

Conceptual Model of Human Capacity for Coping with Potential Disasters Arising from Nickel Mining: A Case Study in Sulawesi

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ABSTRACT : Nickel mining has expanded rapidly in Indonesia, particularly in Sulawesi, generating significant economic opportunities while simultaneously creating environmental and socio-economic pressures for surrounding communities. This study aims to develop a conceptual model of human capacity for coping with potential disasters arising from nickel mining activities. A Conceptual Literature Review approach combined with Thematic Synthesis was employed to identify, examine, and integrate relevant concepts and findings from previous studies. The literature was organized around mining-related risks, hazards, exposure, sensitivity, community vulnerability, adaptive capacity, and community resilience. The synthesis identified four complementary dimensions of adaptive capacity: economic, social, information, and institutional capacity. The findings indicate that mining activities may generate or intensify socio-ecological hazards, while the resulting level of community risk is shaped by exposure, sensitivity, vulnerability, and adaptive capacity. Economic capacity provides material resources and livelihood security; social capacity facilitates trust, networks, solidarity, and collective action; information capacity enables risk recognition, communication, and decision-making; and institutional capacity provides coordination, organizational support, rules, and access to resources. These dimensions are integrated into a broader construct of human capacity, expressed through the ability to recognize, prepare, respond, adapt, recover, and learn. The proposed model positions human capacity as a critical mechanism linking vulnerability and community resilience. Its conceptual contribution lies in shifting the analytical focus from the impacts of mining on communities toward the capacity of individuals, households, and communities to manage risks generated or intensified by mining activities. The model provides a foundation for further empirical testing and for developing community-based disaster risk reduction strategies in nickel-mining regions.

KEYWORDS: *nickel mining; human capacity; community vulnerability; adaptive capacity; community resilience; disaster risk; Sulawesi.*

I. INTRODUCTION

The increasing demand for nickel as a raw material for stainless steel production and low-carbon energy technologies has driven the expansion of nickel mining across various regions of Indonesia. Sulawesi is one of the major nickel-producing regions and, at the same time, serves as a living space for communities whose livelihoods depend on agriculture, plantations, fisheries, and local natural resources. This situation creates a development dilemma because mining activities can provide economic benefits and infrastructure development while, at the same time, generating pressures on the environment and community livelihoods. The impacts on community well-being are also multidimensional, encompassing living standards, environmental quality, infrastructure, health, social cohesion, and education. Although improvements may occur in several aspects, particularly infrastructure and living standards, declining environmental well-being remains an important concern.

These findings indicate that nickel mining cannot be analyzed solely in terms of its contribution to economic growth. Mining is also a process of socio-ecological transformation that can alter environmental conditions, livelihood patterns, community access to resources, and social relationships. Consequently, communities living around mining areas may experience multiple and simultaneous pressures, including both environmental and socio-economic changes.

Environmental changes resulting from mining activities become increasingly important when viewed from a disaster-risk perspective. Vegetation clearing, land-use changes, the construction of mining roads, material transportation, alterations to drainage systems, sedimentation, and changes in water quality may increase community exposure to particular hazards. Under certain conditions, these pressures may contribute to flooding,

erosion, landslides, sedimentation of water bodies, pollution, and health disturbances. Therefore, disaster potential in mining areas needs to be understood more broadly than merely as a natural disaster phenomenon. Risk can emerge from the interaction among hazard, exposure, vulnerability, and capacity. Communities living close to sources of pressure but possessing high capacity may be able to reduce the resulting impacts, whereas communities with low capacity may experience greater impacts even when exposed to relatively similar pressures.

Hudayana et al. (2020), in their study in Bahodopi, Morowali, Central Sulawesi, demonstrated that mining-related problems may develop into social conflict. Their study found that environmental degradation and the appropriation of community land were factors contributing to conflicts between local communities and mining companies. The authors also emphasized the importance of trust, dialogue, community empowerment, and corporate social responsibility (CSR) in preventing conflict escalation. These findings are important because they demonstrate that mining risks are multidimensional. Risks do not end with environmental degradation but may extend to the loss of access to resources, disruption of livelihoods, conflict, and weakened relationships among communities, government, and companies. Therefore, community capacity should be positioned as a key component of risk management.

The impacts of mining on communities are also associated with their ability to obtain economic benefits and sustain their livelihoods. Nasution et al. (2024) through research conducted in Pomalaa, Kolaka Regency, Southeast Sulawesi, found that the expansion of nickel mining was associated with the marginalization of the Bajo community. Three major issues were identified: water pollution, limited alternative livelihood opportunities, and weak community bargaining power in decision-making processes. Nasution et al. (2024) findings demonstrate that communities do not experience risks uniformly. Groups with high dependence on natural resources, limited economic access, and weak institutional positions tend to have higher levels of vulnerability. Therefore, disaster-risk analysis in mining areas needs to incorporate the socio-economic characteristics of communities as part of the process through which risk is formed.

