Collaborative Transdisciplinary Research, Knowledge Sharing and Governance for Disaster Prevention and Mitigation

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Abstract: *Considering a range of possible natural and anthropogenic hazards and socio-economic disruptions, the article hypothesis is that the planning of their prevention and mitigation requires transdisciplinary collaboration of science, governance organisations, affected population, and civil society. The literature review enabled identifying types and causes of disruption threats, their scale, governance approaches and recommendations for collaboration in transdisciplinary research, knowledge sharing and governance. Qualitative analysis of the recommendations given in the above studies confirms validity of the above hypothesis. The findings indicate the significance of developing knowledge and skills needed for effective transdisciplinary collaboration. The research value is in providing evidence related to the need for building capacities and capabilities for transdisciplinary collaboration in science, at all levels of governance, and in communities.*

Keywords: Collaborative transdisciplinary research, knowledge sharing and governance; disruptions in natural and manmade environment; resilience; risk mitigation and recovery.

1 Introduction

The aim of this article is to investigate if there is evidence of collaborative transdisciplinary research, knowledge sharing and governance in the context of increasingly complex and combined existing and possible risks to biodiversity and humanity. Such evidence is considered in relation to the severity of impacts (from global and existential risks to those that affect regions, cities, and rural areas, both on community and individual human scale) and in relation to the identified collaborative prevention and mitigation activities, the barriers to their implementation and possible routes for overcoming them. The research outcomes raise awareness of the need for increasing collaboration in transdisciplinary research, knowledge sharing, and governance related to the prevention and mitigation of natural and anthropogenic hazards that affect ecosystems and humanity.

The significance of answering the above research question is evidenced in the mid-term review of the United Nation's Sendai Framework for Disaster Risk Reduction 2015-2030 by the comment that biological and technological sources of risks have been barely discussed due to the focus on natural hazards resulting from the lack of inclusion of a wider range of expertise among the staff involved in the framework development (Stauffer et al., 2023), indicating insufficient transdisciplinary collaboration (TDC) at the highest level of global governance. In accordance with the previously mentioned review, there is increasing proof that the direst scenario, or existential danger is becoming more probable and is being fuelled by advancements in technology. It highlights that biotechnology and artificial intelligence are of particular concern as key forces driving rapid change (Stauffer et al., 2023). While advances in technology and existential danger are in the scope of the Sendai Framework (Article 15), the report notes that it is not living up to its potential for existential risk mitigation due to (1) lack of terminology such as definition of risk (which is different from disaster risk) and very little discussion of risks as outcomes to be prevented; (2) neglect of scale as there is little discussion of extreme scenarios; (3) neglect of source as discussions revolve around natural hazards, and barely discuss biological disasters like pandemics; they almost never discuss technological disasters: (4) lack of prevention as its targets are mostly reactive (Stauffer et al., 2023).

Similar to the definition proposed by Bostrom (2002), an existential risk is the likelihood that a certain event would result in either human extinction (the extinction of the human species globally) or an irreversible demise of development (Stauffer et al., 2023). Climate change is increasingly considered as an existential risk (King et al., 2015; Dunlop & Spratt, 2017; Xu & Ramanathan, 2017; Halstead, 2018; Mishra et al., 2021; Huggel et al., 2022; Leiria & Martins, 2022; Pamlin & Armstrong, 2023; Stauffer et al., 2023). With a warning that "without technology, our chances of avoiding existential risks would therefore be nil," Bostrom (2002) examined a broader range of potential risks and came to the conclusion that "in general, the greatest existential risks on the timescale of a couple of centuries or less appear to be those that derive from the activities of advanced technological civilisations" (p. 19). Although "the biggest hazards are now those caused by technology itself, we do have some opportunity with it" (p. 20). The classification of technological risks by Stauffer et al. (2023) refer to research on existential risks caused by a nuclear war (Hellman, 2008; Barrett et al., 2013; Lundgren, 2013; Pamlin & Armstrong, 2023; Idejiora-Kalu, 2024), nanotechnology (Sandberg & Bostrom, 2008), artificial intelligence (Nicolescu, 2016; Turchin, 2019; Pamlin & Armstrong, 2023; Loisel, 2024) and pandemics caused by natural processes (Day et al., 2006; Madhav, 2013; Fouchier, 2015; Fan et al., 2018; Manheim, 2018) or potential biotechnological research mishaps such as a lab escape of a potential pandemic pathogen (Klotz & Sylvester, 2014; Lipsitch & Inglesby, 2014; Millett & Snyder-Beattie, 2017).

The above listed deficiencies of the United Nation's Sendai Framework for Disaster Risk Reduction, identified by Stauffer et al. (2023), highlighted insufficient TDC, affecting the confidence in the comprehensiveness of the above framework and its effectiveness in supporting governance related to preventing existential risks beyond climate change. Therefore, the questions that require investigation are related to the capabilities for TDC and the effectiveness of knowledge sharing that enables such collaborations and increases competencies for risk prevention within global, cross-boundary, national, regional, and urban governance organisations. As the above literature review includes outputs of transdisciplinary research collaboration within the institutes, organisations and associations that support or undertake research on existential risks, it raises questions of effectiveness of knowledge sharing methods, the capacities of governance organisations for identifying relevant expertise, and their openness and capabilities to engage in TDC.

