental management, service quality, service process orderliness, staff knowledge, staff adequacy, staff friendliness, staff responsiveness, staff promptness in assisting tourists, tourism information posts, Wi-Fi access,

toilets, parking areas, street vendors, entrance queues, waste bins, hospital or medical facility access, and directional signage. The internal process dimension represents risks associated with failures in service processes and operational procedures, while the human resources dimension concerns employee capacity and performance. The software systems dimension represents risks related to information systems and technology, and the supporting facilities and infrastructure dimension covers risks associated with facilities supporting tourists' safety, comfort, and mobility (Sugiarto, 2023; Sugiarto et al., 2024).

Each attribute was assessed through four aspects: risk frequency, risk impact, importance, and performance. Risk frequency represented how often a particular operational risk occurred, while risk impact reflected the severity of its consequences. Importance represented the extent to which an attribute was considered important by tourists, whereas performance reflected tourists' perceptions of the actual condition or performance of the attribute at the destination. Before the main analysis, the instrument was tested for validity and reliability. Validity was examined using the Pearson Product-Moment correlation at a significance level of 5%, with items considered valid when the calculated *r*-value exceeded the critical *r*-value and the significance value was below 0.05 (Ghozali, 2021; Sugiyono, 2023). Reliability was assessed using Cronbach's alpha, with a coefficient of ≥ 0.60 indicating acceptable internal consistency (Sekaran, 2020; Sugiyono, 2023). In this study, all instrument items have been tested for validity and reliability.

Data analysis consisted of two complementary methods: Risk Evaluation Matrix (REM) and Importance Performance Analysis (IPA). REM was used to evaluate operational risks based on the combination of risk frequency and impact (Sugiarto, 2023). The resulting risk categories consisted of *retain risk* for low-frequency and low-impact risks, *transfer risk* for low-frequency and high-impact risks, *reduce risk* for high-frequency and low-impact risks, and *avoid risk* for high-frequency and high-impact risks. Subsequently, IPA was used to compare the perceived importance and performance of each operational attribute (Sugiarto, 2023). The attributes were mapped into four quadrants: Quadrant I (*Concentrate Here*), indicating high importance and low performance and therefore requiring priority improvement; Quadrant II (*Keep Up the Good Work*), indicating high importance and high performance that should be maintained; Quadrant III (*Low Priority*), indicating low importance and low performance; and Quadrant IV (*Possible Overkill*), indicating low importance but high performance. The integration of REM and IPA enabled the identification of operational risks with significant frequency and impact while simultaneously determining attributes that require priority improvement from the tourists' perspective, thereby providing an empirical basis for operational risk mitigation and sustainable management of the Rammang-Rammang Karst Area.

RESULTS AND DISCUSSION

The Rammang-Rammang Karst Area in Maros Regency, South Sulawesi, represents a distinctive nature-based tourism destination characterized by ancient limestone formations, natural rivers, caves, rice fields, and diverse geological and cultural resources. Administratively located in Salenrang Village, Bontoa District, the area is relatively accessible from Makassar, which has contributed to increasing tourist activity. The Pute River serves as the main transportation route to several attractions within the area, with traditional boat tours providing visitors with direct access to the karst landscape. In addition to its geological value, Rammang-Rammang contains prehistoric caves with archaeological remains and cultural heritage, creating an integrated tourism experience based on natural, historical, and cultural resources. These characteristics provide substantial opportunities for tourism development but simultaneously create operational challenges because the destination combines open natural spaces, water-based transportation, fragile geological formations, and culturally significant sites within a single tourism area.

Field observations indicated that tourism activities in Rammang-Rammang are supported by several facilities, including parking areas, boat departure points, pedestrian paths, toilets, prayer facilities, food stalls, information facilities, rest areas, and ticketing services. The destination operates daily from 08:00 to 17:00 WITA, with operating hours established partly to reduce safety risks associated with reduced visibility and limited supervision outside operational hours. Visitors are charged an entrance fee of IDR 10,000 per person, while boat transportation through the Pute River generally costs approximately IDR 200,000–300,000 per boat depending on capacity and route. The involvement of local communities in boat services, homestays, culinary businesses, and souvenir sales demonstrates the economic contribution of tourism to local livelihoods and reflects a community-based management approach. Nevertheless, the combination of increasing visitor activity, dependence on water transportation, diverse supporting facilities, and high ecological sensitivity requires continuous monitoring and operational risk management. In particular, safety, environmental cleanliness, facility maintenance, visitor flow, service quality, accessibility, and emergency preparedness represent important operational aspects that may influence both tourist experience and destination sustainability.