Zainuddin Rela et al. (2021) also demonstrated that farming communities surrounding nickel mining areas in Southeast Sulawesi face sustainability challenges associated with economic conditions, the environment, social capital, community competence, and information and communication. Their study developed a farming community resilience model based on data from 295 respondents across 10 villages located near nickel mining industries. Thus, local literature demonstrates that the vulnerability of communities surrounding mining areas is not caused solely by the presence of hazards but is also influenced by communities' ability to access resources, information, social networks, alternative livelihoods, and decision-making processes. In disaster studies, attention is no longer focused solely on hazard identification but also on the capacity of communities to anticipate, respond to, adapt to, and recover from disturbances. Norris et al. (2008) conceptualized community resilience as a process linking networks of adaptive capacities with the ability of communities to adapt following disturbances or adversity. This framework identifies economic capacity, social capital, information and communication, and community competence as important elements in building resilience.

This perspective provides a basis for understanding that a resilient community is not necessarily a community that does not experience impacts, but rather one that possesses the ability to manage impacts and adapt to change. In the context of nickel mining, this concept is particularly relevant because communities may experience pressures that develop gradually and repeatedly rather than only sudden-onset disasters. Zainuddin Rela, et al. (2020) specifically examined the relationship between CSR and community resilience among communities surrounding nickel mining areas in Southeast Sulawesi. Using PLS-SEM, the study found that CSR had a positive and significant relationship with community resilience, particularly through collective efficacy, community action, and community adaptation.

These findings indicate that community capacity can be strengthened through social and institutional interventions. However, the study primarily positioned resilience at the community level, while human capacity as a more specific unit of capacity was not the main focus. Human capacity constitutes an important foundation for building the ability to cope with risk. In a disaster context, individuals need to be able to recognize hazards, understand risk information, make decisions, undertake protective actions, and assist vulnerable family or community members. Therefore, human capacity cannot be reduced merely to formal education or knowledge. In this study, human capacity can be understood as the ability of individuals to utilize knowledge, skills, health, experience, information, and response capabilities in dealing with potential disturbances or disasters. This concept is closely related to *adaptive capacity*, but provides a more specific focus on human beings as actors. Sutrisno et al. (2024) demonstrated that community adaptive capacity in mining areas can be understood through five important components: assets, flexibility, organization, learning, and agency. Their study emphasized that communities surrounding mining areas need the ability to adjust to changes and develop more sustainable livelihood strategies.

Accordingly, human capacity in this study does not exist in isolation. Individual capacity needs to be viewed as part of a broader system comprising households, communities, local institutions, government, and companies. Individuals who possess knowledge of risks but lack access to information, social networks, or institutional support may nevertheless face difficulties in undertaking adaptive actions.

Based on this literature, the relationship between mining activities and community resilience can be understood as complex rather than linear. Mining activities may generate pressures or hazards; these hazards interact with the level of community exposure and sensitivity; subsequently, the impacts experienced are strongly influenced by community capacity. The position of human capacity within this chain is therefore important because two communities facing relatively similar mining pressures may experience different levels of impact if their capacities differ. Although research on nickel mining and communities in Sulawesi has developed considerably, several research gaps remain. First, studies of nickel mining in Sulawesi have predominantly examined environmental change, well-being, conflict, marginalization, and CSR, as demonstrated Pambudi, P. A. (2025), Hudayana et al. (2020), Nasution et al. (2024), and Zainuddin Rela et al. (2021). Second, research on resilience among mining-affected communities has identified dimensions including economic capacity, social capital, community competence, information, communication, adaptation, and institutional capacity. Zainuddin Rela et al. (2021), for example, developed a resilience model for farming communities surrounding nickel mining areas in Southeast Sulawesi, while Sutrisno et al. (2023) developed an *adaptive capacity* framework for communities in mining areas. Third, research explicitly integrating disaster potential arising from mining pressures, vulnerability, and the importance of human capacity to cope with disasters within a single conceptual model remains limited, particularly for communities living in nickel mining areas in Sulawesi.

Accordingly, this study seeks to address this gap by developing a Human Capacity Model for Coping with Potential Disasters Arising from Nickel Mining. The model positions people not merely as objects affected by mining activities, but as active agents who possess the capacity to recognize risks, make decisions, respond to disturbances, adapt to changing conditions, and contribute to the development of resilient communities.

II. LITERATURE REVIEW

2.1 Nickel Mining and Potential Disaster Risks

Nickel mining in Indonesia has distinctive characteristics because most nickel resources occur as laterite deposits located relatively close to the surface and are therefore predominantly extracted through open-pit mining. This extraction method requires extensive land clearing and landscape transformation, including vegetation removal, topsoil stripping, ore excavation, haul-road construction, material stockpiling, and the development of processing and refining facilities. The rapid growth of nickel demand associated with the energy transition and battery industries has accelerated mining and processing expansion, generating substantial environmental pressures. Studies by Agusdinata et al. and Heijlen and Duhayon indicate that nickel extraction can produce significant land-use change, while Nasution, et al. (2026) found extensive forest transformation and carbon losses across nickel concessions in Indonesia. These changes may alter ecological functions through increased surface runoff, erosion, sedimentation, hydrological disturbance, habitat degradation, and pressure on water resources. Consequently, mining-related risks originate not only from extraction activities themselves but also from landscape transformation that can create or intensify pathways for environmental hazards.