The recently published report by Stauffer et al. (2023) is considered in the introduction of this article because only if the existential risks are prevented, the prevention, reduction and mitigation of other potential disasters and hazards that can affect ecosystems and humanity make sense. The subsequent article sections describe research methods and present the results of literature review of recent research on the latter risks. The research findings indicate the need for developing training programmes for TDC of science, governance, and civil society. The transdisciplinary research process, case studies, and conclusions outline significance of research findings and recommendations for future research.

2 Research Methods

A systematic literature review (Kitchenham, 2004; Kitchenham et al., 2011) was conducted by using the search strings "Transdisciplinary collaboration disruption recovery city governance", "Urban, global, and regional disruption mitigation recovery and governance", "Regional conflict mitigation recovery", and "Regional energy and food disruption mitigation recovery" for identifying studies indexed in ScienceDirect, collecting 19,433 studies. Duplicates were then removed and then keywords from other domains (such as business, physics, chemistry, artificial intelligence, and medicine) were used to screen the results. After scanning the remaining 1,962 research articles by title and abstract, 698 studies remained, necessitating the creation of inclusion and exclusion criteria. The online availability of scholarly publications in English that addressed TDC in reducing regional and worldwide disruptions in towns and cities was one of the inclusion criteria. Academic resources from various disciplines, including history, economics, and health sciences, were excluded based on certain criteria. The literature review contained 70 papers in total.

Content analysis (Frey et al., 2000) was used to identify types of risks, disasters and hazards that were addressed in the studies, geographic scope, evidence of and recommendations for transdisciplinary research and/or governance collaborations, including the capacity building for TDC and knowledge sharing through upskilling, barriers to such collaborations, and key recommendations.

3 Results

This article focuses on potential disruptions brought on by a variety of disasters (a significant disturbance to the functioning of a community or society at any level, caused by hazardous events combined with factors such as exposure, vulnerability, and capacity. This disruption often leads to material, economic, or environmental losses and consequences) (Stauffer et al., 2023) and hazards (an event, process, or human activity that has the potential to result in loss of life, injuries, health issues, property destruction, social and economic disturbances, or harm to the environment) (Schneiderbauer & Ehrlich, 2004). In this article, TDC is considered as a process that entails collaboration in sharing knowledge pertinent to different disciplines with stakeholders who might be affected by disasters and hazards and with governance organizations responsible for risk prevention and mitigation at the global, cross-boundary, regional, national, and local (urban or rural) level.

The content analysis of selected literature is presented in two subsections: types of risks and risk-related governance.

3.1 Types of Risks

The content analysis identified three types of risks related to their causes: natural hazards, anthropogenic disasters, and their combination, presented in the below subsections. The listed risks are those identified in the studies selected for the literature review, and do not include all possible risks. From each analysed study, problems and approaches to solving them are outlined.

3.1.1 Natural Hazards

In Indonesia, seismic hazards are exacerbated by collateral hazards like liquefaction, ground subsidence, landslides, rock avalanches, and tsunamis. These factors also contribute to the failure of buildings and infrastructure, such as a lack of knowledge about local hazard situations, noncompliance with seismic-resistant codes and standards for buildings and infrastructure, and problematic soil conditions. To address the issue of the lack of information and knowledge on the performance and resilience of infrastructure during earthquakes, research was conducted on the lessons learned from five major earthquakes (Pribadi et al., 2021). Similarly, a team from China, the UK, and the US developed a transdisciplinary participatory project and related knowledge-sharing outcomes to improve earthquake preparedness in China. The project generated two knowledge-sharing resources: a narrative report containing technical information

and recommendations for pertinent local agencies, and a concise graphic novel providing earthquake preparedness and mitigation advice for the public (Rodgers et al., 2020).

A transdisciplinary multi-scalar approach that examines the quality and spatial adaptations of the built environment, as well as important long-term social implications, was used to identify the lessons learnt from Ecuador's housing reconstruction following the 7.8 magnitude 2016 earthquake (Testori et al., 2021). A transdisciplinary narrative of Ōtautahi Christchurch was created in the wake of the 2010–2012 earthquakes in New Zealand. It used a socio-cultural history approach to depict many disturbances that resulted in the city's current urban structure and the resilience of its communities (Hobbs et al., 2022).

Research on *hurricanes, cyclones and typhoons* in the Mexican Caribbean, provides a critique of the development vision that supports mass tourism growth, of the governance structures that create political hegemony of government and developers in decision making, and of coping strategies based on effective evacuation and attracting investments for rapid economic recovery, indicating the need for a shift towards sustainable development, more effective governance structures, and the adoption of innovative coping strategies that require political will, financial resources, and community engagement (Manuel-Navarrete et al., 2011).

New strategies for managing *urban flooding* brought on by heavier and more frequent rainfalls are proposed using the resilience concept (Zhu et al., 2021; Wu et al., 2022). These strategies include decision support methods that can consider the viewpoints, goals, trade-offs, viable alternatives, and indicators of multiple stakeholders (Aidinidou et al., 2023). Enhancing improved co-production practices on emergency responses and recovery measures between authorities is crucial, as evidenced by the unprecedented disruptions to urban road transport caused by urban floods in and around megacities (Lu et al., 2022). This includes governance collaboration and knowledge and information sharing.