Figure 1. The natural beauty of the Rammang-Rammang karst

The observed characteristics further demonstrate the relevance of evaluating operational risks using the Risk Evaluation Matrix (REM) and Importance Performance Analysis (IPA). The ecological sensitivity of the karst environment means that operational failures may produce consequences that extend beyond short-term service problems to environmental degradation and reduced destination quality. At the same time, the diversity of tourism services and the direct involvement of local communities create multiple operational points at which risks may emerge. Therefore, the assessment of risk frequency and impact through REM is important for determining the level and management priority of operational risks, while IPA provides a complementary perspective by identifying attributes that are considered important by tourists but whose performance remains inadequate. The integration of these approaches is particularly relevant to Rammang-Rammang because sustainable destination management requires not only the preservation of its geological, environmental, and cultural resources but also the continuous improvement of operational services and visitor safety. Accordingly, the empirical analysis of operational risk attributes provides a basis for identifying priority areas for improvement and developing more targeted management strategies for the long-term sustainability of Rammang-Rammang as a nature-based tourism destination.

1. Importance Performance Analysis

Table 1. Operational Risk Indicator Table

No	Operational Risk Indicators	Average Importance	Average *Performance*	Zone 1	Zone 2	Zone 3	Zone 4
1.	A Safe Tourism Environment	3,70	4,38	-	-	-	X
2.	Availability of Safety Information	3,80	4,38	-	-	-	X
3.	Environmental Management	3,79	4,47	-	-	-	X
4.	Good Service Quality	3,76	4,43	-	-	-	X
5.	Orderliness of the Service Workflow	3,76	4,34	-	-	-	X
6.	Staff Knowledge	3,77	4,39	-	-	-	X
7.	Number of Personnel	3,74	4,36	-	-	-	X
8.	Staff Friendliness	3,84	4,38	-	X	-	-
9.	Staff Sensitivity	3,75	4,26	-	-	-	X
10.	Staff Promptness in Assisting Tourists	3,77	4,29	-	-	-	X
11.	Tourist Information Post	3,79	4,27	-	-	-	X
12.	Stable and Reliable WiFi Access	3,38	3,52	-	-	X	
13.	Toilet	4,37	2,21	X	-	-	-
14.	Parking area	3,73	3,72	-	-	X	-
15.	Street vendors	3,61	3,86	-	-	-	X
16.	Entrance queue	3,72	3,99	-	-	X	-
17.	Rubbish bin	4,39	2,39	X	-	-	-
18.	Hospital	3,44	3,55	-	-	X	-
19.	Directional Sign	4,57	2,37	X	-	-	-

The results presented in Table 1 indicate that the *Importance Performance Analysis* (IPA) should be interpreted together with the *Risk Evaluation Matrix* (REM) results in Table 3 to provide a more comprehensive understanding of operational risks in the Rammang-Rammang Karst Area. The IPA results show that toilets, waste bins, and directional signage are located in Quadrant I (*Concentrate Here*), indicating high importance but relatively low performance. In contrast, staff friendliness is positioned in Quadrant II (*Keep Up the Good Work*), indicating high importance and satisfactory performance. Meanwhile, stable and reliable Wi-Fi access, parking areas, entrance queues, and hospital/medical facilities are located in Quadrant III (*Low Priority*), while the remaining attributes are positioned in Quadrant IV (*Possible Overkill*). This distribution suggests that the primary operational weaknesses in Rammang-Rammang are more strongly associated with supporting facilities and infrastructure than with the quality of staff services.

The findings in Quadrant I (*Concentrate Here*) demonstrate that toilets, waste bins, and directional signage represent the most urgent areas for improvement. These attributes are considered highly important by tourists but have not yet achieved satisfactory performance. Toilets are essential for maintaining visitor comfort, hygiene, and health, while adequate waste bins are necessary to prevent litter accumulation and maintain environmental quality. Similarly, directional signage plays an important role in helping visitors navigate the destination and identify appropriate routes, including potential evacuation routes during

emergencies. Therefore, improvements should include maintaining toilet cleanliness and functionality, increasing the availability and management of waste bins, and providing clear, informative, and strategically positioned directional signage. These findings are particularly relevant to the REM results because weaknesses in these facilities may increase the likelihood or consequences of operational risks associated with visitor safety, environmental cleanliness, and movement within the destination.