The environmental pressures generated by nickel mining interact with socio-economic changes, making mining risk a multidimensional socio-ecological phenomenon. Lo et al. (2024), based on an analysis of 7,721 villages in Sulawesi, found that nickel-mining villages experienced substantially higher deforestation while showing mixed outcomes in community well-being. Some dimensions, including infrastructure, health, and social relationships, may improve, whereas environmental well-being and, in some contexts, living standards and education may deteriorate. Warburton (2024) similarly characterizes Indonesia's nickel-based growth as having enclave-like features, in which economic benefits may be unevenly distributed while social and environmental costs are disproportionately borne by surrounding communities. At the local level, dependence on mining can create new income and employment opportunities but may simultaneously increase vulnerability by reducing livelihood diversification and increasing dependence on a single economic sector. Communities located close to mining operations, dependent on affected agricultural land, fisheries, or natural resources, and possessing limited assets and livelihood alternatives are therefore likely to experience greater exposure and sensitivity to mining-related disturbances.

From a disaster-risk perspective, nickel mining does not automatically produce disasters, but it can contribute to the formation and amplification of risk through the interaction of hazard, exposure, and vulnerability, while the resulting impacts are strongly influenced by community adaptive capacity. Potential hazards include slope instability and landslides, erosion and sedimentation, flooding and altered runoff, soil and water contamination, coastal ecosystem degradation, pollution-related health disturbances, industrial accidents, and social conflict associated with land-use change and unequal benefit distribution. The severity of these impacts varies according to community exposure, sensitivity, and capacity. Communities with limited economic assets, weak livelihood

diversification, inadequate access to information, limited organizational capacity, and weak institutional support may face greater difficulties in anticipating, responding to, and recovering from disturbances. Conversely, communities with stronger economic assets, social networks, information access, organizational capacity, and institutional support are better positioned to reduce impacts and recover more rapidly. Thus, human capacity becomes a critical determinant of whether mining-related pressures develop into greater vulnerability or can instead be managed through anticipation, response, adaptation, and recovery.

2.2 Concept of Community Vulnerability

Community vulnerability in disaster studies refers not merely to the degree to which a population is exposed to a hazard, but to the social, economic, environmental, physical, and institutional conditions that determine the extent to which people are likely to experience harm. The Pressure and Release (PAR) model developed by Rufat (2024) conceptualizes disasters as the intersection between hazards and vulnerability, with vulnerability being progressively produced through *root causes*, *dynamic pressures*, and *unsafe conditions*. From this perspective, vulnerability is not an inherent characteristic of a community but is socially constructed through unequal access to resources, assets, information, livelihood opportunities, and decision-making processes. Similarly, Cutter's (1996) *hazards-of-place* perspective emphasizes that vulnerability emerges from the interaction between biophysical hazards and the social characteristics of a particular place. Cutter et al. (2003) further demonstrate that social vulnerability varies according to demographic, socioeconomic, and contextual conditions, while Adger (2006) emphasizes that vulnerability is closely associated with exposure, sensitivity, and the capacity of individuals and communities to cope with environmental change. Synthesizing these perspectives, community vulnerability in this study is understood as the propensity of communities to experience adverse consequences from hazards as a result of their exposure, sensitivity, socioeconomic conditions, resource dependence, and limited capacity to anticipate, respond to, adapt to, and recover from disturbances.

In the context of potential disasters associated with nickel mining, community vulnerability needs to be understood as a socio-ecological process rather than simply as exposure to mining hazards. Land clearing, vegetation loss, erosion, sedimentation, altered drainage, water pollution, loss of productive land, livelihood transformation, and increasing economic dependence on mining may simultaneously increase community exposure and sensitivity. Mining-related disturbances may therefore amplify existing vulnerabilities, particularly among households whose livelihoods depend heavily on agriculture, fisheries, forests, or other natural resources. Research in mining-affected communities also demonstrates that environmental degradation, land appropriation, unequal distribution of benefits, and weak community bargaining power can generate social and economic vulnerabilities and, in some cases, contribute to social conflict. In the author's synthesis, vulnerability in nickel-mining areas is therefore the result of the interaction between mining-induced hazards, community exposure and sensitivity, and the capacity of people and institutions to cope with those pressures. Two communities facing similar mining pressures may consequently experience very different levels of risk because of differences in economic assets, livelihood diversification, social networks, knowledge and risk information, organizational capacity, and institutional support. This perspective is particularly important for the development of the Human Capacity Model, because low human and institutional capacity can transform environmental and socio-economic pressures into greater vulnerability, whereas stronger capacity can reduce exposure, strengthen adaptation, and facilitate recovery.