3.1.2 Anthropogenic Hazards

International cooperation is necessary for the study, creation, testing, and widespread implementation of various emission-reduction technologies, such as carbon capture and storage, in order to mitigate *climate change* (Cook, 2017). To address the issue of climate change adaptation in urban areas, a cooperative, sociotechnical agenda must be created to guarantee that social justice is considered when creating new technological solutions (Carter et al., 2015). Researchers are adopting a multidisciplinary critical perspective to explore how climate change responses can strengthen, amplify, or reshape elite power. They highlight that low-carbon transition pathways may intersect with and even perpetuate processes and systems of inequality, exclusion, and injustice (Sovacool et al., 2019). According to empirical evidence, effective action relies on the willingness of diverse stakeholders to collaboratively negotiate a shared way forward. It also depends on national and international commitments to tackle the root causes of climate change, as seen in how actors within adaptive governance systems navigate acute climate crises and the factors shaping their responses (Barnes et al., 2022).

Climate change has amplified water scarcity and highlighted its wide-ranging impacts that call for participative decision-making and knowledge sharing to improve governance. Collaboration of the representatives of stakeholders from three counties and three cities in Southeast USA with the regional water service provider, in the context of population growth, water demand and quality, environmental impacts, governance and policy issues, and social and economic impacts, resulted in integrated regional water supply planning that incorporates socio-economic, policy, governance, and sustainability considerations (Asefa et al., 2014). Water scarcity has led to the exploration of aquifer storage and recovery as a water storage alternative in Texas (Smith et al., 2017).

Australia's Murray-Darling Basin (Basin) has historically had a pro-farmer water resource policy that left the environment as the residual claimant. This led to research on potential reform alternatives that could help governments act as a catalyst for collaboration for effective adaptation (Mallawaarachchi et al., 2020). Because part of coastal contamination also results from deposition by rivers downstream at their confluence into the sea (Banerjee et al., 2022), desalination technologies are part of the water management strategies in coastal cities. These technologies require further research in intensive simulations of inland

waterways and associated waste dumps, indicating the need for the related regional TDC in research, knowledge sharing, and governance.

The hydrological cycle and water resources in various socio-environmental systems are affected by glacier recession in tropical highlands, which necessitates cooperative research that integrates biophysical and social processes while recognizing the complex and multifaceted nature of exposure, risk, vulnerability, and resilience to hydrologic change (Mark et al., 2017).

Research on heat waves has used technical, social, and economic approaches. These include examining the creation, use, and communication of building information and verifying that a mix of responses is required to adapt to heat waves and lower the associated risk (Miller, 2015). To explore the potential for a holistic systems approach to the built environment that addresses various environmental, economic, and disaster management challenges, researchers advocate for increased collaboration across sectors (Miller, 2015). A multidisciplinary collaborative approach to developing a regional scale climate adaptation plan with the health sector (Tonmoy et al., 2020) and knowledge sharing among science, governance institutions, and the population are crucial, according to research on mitigating the health impacts of heat waves (Miller, 2015).

The availability, affordability, and accessibility of energy (i.e., energy crises) could impact the economic, political, social, mobility, and health systems as well as the development of technologies and innovations. This is because fossil fuel resources are limited and the transition to renewable energy sources is slow (Erker et al., 2017). Therefore, it is imperative that resilience-thinking be incorporated into future energy strategies. Emerging *corruption* concerns in renewable energy markets pose a threat to the effectiveness of the energy transition to renewable sources (Sovacool, 2021).

Invasive species, habitat loss, altered hydrology, and climate change are just a few of the *problems in ecosystems* caused by human activities. To mitigate these issues, cooperation is required to gather pertinent data, which are frequently dispersed throughout the scientific literature and need to be actively put together into logical conceptual and quantitative frameworks (Crook et al., 2015).

Some economic activities, such as *globalization,* have negative impacts both on people (growing social inequality) and ecosystems (environmental degradation) (Garza, 1999). Despite estimates of 318 GW of renewable energy production capacity, Afghanistan has remained underdeveloped with a low electrification rate of only about 30 to 38% due to political disagreements that caused *water sharing disputes* between Afghanistan and most of its neighbors (Ahmadzai & McKinna, 2018).

Proactive steps like redundancy and resilience are necessary because *technical failures,* like those in telecommunications, impact other vital infrastructure elements and the overall economy (Armbruster et al., 2012). More cross-disciplinary collaborations between authorities, operators, and researchers are required to turn knowledge into workable strategies to strengthen the resilience of critical infrastructure systems, such as electric power, transportation, water supply and sewage handling, information and communication, and banking systems, which have grown more complex and interdependent (Mattsson & Jenelius, 2015). According to Münzberg et al. (2017), successful disaster management techniques including power outages—one of the most severe Critical Infrastructure (CI) disruptions—require cooperation between disaster management authorities and impacted CI suppliers. With the increasing prevalence of ICT technologies in smart cities, the *security of urban data repositories* has become a risk. This calls for a better understanding of complex systems and new methods for addressing engineering and technological problems related to human systems (in terms of efficiency, resiliency, control, optimization, management, and forecast). It additionally requires for TDC of and knowledge sharing from a variety of disciplines, including computer science, data science, urban planning, urban design, efficiency, resiliency, modeling and simulation, systems thinking, systems theory, complexity science, and sustainability science (Bibri, 2018).