The Quadrant II (*Keep Up the Good Work*) finding shows that staff friendliness is an important attribute with satisfactory performance. This indicates that interpersonal service provided by destination staff has generally met tourists' expectations and represents one of the strengths of the destination. Meanwhile, Wi-Fi access, parking areas, entrance queues, and hospital/medical facilities are positioned in Quadrant III (*Low Priority*), indicating relatively low importance and low performance from the tourists' perspective. Although these attributes are not immediate priorities, their conditions should still be monitored and gradually improved, particularly in response to increasing visitor numbers and changing tourist expectations. Conversely, attributes in Quadrant IV (*Possible Overkill*), including a safe tourism environment, safety information, environmental management, service quality, service process orderliness, staff knowledge, staff adequacy, staff responsiveness, staff promptness, tourism information posts, and street vendors, demonstrate relatively high performance despite being perceived as less important. This suggests that existing resources allocated to these attributes may be reviewed and optimized without compromising the quality of services that have already been achieved.

When examined across the operational dimensions, the findings indicate that internal processes and human resources generally perform well, whereas supporting facilities and infrastructure represent the most significant area of concern. Safety, safety information, environmental management, service quality, and service process orderliness are located in Quadrant IV, suggesting that basic operational procedures have been implemented effectively. Similarly, most human resource attributes are located in Quadrant IV, while staff friendliness is positioned in Quadrant II, indicating that service personnel generally meet or exceed tourist expectations. In contrast, the supporting facilities and infrastructure dimension demonstrates a more substantial performance gap, particularly for toilets, waste bins, and directional signage. This pattern suggests that operational risk mitigation should focus less on major changes to staff performance and more on strengthening physical facilities and infrastructure that directly support safety, comfort, environmental quality, and visitor mobility.

Overall, the integration of the IPA and REM findings demonstrates that operational risks in the Rammang-Rammang Karst Area are more closely associated with weaknesses in supporting facilities than with internal processes or human resources. The concentration of toilets, waste bins, and directional signage in Quadrant I establishes these three attributes as the primary priorities for intervention. Improving these facilities may reduce the likelihood of accidents, improve environmental cleanliness, enhance visitor comfort, and strengthen the destination's preparedness for operational and emergency risks. Thus, IPA provides not only an assessment of the gap between tourist expectations and perceived performance but also a practical basis for prioritizing risk mitigation, while the REM results provide additional evidence regarding the frequency and potential impact of operational risks. The integration of both approaches therefore offers a more targeted basis for improving the sustainability of

Rammang-Rammang as a nature-based karst tourism destination.

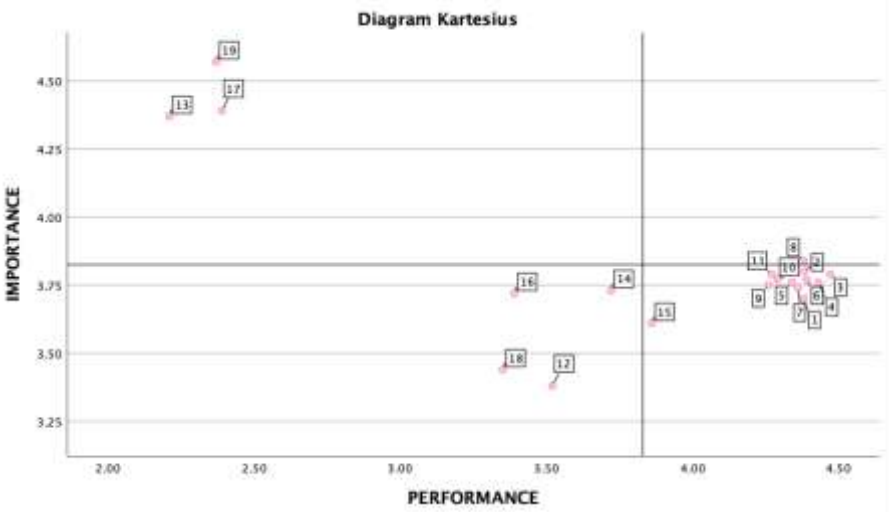

Figure 2. Risk quadrant of the Rammang-Rammang karst

Based on the results shown in Diagram 2, there are several operational aspects of the Rammang-Rammang Karst Area that require special attention from management, particularly regarding efforts to strengthen operational risk mitigation at the tourist destination. A risk quadrant analysis reveals a gap between the level of importance perceived by tourists and the actual performance delivered by management across several service attributes. This gap indicates the existence of operational aspects that could compromise tourist comfort, safety, and experience quality if improvements are not promptly made. Consequently, the quadrant mapping results serve as the basis for prioritizing operational risk management in the Rammang-Rammang Karst Area.