2.3. Concept of Community Resilience

The concept of community resilience has evolved from an initial emphasis on resistance to hazards toward a broader understanding of the capacity of communities to anticipate, absorb, cope with, adapt to, and recover from disturbances. One of the influential conceptualizations was proposed by Norris et al. (2008), who define community resilience as a process linking a network of adaptive capacities to successful adaptation following adversity. Their framework identifies four major resources of community resilience: economic development, social capital, information and communication, and community competence. Similarly, Magis (2010) conceptualizes community resilience as the collective capacity of a defined community to respond to, influence, and recover from change, emphasizing participation, collective action, and community resources. Cutter et al. (2008), through the *Disaster Resilience of Place (DROP)* model, further emphasize that resilience is shaped by the interaction between social vulnerability, exposure, environmental conditions, and the capacity of communities to prepare for and recover from hazards. More recent resilience research also highlights that resilience is not simply the ability to return to a previous condition (*bounce back*), but may involve learning, transformation, and the development of new capacities to cope with future disturbances. Thus, based on these theoretical perspectives, community resilience in this study is understood as the collective capacity of a community to anticipate risks, mobilize resources, respond to disturbances, adapt to changing conditions, learn from experience, and recover while maintaining or improving essential social, economic, and environmental functions.

Community resilience becomes particularly important because mining-related disturbances may be gradual, cumulative, and recurrent rather than limited to sudden-onset disasters. Changes in land cover, water systems, livelihoods, environmental quality, and local economic structures may progressively affect community well-being and create new forms of vulnerability. Empirical research in nickel-mining areas of Southeast Sulawesi provides evidence that community resilience is associated with economic conditions, social capital, community competence, information and communication, and adaptive capacity. Rela et al. (2020), for example, found a positive relationship between CSR interventions and community resilience among communities surrounding nickel mining, particularly through collective efficacy, community action, and community adaptation. Rela et al. (2021) further developed a farming community resilience model in nickel-mining areas, demonstrating the importance of economic, environmental, social, competency, and information-related dimensions, while Sutrisno et al. (2023) emphasized assets, flexibility, organization, learning, and agency as important components of adaptive capacity in mining-affected communities. In the author's synthesis, community resilience in nickel-mining areas should therefore be positioned as the mechanism that connects vulnerability with human capacity. Mining pressures may increase hazards, exposure, and sensitivity, but their consequences depend partly on whether communities possess sufficient human knowledge and skills, economic resources, social networks, information, organizational capacity, and institutional support to anticipate, respond, adapt, and recover. Consequently, the proposed Human Capacity Model should not treat resilience as merely an outcome, but as a dynamic process through which individual capacities are mobilized into collective action and strengthened into community-level resilience.

2.4. Concept of Economic Capacity

Economic capacity refers to the ability of individuals, households, and communities to access, manage, mobilize, and diversify economic resources to meet basic needs, cope with shocks, and sustain livelihoods during periods of disturbance. In disaster and resilience literature, economic resources are considered a fundamental component of adaptive capacity because households with adequate assets, savings, income sources, employment opportunities, and access to financial institutions generally have greater ability to absorb losses and recover from shocks. The Sustainable Livelihoods Framework developed by Chambers and Conway (1992) and further operationalized by the Department for International Development (DFID, 1999) emphasizes the importance of livelihood assets—including financial, physical, human, social, and natural capital—in enabling households to develop sustainable livelihood strategies. Similarly, Norris et al. (2008) place economic development among the core resources of community resilience, arguing that economic resources influence the ability of communities to mobilize resources and respond collectively to adversity. Adger (2000) further highlights the relationship between economic and social resources in building resilience, while Cutter et al. (2008) demonstrate that economic conditions are an important component of place-based disaster resilience. Based on this literature, economic capacity in this study is conceptualized as the ability of individuals, households, and communities to mobilize economic assets, maintain income and livelihoods, diversify economic activities, access financial resources, and absorb economic losses resulting from disturbances.

In the context of potential disasters associated with nickel mining, economic capacity becomes particularly important because mining can simultaneously create economic opportunities and generate new forms of economic vulnerability. Mining may increase employment, wages, business opportunities, infrastructure, and local economic activity; however, excessive dependence on mining can reduce livelihood diversification and increase sensitivity to changes in commodity prices, employment opportunities, industrial policies, environmental degradation, or disruptions to mining operations. Communities whose livelihoods depend heavily on agriculture, fisheries, plantations, or other natural resources may also experience economic losses when mining-related land-use changes, water pollution, sedimentation, or environmental degradation affect productive resources. From the perspective of community resilience, therefore, economic capacity should not be measured only by income level, but also by the ability to maintain and diversify livelihoods, possess productive assets and savings, access credit and financial services, and mobilize alternative sources of income during disturbances. In the author's synthesis, economic capacity functions as an important buffer between mining-related hazards and community vulnerability: stronger economic capacity enables households to absorb losses, maintain consumption, seek alternative livelihoods, and recover more rapidly, whereas weak economic capacity can intensify vulnerability and constrain adaptive action. This position is particularly relevant to the proposed Human Capacity Model, because economic resources provide the material foundation that enables individuals and communities to convert knowledge, skills, information, and social networks into effective responses to potential disasters.