3.1.3 Combined Risks

The below overview of combined risks highlights their geographical scope to indicate their scale. When considering how to prevent multiple risks caused by global climate change, there is the need for increasing capacities for such engagement by addressing vulnerabilities of shrinking cities, informal settlements,

and poverty in wider regions such as Global South (Blanco et al., 2009) as consequences of economic globalization leading to social inequality and environmental degradation (Lauer et al., 2013). Multiple disasters such as earthquake-tsunami-nuclear emergency in Japan, 2011, involve multiple activities over long periods of time (Schreurs, 2021). Disasters, disease outbreaks, and conflicts lead to food shortage, famine, and displacement of people (Sithole et al., 2016).

Climate change, population growth and limited water resources call for greater stakeholder engagement, improved coordination among water management agencies, and more effective communication and education efforts (Larson et al., 2013). The Middle East faces numerous challenges in ensuring water, energy, and food security, including rapid industrialization, environmental fragility, unstable political relations, and transboundary water disputes (Zarei, 2020), indicating the need for strengthening the cooperative framework of the Gulf Cooperation Council (Al-Saidi, 2021).

Research on stakeholder involvement and co-production in developing municipal adaptation strategies is limited, with little empirical evidence available. However, effective climate change adaptation strategies that ensure an ongoing and transformative process in urban areas require transdisciplinary approaches. These approaches must engage both internal and external stakeholders—such as state actors, civil society, and market participants—to collaboratively discover innovative ways to align their efforts and resources (Wamsler, 2017).

The Covid-19 pandemic's intersectoral effects prompted research on its implications for sustainable development (Lawrence, 2020; Elsamadony et al., 2022). In remote regions such as Small Island Developing States, the intersection of disease risks, economic downturns, and underlying climate and biosecurity vulnerabilities prompted communities, governments, and businesses within food systems to develop various strategies for mitigating and adapting to the impacts of the pandemic (Davila et al., 2021). Researchers emphasise that efforts around pandemic recovery and containment must be based on a culture of transdisciplinarity, which calls for stronger contributions and collaborations among various scientific tribes and government sectors (Kareem, 2021). In the UK, the shortcomings of the top-down approach in governing containment of Covid-19 pandemic led the creation of Independent SAGE (working independently from the official Scientific Advisory Group for Emergencies). SAGE adopted a population-based approach to public health, worked in a comprehensive, transdisciplinary manner, and were dedicated to public involvement. They emphasised the significance of learning from local knowledge, the worth of studying other nations, the role of civil society as a vital ally of the government, the need to find suitable connections between science and policy, and the need to view issues through an equity lens (McKee et al., 2022).

Disruptions in interconnected water, energy, and food systems have mutual direct or indirect impacts, but their interactions at the household level in a disaster setting have not yet been studied (Dargin et al., 2020). Research is being conducted to develop predictive capabilities that could help mitigate or prevent some health consequences related to disasters. On an individual level, the combined impacts of environmental disasters, pandemics, and other major traumatic events, such as the Covid-19 pandemic or war, contribute to psychosocial stress, which can result in a variety of mental and physical effects (Sandifer et al., 2022).

3.2 Risk-related Governance

3.2.1 Global Governance

To address the speed and scale of the sustainability challenge, researchers emphasise that coordinated reforms of both policy and knowledge systems are urgently needed. These reforms include more adaptive governance, mainstreaming participatory policy making, integrating systems-thinking literacy, increasing the capacity to conduct transdisciplinary research, and fostering continuous organisational learning (Oliver et al., 2021). According to Nikas et al. (2020), scientific support for climate action involves evaluating feasibility and desirability in terms of "when," "where," and most importantly, "whom," in addition to investigating the potential of "what" in terms of policy and consequence. Technological advancements and policy measures focused on energy efficiency and clean energy will not be sufficient on their own to achieve greenhouse gas emissions trajectories in line with the Paris Agreement in the coming decades. A

transdisciplinary scientific approach is needed to co-develop the goals and scientific processes that support the transition to a circular, net-zero economy, involving stakeholders from policy, industry, and civil society (Nikas et al., 2022). In their evaluation of socio-ecological resilience to climate change extremes such as severe droughts, floods, and destructive storms, Rammig et al. (2020) applied a transdisciplinary research strategy and concluded that the focus of governance needs to change from "effectiveness" to "resilience."