These results were derived from the analysis of questionnaire data evaluating the importance and performance levels of each operational attribute in the Rammang-Rammang Karst Area using the Importance-Performance Analysis (IPA) method. Through this analysis, all indicators were mapped into four quadrants based on their priority levels. The findings indicate that restrooms, trash receptacles, and directional signage fall into Quadrant I ("Concentrate Here"); this signifies that while tourists consider these three attributes highly important, their current performance fails to meet expectations. Therefore, the indicators located in Quadrant I have been designated as top priorities for formulating operational risk mitigation strategies and are discussed further in the subsequent subsection.

Table 2. Operational Risk Indicators in the Rammang-Rammang Karst (Quadrant 1)

Nomor indicator	Operational risk indicators
13	Toilet
17	Rubbish bin
19	Directional Sign

The findings presented in Table 2 show that three operational risk attributes—toilets, waste bins, and directional signage—are located in Quadrant I (*Concentrate Here*) of the *Importance Performance Analysis* (IPA). These attributes are perceived as highly important

by tourists, but their performance remains below expectations, indicating a clear gap between visitor expectations and the actual quality of facilities provided in the Rammang-Rammang Karst Area. The position of these three attributes confirms that supporting facilities and infrastructure represent the primary operational weakness of the destination. Because these facilities directly influence visitor comfort, safety, environmental quality, and mobility, their improvement should become a major priority in destination management and operational risk mitigation.

Toilets were identified as one of the most important attributes requiring immediate improvement. Their position in Quadrant I indicates that the available sanitation facilities have not fully met tourists' expectations. Inadequate maintenance, cleanliness, or supporting sanitation equipment may reduce visitor comfort and negatively influence perceptions of destination quality. From an operational risk perspective, poorly managed sanitation facilities may also contribute to environmental pollution, declining hygiene standards, and potential health-related concerns. This issue is particularly important in a nature-based tourism destination such as Rammang-Rammang, where environmental protection and visitor health are closely connected to sustainable tourism management. Therefore, mitigation measures should include regular maintenance schedules, improved cleanliness standards, adequate sanitation supplies, and routine monitoring of facility conditions.

Waste bins were also positioned in Quadrant I, demonstrating that waste management is another critical concern from the tourists' perspective. Insufficient numbers or inappropriate placement of waste bins may increase the likelihood of litter accumulation, environmental pollution, and deterioration of the visual quality of the destination. These risks are particularly significant in the Rammang-Rammang Karst Area because its ecological characteristics are sensitive to environmental disturbances. Poorly managed waste may affect surrounding habitats and water resources, including the Pute River, which constitutes an important component of the tourism experience. Therefore, risk mitigation should include increasing the number of waste bins at high-traffic locations, implementing waste segregation, increasing the frequency of waste collection, and providing environmental education for visitors. Collaboration among destination managers, local communities, and tourists is also essential to establish responsible waste management practices.

The third priority attribute, directional signage, was likewise located in Quadrant I, indicating that tourists consider clear directional information highly important but perceive its current performance as inadequate. The geographical characteristics of Rammang-Rammang, with attractions and facilities distributed across a relatively complex natural landscape, make effective directional information essential for visitor mobility. Insufficient signage may increase the risk of visitors becoming disoriented, choosing inappropriate routes, or entering areas that are not designated for tourism activities. From a risk management perspective, directional signage therefore functions not only as an information facility but also as a mechanism for controlling visitor movement, supporting safety, and protecting environmentally sensitive areas. Improvements should include installing signs at intersections, routes leading to major attractions, and locations of public facilities; using easily understandable language and internationally recognizable symbols; and conducting regular inspections and maintenance to ensure that signs remain visible, readable, and functional.