2.5 Konsep Kapasitas Sosial

Social capacity refers to the ability of individuals and communities to build and mobilize social relationships, trust, networks, cooperation, collective action, and mutual support to cope with disturbances and pursue common interests. In disaster and resilience theory, social capacity is closely associated with the concept of social capital. Adger (2003) argues that social capital and collective action can strengthen communities' ability to respond to environmental change by facilitating cooperation and access to resources. Similarly, Norris et al. (2008) position social capital as one of the fundamental adaptive resources of community resilience because social networks enable communities to exchange resources, provide mutual assistance, and organize collective responses during crises. Putnam (2000) distinguishes social capital into bonding, bridging, and linking relationships, which provide different forms of social connectivity and access to resources. Aldrich and Meyer (2015) further demonstrate that social networks, trust, civic engagement, and community organizations can significantly influence disaster preparedness, response, and recovery. Based on these theoretical perspectives, social capacity in this study is conceptualized as the ability of individuals and communities to establish trust, maintain social networks, cooperate, mobilize collective action, provide mutual assistance, and connect with external institutions and resources in responding to risks and disturbances.

In the context of potential disasters associated with nickel mining, social capacity becomes particularly important because mining-related risks can affect not only individual households but also shared resources, livelihoods, social relationships, and community interests. Environmental degradation, land-use changes, livelihood disruption, unequal distribution of mining benefits, and disputes over access to natural resources may weaken social cohesion and generate conflict. Conversely, strong social networks and collective organization can enable communities to share information, identify emerging risks, negotiate with mining companies and government institutions, mobilize assistance, and undertake collective responses. Research on extractive industries also indicates that trust, dialogue, community participation, and collective action are important in managing tensions between communities and mining companies. In the author's synthesis, social capacity represents the collective dimension of human capacity that transforms individual abilities into coordinated community action. A community may have knowledgeable individuals, economic resources, and access to information, but without trust, cooperation, social networks, and collective organization, these resources may not be effectively mobilized during a disturbance. Therefore, within the proposed Human Capacity Model, social capacity functions as a mechanism that strengthens community preparedness, collective response, adaptation, and recovery, while simultaneously reducing the likelihood that mining-related environmental and socio-economic pressures will develop into deeper social vulnerability and conflict.

2.6 Concept of Information Capacity

Information capacity refers to the ability of individuals and communities to access, understand, evaluate, communicate, and use relevant information for decision-making and risk management. In disaster and resilience literature, information and communication are not merely supporting resources but constitute fundamental components of community capacity. Norris et al. (2008) identify information and communication as one of the four major adaptive capacities underlying community resilience, emphasizing that communities require accurate information, effective communication networks, and the ability to transform information into collective action. Cutter et al. (2008), through the *Disaster Resilience of Place (DROP)* model, similarly position access to information and institutional resources as important determinants of resilience. Meanwhile, Paton and Johnston (2001) argue that effective disaster preparedness depends partly on people's access to hazard information, their understanding of risk, and their ability to translate knowledge into preparedness behavior. Information capacity therefore extends beyond the availability of information; it includes the ability to obtain timely and reliable information, understand its meaning, assess its credibility, communicate it within social networks, and use it to make appropriate decisions. Based on this literature, information capacity in this study is conceptualized as the ability of individuals and communities to access, understand, verify, exchange, and utilize risk-related information to anticipate hazards, make decisions, undertake appropriate responses, and support adaptation and recovery.

In the context of potential disasters associated with nickel mining, information capacity becomes particularly important because mining-related risks can be complex, cumulative, and difficult for communities to recognize without adequate information. Changes in water quality, land stability, sedimentation, pollution, transportation risks, industrial activities, and environmental management may not immediately be perceived as disaster risks by local residents. Communities therefore need access to information regarding potential hazards, environmental changes, emergency procedures, early warnings, evacuation routes, health risks, and the responsibilities of companies and government institutions. However, information capacity also concerns information asymmetry between communities, mining companies, and government institutions. When communities have limited access to environmental monitoring results, risk assessments, complaint mechanisms, or decision-making processes, their ability to anticipate and respond to disturbances may be weakened. In the author's synthesis, information capacity functions as a critical bridge between knowledge and action.

Information only becomes a community capacity when people are able to understand it, trust it, communicate it, and use it to make decisions. Thus, within the proposed Human Capacity Model, information capacity can reduce vulnerability by strengthening risk awareness, preparedness, early response, collective decision-making, and adaptive learning. Communities with strong information capacity are more likely to recognize emerging risks and mobilize appropriate responses, whereas information deficits can increase uncertainty, delay response, and reinforce dependence on external actors.

2.7. Concept of Institutional Capacity

Institutional capacity refers to the ability of institutions to establish rules, coordinate actors, mobilize resources, implement policies, provide services, and make collective decisions to address risks and support community adaptation. In disaster and resilience literature, institutional capacity is considered an important component of adaptive capacity because effective institutions provide the governance arrangements through which knowledge, resources, authority, and collective action can be mobilized. Berkes and Folke (1998) demonstrate that effective environmental management depends on interactions between social institutions, local knowledge, and ecological systems. Norris et al. (2008) further place organizational resources and community competence within the broader adaptive-capacity framework, while Cutter et al. (2008) argue that institutional and community resources influence the capacity of places to prepare for, respond to, and recover from disasters. More specifically, Folke et al. (2005) highlight the importance of adaptive governance, learning, collaboration, and institutional flexibility in managing complex socio-ecological change. Based on these perspectives, institutional capacity in this study is conceptualized as the ability of local institutions, government, community organizations, and other relevant actors to coordinate resources, establish effective rules, provide risk-related services, facilitate participation, implement risk-management measures, and support collective adaptation and recovery.