3.2.2 Cross-boundary Governance

Hampl (2022) believed that for the energy transition in Latin America and the Caribbean to be both equitable and climate-compatible, new approaches must be developed to integrate and apply inter- and transdisciplinary knowledge. This can be achieved by creating an interface between local communities (local and community knowledge), the research community (local and international climate-energy knowledge), and policymakers (policy knowledge). According to Naderi Beni et al. (2021), the situation is expected to get worse rather than better unless there is a coordinated effort to lessen the consequences of climate change and support the reorientation of the economy of the Persian Gulf Region. Afghanistan's irrigation and power infrastructures depend on transboundary water management agreements (Ahmadzai & McKinna, 2018). Each city cluster may require a customized approach that fits the spatial, temporal, and technical profiles, which is anticipated to be developed through TDC of various organizations and communities, according to research on regional infrastructure resilience within the cross-border city cluster in the Pearl River Delta in China (Ng et al., 2018).

3.2.3 National Governance

To guarantee mutual outreach, partnership, role complementarity, accountability, and follow-up, the UNDRR's Sendai Framework, institutionalized through Japan's National Resilience, emphasizes the need for "full engagement of all state institutions, both executive and legislative, at national and local levels, along with a clear delineation of responsibilities across public and private stakeholders, including businesses and academia" (DeWit, 2021). It has fostered extensive collaboration among government agencies, the private sector, and civil society, as demonstrated by the diverse participation of NPOs, disaster professionals, local governments, business associations, and other stakeholders in developing national and local resilience plans. This is further evidenced by the formation of 19 working groups within the Association for Resilience Japan, which compile sectoral studies on topics such as green infrastructure, fire prevention, landslide countermeasures, underground infrastructure mapping, and more (DeWit, 2021).

Through the implementation of strategies centred on digital innovations and data sharing, greening the economy and infrastructure, and governance for the benefit of all, Gürdür Broo et al. (2021) suggested that the United Kingdom adopt scenarios planning methodology in order to provide a clearer view on the pathways towards reaching the Sustainable Development Goals. Innovative governance frameworks that connect public and private interests, as well as bottom-up and top-down decision-making, were successful in reversing the depletion of an aquifer in Spain. This depletion had been driven by market incentives, weak enforcement capacity, and internal factors linked to the socioeconomic characteristics of users, coupled with a lack of governance rules (Delgado-Serrano & Borrego-Marin, 2020).

Morzillo et al. (2022) describe the dynamic interaction of decision-making and governance processes across various locations as they progressed toward desired forest conditions through a collaboration of diverse governance structures. These included top-down municipal resources, regional conservation efforts led by landowners, and community-driven stewardship. They also explain how a transdisciplinary knowledge co-production framework was employed to identify key management challenges or dilemmas driving changes in forest patch management in Chicago, New York City, Philadelphia, and Baltimore.

As climate change mitigation entails reducing carbon emissions, the analysis of data from 283 cities in China from 2004 to 2017 demonstrated the negative effect of natural resource dependence on the carbon emission efficiency and highlighted positive impacts of national environmental regulations (Fan et al., 2022). Economic downturns, industry shocks, and currency crises are just a few of the economic shocks that national governance must deal with. However, regional resilience depends on both inherent (the

region's economic structure, innovation system, skills base, and competitiveness level prior to the shock) and adaptive (the combination of actions and decisions for accelerating regional resumption) capabilities (Palekiene et al., 2015). At the city-region level, the governance of infrastructure funding and financing plays a critical role in identifying mechanisms to direct investment into transport infrastructure, particularly amid the challenges of the global financial crisis, austerity measures, and uneven growth (O'Brien et al., 2019). This calls for multidisciplinary collaboration of various disciplines, including geography, engineering, meteorology, and climatology (Pregnolato et al., 2020).

3.2.4 City Governance

A comprehensive, experimental, and inclusive approach to climate governance is emerging, covering multiple policy sectors such as transport, energy, health, and justice. This approach involves a diverse range of actors and encourages innovative solutions, as highlighted in a comparison of transformative climate governance capacities in Rotterdam and New York City (Hölscher et al., 2019). A comparative study of how the processes of setting and implementing urban resilience agendas in London and Montreal in the early stages of developing their urban resilience policies shows the need for capacity building and shifting to collaborative networks centered on preparedness and vulnerability reduction (Therrien et al., 2021). Urban Shock-Proofing (short-term & system focus), Resilience Planning (long-term & system focus), Community Disaster Resilience (short-term & community focus), and Resilient Community Development (long-term & community focus) represent the four typical frameworks for urban (climate) resilience, however, Wardekker (2021) noted that the concept is inherently flexible and can be framed in various ways, highlighting different problems, causes, moral judgments, and solutions. The latter aspect remains underdeveloped, as it addresses issues of community self-determination, equity, and the deeper, long-term socio-political factors that influence vulnerability.

According to DeWit (2021), Tokyo's inclusive and integrated governance may be its most valuable lesson for other urban areas. Strong integration in governance and risk identification is demonstrated by the analysis of the United Nations Office for Disaster Risk Reduction's (UNDRR) resilience attributes across 11 Metro Manila cities; however, there are gaps in ecosystem protection, city-to-city learning, and the involvement of disaster victims in recovery planning (Ner et al., 2022). To combine professional practice and science, Ramyar et al. (2021) suggest a transdisciplinary paradigm for adaptive urban Green Infrastructure design.

