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Hazard Identification and Risk Assessment Using the HIRADC Framework in Travel and Tourist Activities at Mudal River Ecotourism, Kulon Progo, Yogyakarta

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ABSTRACT

Introduction: Safety and security are important considerations for nature-based tourism, even more so if destinations are prone to disasters that reinforce the risk of transport, environmental and activity-related hazards. Kulon Progo, Yogyakarta's Mudal River Ecotourism reflects these issues through the presence of steep and curving roads, unpredictable hydrometeorological conditions and insufficient safety facilities which together increase risk exposure during travel to the destination as well as when executing activities at site.
Methods: This research used a qualitative case study approach that purposively juxtaposes the HIRADC framework with the DRR principles in a complex ecotourism context. Data were gathered through fieldwork, semi-structured interviews with managers, tourists and government organizations, document analyses; the risk assessment was based on the AS/NZS 4360:2004 standard considering probability (A–E) and severity (1–5) scales.
Results: The findings identified critical hazards along the travel route (landslides, slippery and narrow roads, brake failure on steep slopes, and interaction with village traffic) and within the tourism area (slipping on rocks, sinking in deep pools, being swept away by strong currents, falls from heights, structurally vulnerable bridges, and animal bites). Most hazards were classified as high risk, particularly those associated with aerial recreation and landslide-prone access, leading to the management of a layered control package that combines engineering measures, administrative procedures, tourist safety education, and community-based monitoring aligned with disaster risk reduction strategies.
Conclusion: This study demonstrates how the application of the HIRADC framework and disaster risk reduction concepts can strengthen tourism safety governance in nature-based destinations exposed to geological and hydrometeorological hazards. The proposed safety management roadmap provides a practical reference for destination managers and policymakers and offers insights that can be applied to developing more resilient risk management models in similar ecotourism contexts.

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INTRODUCTION

The tourism industry is a sector that makes a significant contribution to the global and national economy. In 2019, the tourism sector contributed approximately 10.4% to the world's Gross Domestic Product (GDP) and created more than 300 million jobs, according to the World Travel and Tourism Council (WTTC) (1,2). The Central Statistics Agency (BPS) in Indonesia said that 16.1 million foreign tourists came to the country in 2019. However, this number dropped to about 4 million in 2020 because of the Covid-19 pandemic (3–5). As recovery progresses, the number of domestic tourist arrivals is expected to increase again to more than 700 million trips by 2023 (6). These figures underscore the importance of destination hospitality in ensuring tourist safety as a key factor in tourism desirability (7).

Safety and security are key considerations for tourists. A 2022 survey by the World Tourism Organization (UNWTO) shows that around 70% of global tourists consider safety to be an important factor when choosing a tourist destination (8). This is like what happened in Indonesia, where a number of things have shown that the tourism industry doesn't do a good job of managing risks. In 2023, the Geong Glass Bridge in Banyumas fell down, killing one tourist and hurting a lot of others (9). In 2024, a tourist bus accident occurred in Ciater, Subang, West Java, killing 11 people and injuring dozens of passengers (10). The tourist boat accident in Komodo National Park in 2023 is another example of a tourism accident caused by bad weather and a lack of safety (11). These incidents not only caused casualties but also had a negative impact on the image of tourist destinations and public trust (12,13).

In this article, news reports and institutional documents are used only to contextualize recent tourism incidents and disaster trends, whereas the core empirical analysis and conclusions are grounded in peer-reviewed scholarly sources and primary field data.

Indonesia is more likely to be in danger because it is on the Ring of Fire. The National Disaster Management Agency (BNPB) reported that Indonesia had over 3,000 natural disasters in 2023, such as floods, landslides, earthquakes, and volcanic eruptions. This shows that tourist spots in Indonesia are in danger of both natural disasters and accidents on the road that could happen at any time (14,15).

In Kulon Progo Regency of the Special Region of Yogyakarta, the Mudal River is an ecotourism site where visitors can enjoy gorgeous waterfalls, natural pools, and even participate in activities that help protect and preserve the environment. However, there are many risks that may endanger visitors trying to access the site due to steep and winding roads, the possibility of inclement weather, and a lack of adequate safety measures. Given the lack of planning to address the risks, there is a high likelihood of accidents on the way to the site and during activities associated with tourism in the area.