In the context of potential disasters associated with nickel mining, institutional capacity is particularly important because mining-related risks involve multiple actors and cannot be managed effectively by households or communities alone. Government institutions, village organizations, mining companies, community groups, and other stakeholders have different responsibilities, resources, authorities, and interests in managing environmental and social risks. Weak coordination, limited community participation, inadequate enforcement, poor access to environmental information, and unclear institutional responsibilities can increase community vulnerability, particularly when mining activities affect land, water resources, livelihoods, and public health. Conversely, institutions that are responsive, transparent, participatory, coordinated, and capable of enforcing rules can strengthen community preparedness and reduce the escalation of mining-related pressures into disaster risks. In the author's synthesis, institutional capacity represents the governance dimension of human and community capacity: it provides the enabling environment through which individual knowledge, economic resources, social networks, and information can be transformed into effective collective action. Thus, within the proposed Human Capacity Model, institutional capacity should be viewed not merely as the presence of formal organizations, but as the actual ability of institutions to coordinate, communicate, facilitate participation, mobilize resources, enforce regulations, resolve conflicts, and support communities before, during, and after mining-related disturbances.

III. METHODOLOGY

This study employs a Conceptual Literature Review approach using the Thematic Synthesis method to identify, examine, and integrate concepts and findings from previous studies relevant to the risks associated with nickel mining activities and community capacity to cope with potential disasters. The literature was reviewed based on several major themes, including mining activities and hazards, exposure, sensitivity, vulnerability, adaptive capacity, and community resilience. Subsequently, literature related to *adaptive capacity* was analyzed and classified into four main dimensions: economic capacity, social capacity, information capacity, and institutional capacity.

The results of the *thematic synthesis* were subsequently used to undertake conceptual integration in developing the Human Capacity Model. The model explains that nickel mining activities can generate various socio-ecological pressures or *hazards* that interact with community *exposure* and *sensitivity*, thereby contributing to community vulnerability. The ability of communities to cope with these conditions is determined by their *adaptive capacity*, which is derived from economic, social, information, and institutional capacities. These four capacities are subsequently integrated into the concept of human capacity, manifested through the community's ability to recognize, prepare, respond, adapt, recover, and learn, thereby supporting the development of *community resilience*. Thus, *thematic synthesis* is used to identify themes and patterns of relationships across the literature, while the Conceptual Literature Review provides the basis for establishing relationships among the concepts and developing the proposed conceptual model.

IV. RESULTS AND DISCUSSION

4.1. Results of Thematic Synthesis

The results of the literature review indicate that risks associated with nickel mining activities constitute a multidimensional and socio-ecological phenomenon. The impacts of mining are not limited to the emergence of environmental hazards, but are also influenced by the levels of exposure and sensitivity, as well as by the capacity of communities to anticipate and cope with change. Based on the thematic synthesis process, the reviewed literature was subsequently classified into several major themes, including mining-related risks, hazard, exposure, sensitivity, vulnerability, adaptive capacity, and community resilience, as well as four dimensions of community capacity: economic, social, information, and institutional capacity. This thematic classification was used to identify patterns of relationships among the concepts and to determine the position of each concept in explaining the ability of communities to cope with potential disasters.

The synthesis further indicates that these four capacity dimensions do not operate independently but complement one another in constituting human capacity. Economic capacity provides material resources and livelihood support; social capacity strengthens networks, solidarity, and collective action; information capacity facilitates risk recognition, interpretation, and decision-making; while institutional capacity provides organizational structures, coordination mechanisms, rules, and access to resources. The integration of these four dimensions generates the ability of communities to recognize, prepare, respond, adapt, recover, and learn, which subsequently provides the foundation for the development of community resilience. The results of the thematic synthesis and the resulting conceptual integration are presented in the following table.