City governance is crucial in mitigating not only the risks related to climate change but also those emerging from recent socio-economic changes such as mass tourism that relies on peer-to-peer platforms and causes problems such as lack of housing in cities affected by mass-tourism and reduced quality of life for local people (Foth et al., 2021). Urban policies that can promote sustainable economic development and address social and environmental challenges, in the face of economic globalization, are called for (Garza, 1999). Local governance policies that aim to achieve short-term financial gains through large-scale urban expansion can have negative impacts if actual social and economic demand is not considered (Wang & Zhang, 2022).

New methods for moving from non-digital to data-driven urban management are being investigated, along with their effects on the institutional and physical restrictions currently placed on the built environment and different planning techniques, as well as related ethical and social issues (Engin et al., 2020).

Political conflicts sometimes lead to terrorism in cities, requiring a multi-agency approach, including the coordination of emergency services, local authorities, and other stakeholders (Williams et al., 2000).

3.2.5 Rural Governance

With the goal of understanding the concerns and priorities of the local population and create a strategic plan for the area across social, economic, and environmental domains, McGookin et al. (2022) outlined a three-year project planned for the Dingle Peninsula, a rural and remote area in southwest Ireland. The project included coordinating research through a transdisciplinary partnership and engaging the community through fifteen meetings with around 400 participants.

4 Transdisciplinary Research Process for Hazard Management

The graphical representation delineates the transdisciplinary research process critical for the effective management of natural and anthropogenic hazards (Figure 1). It conceptualizes the interaction between three key domains—scientific research, governance frameworks, and community engagement—and highlights the iterative and collaborative nature of this approach.

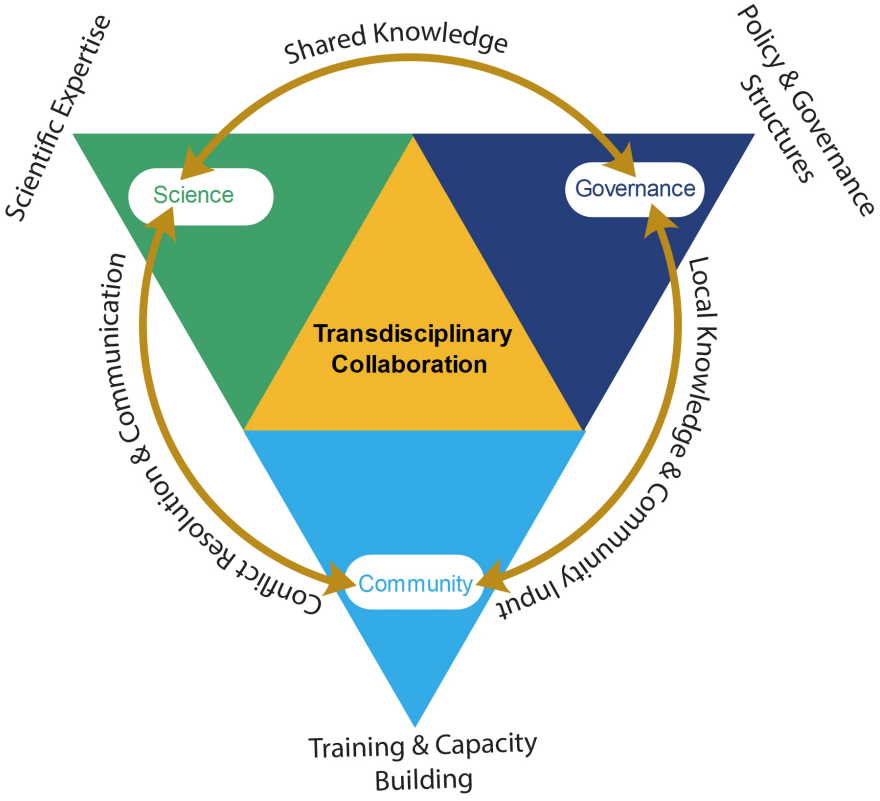

Figure 1: Transdisciplinary research process for hazard management.

At the center of the framework lies the transdisciplinary collaboration core, representing the integration of diverse expertise, methodologies, and stakeholder input. This core fosters a shared platform for communication, cooperation, and joint decision-making. It ensures that strategies for hazard mitigation are scientifically robust, socially inclusive, and politically actionable. The centrality of this component shows its role in coordinating the efforts of the three domains.

The relationship between science and governance is characterized by a shared knowledge pool. Scientific expertise provides evidence-based insights, predictive models, and advanced methodologies for policy development and decision-making. Simultaneously, governance structures guide scientific research by identifying societal priorities and gaps in policy, ensuring that science addresses practical challenges. This reciprocal exchange fosters innovation and actionable solutions.

The connection between governance and community emphasizes integrating local knowledge and community input into governance processes. Communities contribute cultural values, traditional practices, and heuristic experiences, which are essential for developing context-specific policies. Governance structures, in turn, create inclusive frameworks that address the vulnerabilities and needs of communities, empowering them through targeted initiatives and participatory decision-making. This interaction builds trust, inclusivity, and responsiveness.