An excellent tool for handling these challenges is the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method. It identifies potential hazards, evaluates the level of risk, and develops control measures to mitigate the risks prior to the occurrence of incidents. This study utilizes the HIRADC method in conjunction with the AS/NZS 4360:2004 standard, which is one of the few standards that provides HIRADC users with a simple semi-quantitative risk matrix that includes easily definable and classifiable metrics for both probability and severity so that destination managers can understand easily. Although newer standards such as ISO 31000 offer a principles-based framework, they are less prescriptive in defining operational scoring tools, so AS/NZS 4360:2004 is prioritized here to ensure methodological clarity and consistency with previous tourism and occupational safety studies. Previous studies have applied HIRADC to various tourist destinations, such as the Merapi lava tour, the Malioboro area, Leuwi Kenit tourism, and Pindul Cave tourism (16–18). While these studies demonstrate that HIRADC is effective for mapping site-specific hazards and prioritizing controls, they generally treat risk management as a predominantly technical or operational exercise, with limited attention to how safety measures are embedded within broader tourism safety governance and disaster risk reduction agendas. By contrast, the present study extends this body of work by integrating the HIRADC framework with disaster risk reduction principles in a disaster-prone ecotourism setting, explicitly linking travel-route and on-site hazard assessment to multi-stakeholder governance arrangements, community participation, and phased safety management planning at Mudal River Ecotourism. In doing so, it advances existing knowledge by moving from isolated, site-level risk checklists toward a more systemic and governance-oriented model of tourism risk management that can be adapted to other nature-based destinations facing similar hazard profiles.

Based on this background, the objectives of this study are to: (1) identify potential hazards encountered by tourists during their journey to and activities within the Mudal River destination; (2) assess the risk levels associated with these hazards; and (3) develop effective control strategies to enhance tourist safety and security.

METHOD

This study uses a qualitative case study approach conducted over a period of six months (January to August 2025) at Mudal River Ecotourism, Kulon Progo, Yogyakarta. A qualitative case study approach was used because tourism safety risk assessment does not only depend on numerical calculations of probability and consequences, but also on a deep understanding of the social and institutional context and the behavior of tourists and managers that shape how risks arise, are perceived, and are controlled in practice. This approach complements the semi-quantitative HIRADC framework. HIRADC provides structured risk mapping, while qualitative analysis allows for a deeper understanding of the meaning, experiences, and practices of safety governance so that the results of risk assessment can be directly linked to disaster risk reduction strategies and the strengthening of safety management at destinations.

Purposive sampling was used to select informants consisting of the head of the tourist site management (1 person), government officials related to tourism safety from the Tourism Office (1 person), the Transportation Office (1 person), the Regional Disaster Management Agency (1 person), and active tourists who had direct experience of activities at the site (6 people), bringing the total number of informants in this study to 10 people. The informant profiles included age, gender, profession, and experience related to tourism activities in the area. Data collection continued until we reached thematic saturation. This was determined by the repeating of the same hazard categories, risk perceptions, and control practices spanning across different stakeholder groups and the absence of new codes after multiple interviews. At that point, the existing dataset was deemed sufficient to capture the main dimensions of tourism safety risk and governance at Mudal River Ecotourism for the purposes of this case study.

Data collection was accomplished via direct observation at the site, recorded and transcribed semi-structured interviews, and supplementary documentation. Researchers made sure that the data was consistent and valid by using source triangulation (cross-checking information from multiple types of informants), method triangulation (making sure that observational data, interviews, and documentation all agree), and an audit trail. Researchers consciously contemplated their role as academics working alongside destination managers and local authorities, acknowledging that this dual capacity might affect the framing of safety concerns and solutions during interviews and analysis. To mitigate potential bias, preliminary interpretations were consistently deliberated within the research team and validated against diverse stakeholder groups to confirm that the identified hazards, risks, and control strategies were grounded in a collective viewpoint rather than exclusively reflecting the researchers' perspective.

