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Natural Hazard Vulnerability and Risk Assessment: The Case of the China-Pakistan Economic Corridor (CPEC)

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Abstract

The coverage area of the China-Pakistan Economic Corridor (CPEC) in Pakistan, including its critical functional zones within which major projects are located, is prone to different types of natural hazards and disasters. Since 2015, efforts have been made to operationalize CPEC without institutionalizing and establishing a comprehensive natural hazard risk assessment mechanism within the China-Pakistan collaborative framework. It goes against the grain of robust, resilient, and sustainable long-term development of CPEC. This study critically argues for the need to set up a multi-hazard risk assessment and disaster response mechanism as part of the institutional framework of CPEC, responsible for identifying, preparing, and planning against primary, secondary, and tertiary risks in accordance with the varied hazard vulnerability prevalence in varying geospatial and functional zones within the coverage area of CPEC. Overall, the study identifies and discusses the risk-prone nature of the current development of CPEC and proposes a real-time, technologically enabled, natural hazard risk assessment of CPEC projects spread over varying geospatial and functional zones in an institutional framework characterized by the uninterrupted collaboration and concentration of experts and resources from China and Pakistan.

Keywords: CPEC; Multi-hazard Vulnerability; Institutionalized Risk Assessment; Disaster Risk Reduction and Management; Collaborative Mechanism.

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1. INTRODUCTION

Pakistan is vulnerable to various natural hazards like floods, avalanches, landslides, heat waves, wildfires, and cyclones. Climate change caused by man-made activities largely contributes to the outbreak of these natural hazards. The annual presage estimated cost of environmental degradation and natural resource damages in Pakistan is about 365 billion

rupees, one billion rupees per day, or six percent of GDP (World Bank, 2023).

Analyzing the data for the period 2000-2019, German Watch's Global Climate Risk Index 2021 Report ranked Pakistan as the 8th most vulnerable country to climate change, having experienced 173 climate-related events and the loss of 0.52 percent of its GDP to climate events during the period studied (Eckstein *et al.,* 2021). According to the World Bank, Pakistan has around a 3 percent annual median probability of severe meteorological drought, which was projected to increase under all emission pathways and could increase dramatically under higher emission pathways. United Nations Disaster Risk Reduction Office (UNDRR) puts Pakistan's average annual losses to floods at about USD 1 billion (Pakistan, World Bank's Climate Change Knowledge Portal, 2022).

This multi-hazard vulnerability of the national territory can be translated directly or indirectly into multiple risks posed to the ongoing development of CPEC including its functional zones, routes, node cities, and significant projects. Pakistan is prone to multiple natural hazards, which makes strategic megaprojects, i.e., CPEC, highly susceptible. Natural disasters can significantly affect the infrastructure and leading projects of CPEC, resulting in substantial economic and human loss. Because of the prevalence of natural hazards in Pakistan, weak institutional disaster management framework, and implicit economic repercussions of natural hazards on CPEC, the vulnerability and risk assessment of natural hazards of CPEC are crucial. Given this situation, this study consists of a critical discussion of the risk posed to the ongoing development of CPEC by the vulnerability of projects to multiple natural hazards like floods, avalanches, GLOFs, landslides, earthquakes, and heatwaves. The vulnerability can compromise the medium-to-long-term integrity and health of CPEC infrastructure, investment, and human capital, possibly negatively affecting societal development, economic growth, and quality of life of people and communities involved. The study's main objectives include extensive risk assessment of CPEC projects and infrastructures vulnerable to multiple natural hazards in disaster-prone regions of Pakistan. The study further explores the avenues of collaborative institutional framework between Pakistan and China for climate resilience of CPEC and disaster risk reduction in vulnerable regions of the country. The study consists of five sections. The second section critically outlines the scope of mapping the vulnerability of CPEC to natural hazards in terms of its coverage areas and functional zones, as well as identifies critical factors for the absence of a proper mechanism for assessment of the risk posed by natural hazards to CPEC

projects. The third section conducts a multi-hazard risk assessment of CPEC projects and routes. The assessment is more in the nature of a critical identification of the risks posed by different types of natural hazards to crucial routes, node cities, and projects of CPEC.