The relationship between community and science focuses on training and capacity building. Scientific institutions provide communities with knowledge, skills, and tools to prepare for, respond to, and recover from hazards. Communities enrich this exchange by sharing indigenous knowledge and practical insights, which help refine scientific approaches to risk mitigation and adaptation. This collaboration strengthens community resilience while enhancing the applicability of scientific research. Cross-domain processes such as conflict resolution and communication play a critical role in ensuring effective collaboration. Differences in priorities, expertise, and perspectives across science, governance, and community can lead to challenges in coordination. Mechanisms for resolving conflicts and fostering open communication ensure that these differences are addressed constructively. This enhances mutual understanding and trust, creating a cohesive framework for implementing disaster management strategies.

Overall, the framework demonstrates how science, governance, and community interact dynamically to manage the complexities of hazards. By fostering shared knowledge, inclusive governance, and community engagement, it promotes resilience and adaptability in addressing natural and anthropogenic risks.

5 Empirical Evidence of Transdisciplinary Approaches for Hazard Management

5.1 Transdisciplinary Approach to Community Flood Resilience in Jakarta, Indonesia

In addressing community flood resilience in Jakarta, Indonesia, a transdisciplinary approach to hazard management is essential. This approach integrates various disciplines and stakeholders, fostering collaboration among government entities, local communities, and experts to develop comprehensive flood risk management strategies (Auerswald et al., 2019). The complexity of flood risks in urban settings like Jakarta necessitates such collaborative frameworks, as they allow for the incorporation of diverse perspectives and expertise, ultimately enhancing the effectiveness of flood resilience initiatives.

One of the primary strategies for enhancing community resilience is through active community involvement in urban planning and flood management. The importance of engaging local communities in the planning processes to develop better flood defences is necessary (Prana et al., 2024). This engagement empowers residents and ensures that flood management strategies are tailored to the specific needs and conditions of the community (Prana et al., 2024). Similarly, Sunarharum et al. (2021) highlight the significance of collaborative approaches in flood risk management, advocating for the integration of local knowledge and practices into formal management strategies. This participatory approach aligns with findings from Bubeck et al. (2016), who note that stakeholder initiatives can significantly influence flood risk management outcomes by enabling a sense of ownership and responsibility among community members.

Moreover, the integration of various stakeholder perspectives is crucial for addressing the multifaceted nature of flood risks. Effective flood risk management requires a blend of structural measures, such as the construction of retention areas, and non-structural measures, including community education and preparedness initiatives (Albano et al., 2015). This dual approach is supported by the work of Kouamé et al. (2022), who discuss the challenges of stakeholder collaboration in flood management, emphasizing the need for clear communication and shared objectives among all parties involved. The complexities of implementing integrated flood management strategies are further illustrated by Dillenardt et al. (2022), who argue that understanding the adaptive behaviors of residents is vital for developing effective flood risk management plans.

In Jakarta, Indonesia, the transdisciplinary approach also involves the use of innovative tools and methodologies to facilitate stakeholder engagement and decision-making. For instance, Jonoski and Evers (2013) propose a sociotechnical framework that promotes participatory flood risk management through collaborative modeling, enabling stakeholders to work together in identifying risks and developing strategies. This framework enhances social learning and fosters a shared understanding of flood risks, which is essential for building community resilience. Furthermore, the role of institutional frameworks in supporting

collaborative governance cannot be overlooked. Ilhami and Achmad (2023) discuss the necessity for reformulating intergovernmental cooperation among various stakeholders, including government agencies, local communities, and private entities, to effectively address flood risks. By developing a culture of collaboration and shared responsibility, Jakarta navigates the challenges posed by flooding and enhances its overall resilience.

In conclusion, a transdisciplinary approach to flood hazard management in Jakarta, Indonesia, is imperative for fostering community resilience. By integrating diverse stakeholder perspectives, promoting active community involvement, and employing innovative collaborative frameworks, Jakarta can develop effective flood risk management strategies, mitigate risks, and empower communities to adapt and thrive in the face of flooding challenges.

5.2 Earthquake Recovery and Urban Planning in Christchurch, New Zealand

The transdisciplinary approach to hazard management in the context of earthquake recovery and urban planning in Christchurch, New Zealand, is a multifaceted strategy that integrates diverse disciplines and stakeholder perspectives to enhance community resilience and recovery. This approach is particularly relevant in the aftermath of the devastating earthquakes of 2010 and 2011, which necessitated a comprehensive understanding of the social, economic, and environmental dimensions of recovery.

One of the key aspects of a transdisciplinary approach is the involvement of various stakeholders, including government agencies, local communities, businesses, and non-governmental organizations. The establishment of the Canterbury Earthquake Recovery Authority (CERA) exemplifies this collaborative framework, as it was tasked with overseeing the reconstruction and recovery efforts in Christchurch (Shrestha et al., 2022). This central agency facilitated coordination among different sectors, ensuring that recovery strategies were aligned with the needs of the community. The integration of local knowledge and experiences into the recovery process is crucial, as highlighted by Brand et al. (2019), who mentioned the role of community-led initiatives in shaping post-disaster urban landscapes through temporary and adaptive urbanism. Such initiatives not only address immediate needs but also foster a sense of ownership and agency among residents, which is vital for long-term resilience.