Risk assessment in this study uses the HIRADC (Hazard Identification, Risk Assessment, and Determining Control) method, which refers to the AS/NZS 4360:2004 standard. There are two main parts to risk assessment: the chance of a hazard happening and the effects or consequences it has. There are five levels of likelihood of occurrence, from A (Almost Certainly), which means that it is likely to happen at any time, to E (Rare), which means that it is only likely to happen in very rare situations. For more details, see Table 1. Meanwhile, the consequences are classified on a scale of 1 to 5, ranging from very minor impacts to fatal impacts such as serious injury or death. See Table 2.

Risk values are calculated by multiplying the probability and consequence levels, then grouped into four risk categories: low, moderate, high, and very high. To facilitate analysis and control decision-making, the risk evaluation results are visualized in a risk matrix as shown in Table 3. This visualization helps prioritize mitigation actions for hazards with high and very high risks. In the context of tourism on the Mudal River, this risk assessment covers travel activities to activities at tourist sites, with the results serving as a reference in the preparation of control measures such as installing warning signs, repairing facilities, developing safety procedures, and educating visitors and destination managers.

Tabel 1. Qualitative Measure of Likelihood

Level	Criteria	Explanation
A	*Almost Certainly*	Expected to occur in every situation.
B	*Likely*	It is likely to happen frequently.
C	*Possible*	It is possible that it will happen several times.
D	*Unlikely*	Possibility rarely occurs/occurs occasionally.
E	*Rare*	Can only occur under certain/exceptional circumstances.

Source: AS/NZS 4360:2004 (19)

Tabel 2. Qualitative Measure of Severity

Level	Criteria	Explanation
1	*Negligible*	The safety and security of tourists is not affected at all.
2	*Minor*	Low safety risk; causes only minor discomfort or slight disturbance.
3	*Moderate*	May cause minor injuries or serious pain; may need minor emergency help.
4	*Major*	Putting the safety of many tourists at risk; could lead to serious injury or major security problems.
5	*Severe*	Threatening the safety of many tourists; high possibility of serious injury or death.

Source: AS/NZS 4360:2004 (19)

Tabel 3. Risk Matrix

AS / NZS 4360: 2004		**SEVERITY**					
		Negligible	Minor	Moderate	Major	Severe	
PROBABILITY	Almost Certainly	H	H	H	VH	VH	A
	Likely	M	H	H	H	VH	B
	Possible	L	M	H	H	H	C
	Unlikely	L	L	M	H	H	D
	Rare	L	L	M	H	H	E
		1	2	3	4	5	

Note: Low (L), Medium (M), Higt (H), and Very Higt (VH)
Source: AS/NZS 4360:2004 (19)

RESULTS

The results of the risk assessment for tourism activities during travel to and within the Sungai Mudal Ecotourism area are presented using a simplified HIRADC format that emphasizes priority hazards and key control strategies. Rather than listing each identified risk item in detail, the tables group similar hazards, standardize terminology, and highlight only those risks classified as high and very high according to the probability–severity matrix. This approach preserves the comprehensiveness of the risk assessment while enhancing readability and analytical focus, thereby enabling clearer interpretation of critical risk patterns along access routes and within the ecotourism area.

Table 4. Priority Travel-Related Hazards and Controls at Mudal River Ecotourism

Activities	Main Hazard Category	Risk Level	Key Control Strategy
Passing through landslide-prone road segments	Landslides blocking or hitting vehicles/pedestrians	High	Weather warnings and route status, slope reinforcement & drainage, emergency evacuation SOP.
Passing through the climbing lane	Brake failure, uncontrolled rollback, skidding on steep slopes	High	Regular brake checks, low tire pressure warning lights, special uphill lanes, guardrails, safe stopping points.
Driving through narrow village roads	Collision with other vehicles, pedestrians, livestock	Medium–High	Convex mirrors at road bends, alternating traffic flow management, and "Caution: Pedestrians/Livestock" warning signs.
Access to gate 1 and 2	Limited visibility on curves and slopes	High	Convex mirrors at road bends, clear road markings, and speed control measures.
Special parking for motorcyclists	Limited visibility on curve into parking; slipping when turning	Medium	Convex mirrors at road bends, clearly marked parking lanes, non-slip flooring, and warning signs.
Walking from parking to entrance	Slipping, falling on slopes; fatigue in vulnerable visitors	Medium	Non-slip pedestrian pathways, safety guardrails, designated rest points at regular intervals, and education on appropriate footwear.