The assessment is initial because the scope and magnitude of a comprehensive risk assessment will naturally go beyond any single study and will involve a bilateral, multi-sectoral, multi-institutional undertaking. The fourth section briefly discusses the salient aspects of an evolving joint mechanism for natural hazard risk assessment and disaster risk reduction and management mechanism between China and Pakistan within the overall collaborative institutional framework of CPEC. The fifth section considers the key determinants of China-Pakistan DRR collaboration before summing up and concluding the study. The primary approach adopted by the study has been the critical qualitative analysis of a broad range of relevant literature on the subject. The analysis has been primarily qualitative since it has dealt critically with texts; it has only been secondarily quantitative as it has analyzed secondary data and figures relevant to the study. This body of literature has consisted of research articles in impact-factor journals, institutional reports and working papers of the departments and organizations of the Government of Pakistan, reports of international organizations, think tanks, and policy papers, reports and presentations of significant seminars and workshops on natural hazard risk assessment of CPEC, newspaper and magazine articles, and relevant online resources on the subject. The findings or recommendations of the study are provisional and time-bound, subject to revision by further studies, changes in the nature of the challenges, and advancement in the state of knowledge in the field.

2. MAPPING NATURAL HAZARD VULNERABILITY OF CPEC

In Pakistan, cities, rural communities, and different levels of projects, including big growth infrastructures like dams and highways, may be increasingly at risk. This risk also extends to the China-Pakistan Economic Corridor (CPEC) and its constituent projects because of CPEC's spatial layout across the length and breadth of Pakistani territory. Projects under the bilateral strategic development program fall in energy, infrastructure, Gwadar development complex, regional industrial development or special economic zones, and social and economic sector development projects. The coverage of CPEC consists of the whole of Pakistan together with the cities of Gilgit, Peshawar, Dera Ismail Khan, Islamabad, Lahore, Multan, Quetta, Sukkur,

Hyderabad, Karachi, and Gwadar serving as key node cities; these node cities are connected through three "broad axes" linking "Lahore and Peshawar, Sukkur and Quetta, and Karachi and Gwadar," further crisscrossed by several rail and highway lines from Islamabad to Karachi and Gwadar (Government of the People's Republic of China and Government of Islamic Republic of Pakistan, 2017)." This geospatial, social, economic, cultural, and developmental diversity of CPEC makes the task of natural hazard vulnerability risk assessment urgent and highly formidable. The fact that Pakistan has hugely varying topography, ecosystems, and climate zones makes the task even more daunting (The World Bank and The Asian Development Bank, 2021). The all-Pakistan coverage of CPEC means that different spatial zones, node cities, developmental axes, transport passages, and regional economic development acceleration projects may be exposed to geophysical, hydrological, meteorological, climatological, and biological events during its operationalization and functional duration (NDMA, 2019). The risk assessment and response planning for safe and resilient CPEC development would, therefore, need to be multi-hazard in orientation with levels of primary, secondary, and tertiary risks following the varied hazard vulnerability prevalence or dominance in varying geospatial and functional zones of the development of CPEC projects.

The study identifies four phases of the disaster cycle - mitigation and preparedness (which occur beforehand), response (during and after), and recovery (short and long-term actions following the disaster) (Von Meding *et al.,* 2011). Thus, for successful, durable, sustainable, and high-quality development of CPEC, natural hazard risk to CPEC projects should be undertaken comprehensively and scientifically with the concentration and collaboration of China and Pakistan's most advanced technological and human resources. Since its inception in 2015, CPEC has been developed without a proper risk assessment and management system. However, it does not mean the need for China-Pakistan natural hazard and disaster risk prevention and management collaboration was not felt immediately after the CPEC development's operationalization (Associated Press of Pakistan, 2018). When seeking solutions to complex problems, collaboration is essential. This is the case for natural disasters, where the impacts are so massive that no entity or organization can solve each issue and help every person in need of aid. Therefore, collaboration is integral to successful disaster relief (Kaltenbrunner and Renzl, 2019).