Table 1. Main Thema of Findings from the Literature

No.	Main Theme	Identified Concepts/Sub-themes	Key Findings from the Literature	Position in the Model
1	Nickel Mining Risks	Mining activities, land-cover change, environmental degradation, socio-economic changes	Nickel mining can increase pressure on forests, the environment, and community livelihoods, while its effects on well-being may vary across regions and population groups (Lo et al., 2024; Heijlen & Duhayon, 2024).	Mining Activities, Hazard
2	Socio-Ecological Hazards/Pressures	Landslides, water/air pollution, sedimentation, biodiversity loss, environmental changes	Landscape and environmental changes resulting from nickel extraction can create or intensify ecological and social pressures.	Hazard
3	Exposure	Settlements, agricultural land, water resources, infrastructure, livelihoods	Risk is determined not only by the existence of hazards but also by the presence of people, assets, and livelihood activities in potentially affected areas.	Hazard, Exposure
4	Sensitivity	Health, dependence on natural resources, socio-economic conditions, vulnerable groups	The impacts on communities vary according to their social, economic, health, and dependence on local resources.	Exposure, Sensitivity, Vulnerability
5	Community Vulnerability	Social vulnerability, livelihood vulnerability, exposure, sensitivity, adaptive capacity	Vulnerability is a multidimensional condition shaped by the interaction of exposure, sensitivity, and the capacity to adapt (Smith & Diedrich, 2024; Nef et al., 2023).	Community Vulnerability
6	Adaptive Capacity	Ability to cope with change, access to resources, adaptation strategies, learning	Adaptive capacity determines the ability of communities to reduce impacts, adjust to changing conditions, and maintain essential livelihood functions.	Vulnerability, Adaptive Capacity
7	Economic Capacity	Savings, emergency funds, productive assets, livelihood diversification, alternative income, access	<i>Livelihood assets</i> contribute to the ability of communities to cope with shocks. Resilience does not depend solely on	Economic Capacity

No.	Main Theme	Identified Concepts/Sub-themes	Key Findings from the Literature	Position in the Model
		to assistance/insurance	financial capital but on a combination of different assets (Prayitno et al., 2025; Ma et al., 2024).	
8	Social Capacity	Trust, social networks, solidarity, reciprocity, mutual assistance, collective action	Social capital supports <i>preparedness, social learning, information sharing</i> , and <i>collective action</i> , while also helping vulnerable groups (Zhao et al., 2024; Sobhaninia, 2024).	Social Capacity
9	Information Capacity	Early warning, risk knowledge, communication access, information literacy, information dissemination	Effective early-warning systems require risk knowledge, monitoring, communication, dissemination, and response capacity (Haque et al., 2024). Trustworthy communication strengthens resilience (Vandrevala et al., 2024).	Information Capacity
10	Institutional Capacity	Leadership, organization, SOPs, contingency planning, coordination, participation, institutional learning	Institutional capacity, cross-level collaboration, institutional learning, and <i>bridging organizations</i> strengthen community capacity to cope with disasters (Choudhury et al., 2021; Alcántara-Ayala et al., 2025).	Institutional Capacity
11	Human Capacity	Resource mobilization, decision-making, action, adaptation, recovery, learning	The four capacities—economic, social, information, and institutional—perform different but complementary functions in shaping community capacity.	Adaptive Capacity; Human Capacity
12	Recognize	Recognizing hazards, understanding risks, identifying vulnerable groups and assets	Risk knowledge and access to information provide the foundation for preparedness and risk-related decision-making.	Human Capacity; Recognize
13	Prepare	Preparedness, planning, resources, evacuation routes, warning systems	Preparedness requires a combination of information, economic resources, social networks, and institutional support.	Human Capacity; Prepare
14	Respond	Rapid action, evacuation, communication, assistance, coordination	Effective response requires timely information, social networks, resources, and institutional coordination.	Human Capacity; Respond
15	Adapt	Livelihood diversification, strategy adjustment, innovation, behavioral adjustment	Adaptation represents the ability to adjust livelihood strategies and behaviors in response to changing conditions and pressures.	Human Capacity; Adapt
16	Recover	Recovery of assets, income, services, and social life	Resilience includes the ability to absorb disturbances and restore essential livelihood and social functions following disruption (Norris et al., 2008; Güngör & Elburz, 2024).	Human Capacity; Recover
17	Learn	Social learning, institutional learning, evaluation, experience, innovation	Social and institutional learning strengthens the ability to cope with subsequent risks and disturbances (Choudhury et al.,	Human Capacity; Learn

No.	Main Theme	Identified Concepts/Sub-themes	Key Findings from the Literature	Position in the Model
			2021).	
18	Community Resilience	Absorb, respond, adapt, recover, transform/learn	<i>Community resilience</i> represents the dynamic capacity of communities to cope with disturbances, adapt, recover, and develop through learning and transformation (Norris et al., 2008; Güngör & Elburz, 2024).	Human Capacit; Community Resilience

Source: Author's synthesis based on the reviewed literature.

4.2. Development of the Human Capacity Concept for Coping with Disasters Arising from Mining Risks

The literature synthesis on nickel mining, vulnerability, and *community resilience* indicates that the risks faced by communities constitute a multidimensional socio-ecological phenomenon rather than merely a direct consequence of physical hazards. Villages in Sulawesi, demonstrated that nickel mining expansion was associated with increased deforestation and produced mixed outcomes in community well-being. Improvements in certain dimensions of living standards occurred alongside declining environmental well-being, while biophysical and socio-demographic characteristics moderated these outcomes. These findings provide a basis for arguing that a *hazard* does not automatically produce the same level of risk, because its consequences are shaped by *exposure*, *sensitivity*, and community adaptive capacity. In the development of *community resilience* literature, Güngör and Elburz (2024), through a systematic review of 47 articles identified from Scopus, Web of Science, and Google Scholar, found that social, economic, physical, and community capital were among the most commonly used dimensions for explaining and measuring community resilience. Accordingly, the seven concepts discussed in this study mining risk, community vulnerability, community resilience, sustainable livelihoods, social capital, information and communication capacity, and institutional capacity/community competence can be positioned within a single theoretical pathway. Mining activities create or intensify environmental and socio-economic pressures; these pressures generate *exposure* and *sensitivity*; and the level of *adaptive capacity* subsequently determines the extent to which communities can reduce or manage their impacts. From this perspective, communities are not positioned as passive recipients of mining impacts, but as social actors possessing the ability to anticipate, absorb, respond to, adapt to, and recover from disturbances.