Table 5. Priority On-Site Hazards and Controls at Mudal River Ecotourism

Activities	Main Hazard Category	Risk Level	Key Control Strategy
Swimming in 1–2 m pools	Drowning, slipping on rocks, hitting bedrock	High	Mandatory life vests, lifeguards, restricted areas according to ability, depth markings & dangerous areas.
Crossing bamboo/wooden bridges	Slippery surface, structural failure/overload	Medium-High	Anti-slip coatings, regular inspections, structural reinforcement, capacity limits and signs.
Trails for hiking and walking	Slipping on wet or muddy paths, tripping, and steps that aren't level	Medium	Installation of handrails, protective fences on the slope side, path leveling, visual markings (yellow/red paint), non-slip footwear education.
Photographing at the edge of a cliff	Slipping/falling from height, strong winds pushing balance, camera falling	High	Safety fences, signs prohibiting approaching the edge, safe photo zones, officer supervision, education about dangerous areas, extreme weather warnings when access is closed.
Picnic near river and pools	Slipping into river, tripping, animal/insect bites	Medium	Riverside fences, picnic trail leveling, vector control (fogging), first aid kits &

Activities	Main Hazard Category	Risk Level	Key Control Strategy
			antivenom medication, safe position education.
Natural environment	Flash floods, landslides	High	Flood/landslide early warning system, evacuation routes and assembly points, area closures during heavy rain, disaster mitigation outreach.

DISCUSSION

This study identifies various significant potential hazards during the journey to the Mudal River and during tourist activities in the ecotourism area. The topography, which consists of uphill, winding roads that are prone to landslides, poses high risks such as vehicle skidding, brake failure, and travel delays due to landslide debris (20). Narrow village roads with potholed surfaces increase the likelihood of traffic accidents, especially for motorcyclists (21). In addition, parking areas and pedestrian paths pose a risk of slipping, and the fatigue experienced by tourists, especially vulnerable groups such as children and the elderly, adds to the complexity of the hazards that must be managed (22–24).

Figure 1. Landslide-Prone Area

Figure 2. Village Road Leading to MRE

Figure 3. Motorcycle Parking Area

Figure 4. Road eading to the MRE Entrance

Within the Mudal River Ecotourism area, various potential hazards were identified in tourist activities. The most dominant risks stem from physical factors, such as slipping on slippery rocks around the pools, drowning in areas deeper than 1.7 meters, being swept away by strong currents during high water flow, and falling from heights while taking photographs on cliff edges. Environmental threats also exist, including the possibility of falling trees injuring tourists, as well as slippery or collapsing bridges caused by overcapacity (25). Biological factors further increase vulnerability, such as insect bites, snakes, or other venomous animals that may cause allergies, infections, or poisoning, along with humid environmental conditions that can lead to minor health issues such as skin irritation. Equally important, hazards also arise from tourists' own behavior, including swimming without life jackets, jumping

from heights without supervision, taking selfies too close to cliff edges, and allowing children to play without parental guidance. Overall, these findings indicate that potential hazards within the Mudal River tourism area are a combination of natural, environmental, and behavioral factors, thus requiring a comprehensive risk control approach (26–28).

Figure 5. Swimming in the 2-meter Pool

Figure 6. Crossing the Bridge

Figure 7. Taking Pictures at the Edge of the Cliff

The results of this study support and reinforce the Safety Management System (SMS) framework that is widely used in international tourism risk management. SMS, as a comprehensive risk management model, emphasizes the need for hazard identification, systematic risk assessment, and the implementation of effective controls that must be carried out proactively (29). This study shows that the application of the HIRADC method at the Mudal River natural destination is in line with the core principles of Safety Management Systems (SMS) and Disaster Risk Reduction (DRR), because hazards are identified systematically, risks are prioritized, and control measures are implemented in a staged and documented way. Beyond its technical value, the integrated framework also speaks directly to tourist risk perception, as visible controls such as warning signs, life jackets, and safety briefings help shape visitors' subjective sense of safety and their willingness to comply with rules in a disaster-prone setting. At the same time, the combination of engineering controls, formal SOPs, and community-based monitoring reflects and reinforces an emerging institutional safety culture in which managers, local authorities, and residents collectively recognize safety as a shared responsibility rather than a purely individual concern of tourists. In this regard, HIRADC is not only a checklist-oriented assessment tool but a mechanism through which safety behavior and safety culture are gradually institutionalized within the everyday governance of nature-based tourism (27).