However, the psychological and social dimensions of recovery cannot be overlooked. Research by Greaves et al. (2015) indicate that psychological recovery varied significantly across different regions of Christchurch, underscoring the importance of tailored interventions that consider the unique experiences of affected communities. This highlights the need for a holistic approach that addresses both physical reconstruction and the emotional well-being of residents. The role of social work in supporting recovery efforts further illustrates the importance of integrating social services into the recovery framework to facilitate sustainable development in the most affected areas (Tudor, 2013).

In addition to social and psychological considerations, the economic aspects of recovery are critical. Dyason et al. (2022) point out that the recovery of retail facilities should be integrated with broader urban recovery processes to help shape a new identity for city centres. This economic integration is essential for revitalizing local economies and ensuring that businesses can thrive in the post-disaster context. The concept of "Build Back Better" (BBB) is particularly relevant here, as it advocates for a comprehensive approach to reconstruction that enhances community resilience by addressing physical, social, economic, and environmental conditions simultaneously (Francis et al., 2018).

Furthermore, the physical infrastructure and urban planning dimensions of recovery are paramount. Rogers et al. (2014) discuss the geotechnical aspects of disaster recovery, particularly in areas affected by liquefaction, emphasizing the need for coordinated recovery planning that considers the unique geological challenges faced by Christchurch. This technical expertise is essential for developing resilient infrastructure that can withstand future seismic events. The use of temporary urbanism also plays a significant role in revitalizing vacant urban spaces, allowing for community engagement and experimentation in urban design during the recovery phase (Wesener, 2015).

The transdisciplinary approach to hazard management in Christchurch's earthquake recovery is characterized by the integration of diverse stakeholder perspectives, the consideration of social and psychological

dimensions, economic revitalization, and technical expertise in urban planning. This comprehensive strategy not only addresses the immediate challenges posed by the earthquakes but also lays the groundwork for a more resilient and adaptive urban environment in the future.

6 Discussion and Conclusions

The content analysis of recent research on planning for risk-prevention and mitigation of negative impacts of natural and anthropogenic hazards provides evidence of increasing complexity of the task that requires collaboration of science, governance structures, and affected population. The reviewed articles include examples of such transdisciplinary collaborations. However, regional political disagreements are noted in some articles as barriers to cross-border collaborations. Only one article discussed the need for building capability and capacity for TDC and proposed establishing Research & Training Centres for collaborative learning across a spectrum of disciplines (Hampl, 2022). Although the reviewed articles provided examples of TDC and of various methods used to engage science, governance structures and affected population, there is no discussion of how such collaborations were prepared to include all relevant scientific expertise, governance experience and local knowledge, and to provide training that would facilitate mutual understanding and communication between the diverse participants.

The introduction to this article includes an example of the lack of adequate preparation for TDC at global governance level (Stauffer et al., 2023) that indicates the need for research on how such collaborations should be planned and managed. Effective hazard management often requires transdisciplinary collaboration to merge expertise from diverse fields. Hampl (2022) emphasized the establishment of Research & Training Centres to foster collaborative learning across disciplines, ensuring all participants understand the interconnectedness of environmental, political, and social risks. Similarly, Panneer et al. (2024) highlight the importance of creating platforms for scientists, policymakers, and affected communities to jointly devise strategies for hazard mitigation. Such collaborations should include robust frameworks for communication, ensuring knowledge exchange between stakeholders. Capacity building through training programs tailored to equip individuals with the skills to address complex hazard scenarios is another essential element. Von Der Porten et al. (2016) explored the need for incorporating local and indigenous knowledge into governance systems to address challenges effectively. These programs should focus on fostering an understanding of local contexts while emphasizing resilience-building strategies that adapt to specific hazard types. One of the major barriers to effective management is regional political disagreements, which hinder cross-border cooperation. Mechanisms for conflict resolution involve establishing international protocols that prioritize hazard prevention over political disputes (Schipper & Pelling, 2006). By creating neutral spaces for dialogue, these mechanisms can help resolve conflicts that arise during collaborative efforts. Advanced technologies like Geographic Information Systems (GIS) and simulation tools have proven to be effective in managing hazards (Tomaszewski, 2020). Using digital tools allows for better data collection, real-time monitoring, and scenario planning, thus enabling proactive rather than reactive management strategies (Khan et al., 2020; Daud et al., 2024).

Research should continuously explore new hazard scenarios and mitigation strategies. Geopolitical risks and environmental changes necessitate policy frameworks that integrate scientific insights with practical measures for sustainable development (Kissinger et al., 2011; Scott & Rajabifard, 2017; Li et al., 2024). Policies need to be flexible, evidence-based, and focused on reducing vulnerabilities. A framework for TDC (including its initiation, management, and knowledge exchange), developed by Butt and Dimitrijević (2023); (Butt & Dimitrijević, 2024), provides a comprehensive set of topics that could be selected as required to organize the related training in Research & Training Centres proposed by Hampl (2022) for enabling professionals to coordinate efforts across the domains of science, governance, and community to bridge critical gaps in disaster management.

The significance of the research findings is in providing evidence related to the need for building capacities and capabilities for TDC in science, at all levels of governance, and in communities (Butt, 2024). Future research on how such training can be efficiently provided in different contexts and at different levels,

from global to local, will be needed. By addressing these gaps, such efforts will strengthen the collective ability to manage the complexities of hazards and foster more resilient societies.

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