Overall, the identification of toilets, waste bins, and directional signage as Quadrant I

attributes provides a clear empirical basis for prioritizing operational risk mitigation in the Rammang-Rammang Karst Area. The three attributes share a common characteristic: they are relatively basic facilities, yet their inadequate performance can generate broader consequences for visitor satisfaction, safety, environmental quality, and destination sustainability. Consequently, management resources should initially be directed toward improving sanitation facilities, strengthening waste management systems, and developing a more effective directional signage system. These interventions can complement the findings of the *Risk Evaluation Matrix* by reducing the probability and potential impact of operational risks while simultaneously improving tourists' experiences. The results demonstrate that strengthening basic supporting infrastructure is an essential component of sustainable risk management in karst-based nature tourism destinations.

2. Risk Evaluation Matrix

Table 3. Risk Evaluation Matrix table

Risk Evaluation Matrix			
Frequency	rarely	Diarrhea or food poisoning caused by unhygienic food or snacks.	Flood
	frequently	Visitor density, toilets, trash bins, and directional signs.	Accidents in tourist areas caused by visitor negligence.
		Low	high
		Impact	

The results of the *Risk Evaluation Matrix* (REM) presented in Table 4.11 demonstrate that operational risks in the Rammang-Rammang Karst Area vary in their management priorities based on the combination of occurrence frequency and potential impact. Food poisoning or diarrhea caused by unhygienic food and beverages is classified as low impact–low frequency, while flooding is categorized as high impact–low frequency. Visitor overcrowding represents a low impact–high frequency risk, whereas accidents in tourism areas caused by visitor negligence constitute a high impact–high frequency risk. This classification provides a systematic basis for determining appropriate risk treatment strategies according to the characteristics and severity of each operational risk.

The REM findings should be interpreted in conjunction with the *Importance Performance Analysis* (IPA) results because risk mitigation should consider not only the level of risk but also the operational attributes that require performance improvement. The IPA results indicate that toilets, waste bins, and directional signage are located in Quadrant I (*Concentrate Here*), meaning that these attributes are highly important to tourists but their performance remains below expectations. These three attributes therefore represent critical intervention points that can support the mitigation of multiple operational risks. Improving their availability, quality, and functionality can contribute to reducing risks related to hygiene, environmental conditions, visitor movement, and safety while simultaneously improving the overall visitor experience.

The low impact–low frequency risk, represented by diarrhea or food poisoning caused by unhygienic food and beverages, can be managed through a risk retention strategy. Although its probability and consequences are relatively limited, preventive monitoring remains

necessary to prevent the risk from escalating. Management measures may include routine inspection of food-service areas, education for food vendors regarding hygiene and sanitation standards, and regular monitoring of food-handling practices. The improvement of waste bins identified as a priority in the IPA analysis also supports this strategy because adequate waste facilities can reduce waste accumulation around culinary areas and minimize potential sources of contamination. Thus, risk retention in this context does not imply neglecting the risk but rather accepting it while maintaining proportionate preventive controls.

The low impact–high frequency risk associated with visitor overcrowding requires a risk reduction strategy because the risk occurs relatively frequently but its consequences can still be controlled through operational improvements. Management can reduce this risk by improving visitor flow, establishing clearer entrance and exit routes, distributing visitors across different attractions, and providing information regarding alternative routes and areas with lower visitor density. The IPA finding concerning directional signage is particularly relevant to this strategy. Clear and strategically positioned signs, supported by area maps and route information, can help visitors navigate independently and reduce unnecessary concentration at particular locations. Consequently, improvements in directional signage can function not only as a service enhancement but also as an operational mechanism for controlling visitor movement and reducing overcrowding.

The high impact–low frequency risk of flooding is categorized under a risk transfer strategy because, although flooding occurs relatively infrequently, it can have serious consequences for visitor safety, infrastructure, and tourism operations. Since the occurrence of flooding is strongly influenced by external environmental and weather conditions, its management requires collaboration with relevant authorities and institutions. Cooperation with local government, disaster management agencies, meteorological authorities, and insurance providers can strengthen early-warning systems, emergency procedures, evacuation planning, and financial protection against potential losses. In this context, the IPA priority concerning directional signage can be integrated into flood mitigation by providing clearly marked evacuation routes, emergency assembly points, and warning information at strategic locations. Such measures can improve visitor preparedness and facilitate rapid evacuation when hazardous conditions occur.