A comparison with international studies elucidates the distinctions and singular contributions of this research. For example, Gavurova and Polishchuk's study of adventure tourism in Europe shows how sensor technology and real-time monitoring can be used to lower risks. On the other hand, Rahman et al.'s study in Nusa Penida looks at community-based ways to reduce risks and teach visitors (30,31). Unlike these two studies, this research integrates two major frameworks, namely HIRADC and Disaster Risk Reduction (DRR), into a cohesive model that is directly applied to natural tourist destinations with very high hazard complexity. This integration demonstrates that technical aspects of risk management, particularly hazard mapping and prioritization based on HIRADC, can be operationalized not only within disaster-prone ecotourism settings but also functionally embedded within a broader tourism safety governance framework. Conceptually, the findings indicate that safety in nature-based tourism destinations constitutes a multidimensional governance issue in which infrastructure quality, regulatory frameworks, organizational capacity, and visitor behavior dynamically interact with underlying geological and

hydrometeorological hazards. The Sungai Mudal case illustrates that semi-quantitative tools such as HIRADC achieve greater analytical and practical value when explicitly aligned with disaster risk reduction principles, multi-stakeholder coordination mechanisms, and a phased implementation roadmap, rather than being applied as isolated technical checklists. From a theoretical perspective, these findings point toward an integrated tourism risk management model that bridges occupational safety approaches and disaster risk governance, positioning destinations as socio-technical systems and offering a transferable framework for other disaster-prone nature-based tourism areas where transportation, environmental, and activity-related risks converge (12,31,32).

The uniqueness of this research also lies in its application in the Mudal River Ecotourism area, which has high geological and hydrometeorological risks that have not been explored in detail in previous literature. The integration of the HIRADC framework with DRR not only increases the effectiveness of risk control but also fills the gap in theory and practice in the management of risks in nature-based tourist destinations in disaster-prone areas (33,34). The emphasis on multi-stakeholder collaboration and a mitigation approach that focuses not only on technical controls but also on education and community capacity building is an important contribution to the development of an adaptive and sustainable tourism risk management model, which can be used as a reference for similar destinations in Indonesia and internationally (35).

Risk Control Plan

Risk control for travel to the tourist site should be implemented through technical, administrative, and educational approaches. It is important to strengthen slopes that are likely to slide to stop natural disasters like landslides that could block access and put people's safety at risk. To lower the risk of landslides, you can build protective structures like gabions and retaining walls (36). To make this dangerous area safer for drivers, the roads should also be improved by fixing slippery and potholed surfaces and putting up warning signs and convex mirrors at sharp turns. It is very important for administrators to make Standard Operating Procedures (SOPs) for emergency evacuations so that rescue operations can be done quickly and in an organized way during disasters (37). Site managers usually work with the Regional Disaster Management Agency (BPBD) and other relevant organizations to give tourists regular updates on road and weather conditions. Furthermore, driver education plays a key role, including reminders to ensure vehicle roadworthiness and raising awareness about the importance of cautious driving when navigating hazardous routes (38,39).

Within the tourism area, risk control measures were developed by incorporating technical, administrative, educational, and biological aspects (40). From a technical point of view, putting up safety fences along the edges of pools and cliffs, making life jackets mandatory, and having lifeguards in water areas are all good ways to keep people from drowning and falling from heights. There were also safety nets put up in areas with strong currents. The bamboo bridges were also made better and had limits on how many people could use them at once to keep them from breaking and causing a lot of accidents. Managers enforced strict rules for water activities, like not letting kids jump from heights and keeping them out of dangerous areas (41). Tourists could learn about possible dangers and stay safe by reading the safety information boards. As part of the educational efforts, there were safety briefings before activities, "safety first" campaigns, and warning signs in high-risk areas (42). The involvement of local communities as informal overseers enhanced social monitoring, enabling swift responses to hazardous events. Biologically speaking, risk control measures included fogging and spraying insecticides to keep insects from spreading disease (43). Providing first-aid kits and anti-venom, as well as training staff to respond to medical emergencies, made the tourism area better prepared for accidents or medical emergencies. All of these efforts to control risk show that the HIRADC (Hazard Identification, Risk Assessment, and Determining Control) method has been used in a way that makes sure tourists are safe both on the way to the site and while they are doing things at the Mudal River natural tourism area in Kulon Progo Safety (44,45).