The literature synthesis further indicates that community *adaptive capacity* is constructed through multiple and complementary forms of resources. From the perspective of the Sustainable Livelihoods Framework, the ability to cope with shocks cannot be adequately explained by income alone, but rather by the combination of livelihood assets and the ability of households to transform these assets into livelihood strategies. Prayitno et al. (2025), based on 372 households in Indonesia, found that *human*, *natural*, *physical*, and *social capital* had strong and positive effects on *adaptive capacity*, whereas *financial capital* did not demonstrate a significant effect when considered independently. This finding reinforces the argument that resilience is not built upon a single type of resource but through the combination of multiple livelihood assets. From the perspective of Social Capital Theory, Zhao et al., through a systematic review of 24 studies, found that social capital strengthens *community disaster resilience* through social learning, collective action, disaster preparedness, information communication, and civic responsibility. Thus, *trust*, *networks*, *solidarity*, *reciprocity*, and *collective action* constitute mechanisms through which social resources can be converted into collective action. Information capacity, meanwhile, enables communities to acquire risk knowledge and transform it into decisions., indicating that information becomes valuable only when it can be received, understood, and translated into action. The systematic review by Vandrevale et al. (2024) also identified a strong relationship between emergency communication and *community resilience*, particularly through trust-building and collaboration, identification and distribution of resources, context-appropriate communication strategies, community engagement, and community feedback. Institutional capacity, in turn, provides the mechanisms for organizing and mobilizing these resources. Choudhury et al. (2021) demonstrated that local institutional capacity, multilevel institutional collaboration, and institutional learning are important prerequisites for strengthening community resilience. Cross-level learning and the presence of *bridging organizations* can further enable local experiences to be translated into improvements in governance. Collectively, these findings demonstrate that human capacity is integrative: economic capacity provides material resources, social capacity provides relational resources, information capacity provides knowledge for decision-making, while institutional capacity provides organizational mechanisms for transforming these resources into action. These dimensions do not operate linearly but constitute an interconnected capacity system in which each dimension can reinforce the others.

Based on this synthesis, this study proposes the concept of “Human Capacity for Coping with Disasters Arising from Mining-Related Risks” as a conceptual construct that bridges the *vulnerability approach* and the *community resilience approach*. Human capacity is defined as the ability of individuals, households, and

communities to recognize risks, mobilize resources, access and utilize information, build social relationships, make decisions, organize collective action, and adapt to and recover from potential disasters associated with mining activities. This concept does not equate human capacity with individual capacity alone. Rather, human capacity is understood as a multilevel capacity consisting of economic, social, information, and institutional capacities, which operate together to constitute *adaptive capacity* and ultimately contribute to *community resilience*. This perspective is consistent with the development of resilience literature, which conceptualizes resilience as a dynamic capability rather than a fixed condition. *Community resilience* encompasses the ability to withstand, adapt to, and recover from disturbances, while community resources and institutions shape how these processes occur. The conceptual contribution of this study lies in shifting the analytical focus from “the impacts of mining on communities” toward “the capacity of people and communities to manage risks generated or intensified by mining activities.” Within this framework, a resilient community does not mean a community that experiences no impacts; rather, it is a community capable of anticipating risks before disturbances occur, absorbing impacts when disturbances occur, responding effectively, adapting to changing conditions, restoring essential livelihood and social functions, and learning from experience to better manage subsequent risks.



Figure 1. Conceptual Model Of Human Capacity For Coping With Potential Disasters Arising From Nickel Mining

V. CONCLUSION

1. Nickel mining-related disaster risks are multidimensional socio-ecological processes shaped by the interaction of hazards, exposure, sensitivity, and vulnerability. Mining activities can intensify environmental pressures and disrupt local livelihoods and socio-economic relationships. Consequently, community risk levels vary according to differences in resources, livelihood dependence, social networks, information access, and institutional support.
2. This study proposes Human Capacity for Coping with Potential Disasters Arising from Nickel Mining as a conceptual bridge between vulnerability and community resilience. Human capacity comprises four interconnected dimensions: economic, social, information, and institutional capacity. Together, these dimensions strengthen adaptive capacity, enabling communities to recognize risks, prepare, respond, adapt, recover, and learn from mining-related disturbances.

3. The model shifts the research focus from merely examining *the impacts of nickel mining on communities* to understanding *how people and communities manage mining-related risks*. A resilient community is therefore one that can anticipate risks, respond collectively, adapt livelihoods, recover essential functions, and learn from past experiences. This model provides a conceptual foundation for empirical research on mining-related hazards, vulnerability, human capacity, and community resilience in nickel-mining regions of Sulawesi.

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