The high impact–high frequency risk of accidents caused by visitor negligence represents the most critical operational risk and requires a risk avoidance strategy. This approach should focus on eliminating or minimizing conditions that may trigger accidents through systematic improvements in facilities, safety information, visitor supervision, and operational controls. The three IPA priority attributes provide direct intervention points: toilets should be regularly maintained and equipped with safe, non-slip surfaces and adequate lighting; waste bins should be provided at strategic locations to prevent litter that may create physical hazards; and directional signage should include safety warnings, safe-route information, restricted-area signs, and emergency directions. Overall, the integration of REM and IPA demonstrates that risk mitigation should not rely solely on the frequency and impact of identified risks but should also address operational performance gaps. Prioritizing improvements in toilets, waste bins, and directional signage can simultaneously strengthen risk retention, reduction, transfer, and avoidance strategies, thereby improving visitor safety, service quality, environmental management, and the long-term sustainability of Rammang-

Rammang as a nature-based karst tourism destination.

3. Risk Mitigation Strategy Formulation

The risk mitigation strategy was formulated by synthesizing the results of the *Importance Performance Analysis* (IPA), which identified operational risk attributes requiring priority improvement in the Rammang-Rammang Karst Area. The analysis indicates that toilets, waste bins, and directional signage are positioned in Quadrant I (*Concentrate Here*), meaning that these attributes are considered highly important by tourists but their current performance remains below expectations. This performance gap indicates potential operational risks that may affect visitor comfort, service quality, environmental conditions, and destination sustainability. Therefore, the mitigation strategy focuses on these three attributes as the primary intervention points because improvements in basic facilities can directly address several operational risks identified through the REM analysis.

The mitigation of toilet-related risks should focus on improving sanitation, cleanliness, and facility functionality through regular maintenance and systematic monitoring. The management should establish routine cleaning schedules, repair damaged sanitation facilities, provide adequate cleaning and hygiene supplies, and conduct periodic inspections to ensure that toilets remain safe and suitable for visitors. These measures are important not only for improving visitor comfort but also for reducing potential health and environmental risks associated with inadequate sanitation. In the context of a sensitive karst ecosystem, proper sanitation management can also help prevent environmental contamination and maintain the overall quality of the tourism destination.

For waste management, mitigation should emphasize the availability, distribution, and systematic management of waste bins. Additional waste bins should be provided at strategic locations with high visitor activity, accompanied by regular waste collection and, where feasible, waste segregation into organic and inorganic categories. Environmental awareness initiatives should also be implemented through information boards and direct education to encourage visitors to dispose of waste properly. Meanwhile, mitigation of risks associated with directional signage should involve increasing the number of signs at intersections, attraction routes, public facilities, and other critical points. The signs should use clear wording, easily recognizable symbols, and durable materials suitable for outdoor conditions. Regular inspection and replacement of damaged or unreadable signs are also necessary to ensure that visitors can navigate the area safely and efficiently.

Overall, the proposed mitigation strategy demonstrates that improving basic supporting facilities can serve as an integrated approach to operational risk management in the Rammang-Rammang Karst Area. Improvements to toilets, waste bins, and directional signage can simultaneously enhance visitor comfort, environmental cleanliness, safety, and accessibility while reducing the potential frequency and impact of operational risks. The strategy also provides a practical basis for allocating management resources toward attributes with the greatest performance gaps. By implementing these interventions in a preventive, systematic, and continuous manner, destination managers and local stakeholders can strengthen operational control and improve the quality of tourism services while maintaining the ecological integrity of Rammang-Rammang as a sustainable nature-based karst tourism destination.

CONCLUSION

The results of the *Importance Performance Analysis* (IPA) indicate that most operational risk attributes in the Rammang-Rammang Karst Area are positioned in Quadrant IV (*Possible Overkill*), reflecting relatively high performance on attributes perceived as less important by tourists. However, toilets, waste bins, and directional signage are located in Quadrant I (*Concentrate Here*), indicating a significant gap between their high level of importance and relatively low performance. These three attributes therefore represent the main operational priorities requiring immediate improvement, particularly in supporting visitor comfort, cleanliness, safety, and accessibility. Accordingly, mitigation strategies should focus on regular toilet maintenance, strengthening waste management through adequate waste-bin provision and collection, and improving directional signage to provide clear and accessible information. The implementation of these measures is expected to reduce operational risks, improve service quality and visitor satisfaction, optimize resource allocation, and strengthen the sustainable management of Rammang-Rammang as a nature-based karst tourism destination.

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