The following is the implementation of safety risk management for Mudal River tourism. There are three phases, which can be seen in Table 6.

Table 6. Implementation of Safety Risk Management for Mudal River Tourism

Fase	Risk Priority	Key Activities	Stakeholders	Implementation Time
Fase I	High Risk	Development of risk management SOPs; Training for managers and communities; Installation of warning signs	Local Government, Area Managers, Community, BPBD	0–6 Month
Fase II	Medium Risk	Repair of critical infrastructure; Installation of safety equipment; Socialization and education	Local Government, Managers, Tourism Office, Community	6–12 Month
Fase III	Evaluation and Improvement	Evaluation of risk control effectiveness; Strengthening of early warning systems; Strategy adjustments	Local Government, Managers, BPBD, Community	12–24 Month

This roadmap for implementing tourism safety risk management has been developed to provide strategic guidance on systematic and measurable risk management. The roadmap aims to identify priority risks that must be addressed immediately, determine the roles and responsibilities of stakeholders, and set a schedule for the implementation of activities in stages. With this approach, risk management is not general and sporadic, but planned and sustainable, so that the effectiveness of control can be optimized and the sustainability of tourist destinations can be maintained.

Recommendations for Future Research

This study advocates for subsequent research utilizing a longitudinal methodology to investigate the causal relationship between risks and accidents in natural tourism destinations like Sungai Mudal, and to enhance understanding of tourist behavior concerning adherence to risk mitigation strategies. Furthermore, expanding the context to other destinations with different characteristics and utilizing digital technologies such as early warning systems are suggested to strengthen preparedness against natural hazards. Future research ought to investigate stakeholder collaboration in risk management to enhance the effectiveness of integrated safety practices, thereby facilitating the development of more pertinent and comprehensive standards and guidelines.

CONCLUSION

This research identified several potential hazards that tourists may encounter en route to and during their visit to the Mudal River Ecotourism site in Kulon Progo, Yogyakarta. The HIRADC method for risk analysis showed that the most dangerous places were steep and winding terrain, areas that were likely to have landslides, and water-related activities that could lead to drowning or slipping in pools and rivers. Some suggested risk controls are technical ones, like building protective structures and fixing roads; administrative ones, like emergency evacuation SOPs; and educating visitors and keeping an eye on what they do by site managers and local people. The study emphasizes the necessity of a comprehensive risk mitigation plan to ensure tourist safety. This means doing things to avoid problems before and during visits to natural tourist spots that have built-in risks to the environment and nature. These ways of controlling risk are meant to cut down on accidents and make visitors feel safer at the site. Future research should concentrate on the creation of a continuous risk monitoring and evaluation system, along with the investigation of more effective educational strategies customized for various tourist demographics.

AUTHOR'S CONTRIBUTION STATEMENT

Andri Daeng Masiki was responsible for data collection, analysis, and manuscript drafting. Bambang Suhardi provided supervision, methodological validation, and conceptual input for the risk analysis. Pringgo Widyo Laksono offered technical guidance, reviewed the research findings, and contributed to the final

editing of the manuscript. All authors have read and approved the final version of this manuscript and made substantial contributions to the research and writing process.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest, financial or personal, that could influence the objectivity and integrity of this research.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors used several artificial intelligence (AI) and language-assistive technologies, including Perplexity, Grammarly, and DeepL, to improve grammar, clarity, and consistency throughout the manuscript. All generated or refined text was carefully reviewed, verified, and edited by the authors to ensure scientific accuracy, academic integrity, and originality of the work.

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