The need for rapid execution of critical infrastructure and energy projects after a gap of more than a decade in which no major infrastructure development project was undertaken, the difficult security situation in the early to mid-2010s, low rates of foreign direct investments during the years preceding the operationalization of CPEC, and the opportunity to benefit from the enhanced global standing of China due to the massive dividends of its sustained peaceful development may have compelled the policy planners and architects of CPEC to initiate the strategic program with little natural hazard risk assessment.

Phase II and later phases of the bilateral development program will necessitate a comprehensive framework for dealing with natural hazards and disasters as the effects of man-made climate change intensify. An elaborate China-Pakistan natural hazard and disaster risk assessment and management system focused on CPEC. It is equipped with new generation stereoscopic monitoring technology to provide a scientific and viable coping and prevention strategy in the face of extreme natural events (Daily Times, 2022). This is especially important for CPEC projects located in Gilgit-Baltistan (GB) since many areas covered by infrastructure projects in GB consist of rugged mountainous terrain prone to natural hazards like earthquakes, seasonal or flash floods, landslide, debris flow, and glacial melting (ECOSF, 2017). Most CPEC projects lie in moderate to very high seismic hazard zones with considerable risk overall. Among several other risks, such as political, economic, and security, natural hazard risk can also negatively impact the stages of transformation and advancement of CPEC from transport infrastructure to trade and logistics development to a full-fledged economic corridor development (Ali, 2018).

3. MULTI-HAZARD RISK ASSESSMENT OF CPEC ROUTES AND PROJECTS

Taking the whole coverage of CPEC in Pakistan into account with the three above-mentioned horizontal axes and the three major arterial eastern, central, and western transport routes of CPEC together with the GB as the entry region of CPEC from China, three major regions – northern, central, and southern - regarding natural hazard risk vulnerability can be identified in so far as CPEC is concerned (Ali, 2018). Pakistan faces the current phenomenon of Glacial Lake Outburst Floods (GLOF). The GLOF-II project initiated by UNDP aims to highlight this problem and offers risk management strategies while helping to improve community preparedness and disaster response. The

northern region localized in GB is exposed to the risks of seismic, glacial lake outburst flood, and earthquake; the central region comprises central and western routes across central and southern Punjab, upper and lower KP, and upper Sindh, and the southern region comprising eastern, central, and western CPEC routes across lower Sindh, central and southern Balochistan are typically prone to risks of seasonal floods and flash floods (UNDP, 2020). It is to be noted that the entry point of CPEC from China into Pakistan and the termination point at Gwadar, along with the surrounding region, are of critical importance because there are no alternatives at these points in terms of route or plan diversion.

Since one region is prone to seismic and glacial risks and the other region is prone to risks like flash floods, droughts, heatwaves, and dust storms, what this essentially means is that CPEC projects and routes at these two points need to be safeguarded, especially against robust bilateral natural hazard and disaster risk assessment, prevention, reduction, and management mechanism must be highlighted (UNDP, 2020).

Considering that seismicity tends to be higher in northern and western parts of the country, transport, dam, and special economic zones will need to be built at safe sites and safeguarded against possible seismic events and any secondary events through robust, technologically advanced accurate early warning systems (National Disaster Response Plan, 2019). The China–Pakistan Economic Corridor (CPEC), a key hub for trade, is susceptible to glacial lake outburst floods, but the distributions and types of glacial lakes in the CPEC area are not well documented (Li *et al.,* 2020). CPEC route traverses next to some of the biggest glaciers outside Polar regions, making it vulnerable to the hazards associated with glaciers, and together with the "combined impact of geohazards," the "Karakoram Highway (KKH), along the CPEC route has been frequently subjected to damages, human loss and disruption by rock fall, sliding of debris and rock, debris flow, mudflow, and flash floods (Khan, 2018)." It has been found that the comprehensive characterization and inventorying of landslides along the entire KKH due to limitations related to monitoring datasets and environmental conditions has been hampering the “process of risk assessment and development of disaster prevention and mitigation strategy for the region (Su *et al.,* 2021)." The fundamental causes of landslides in the region consist of "high-elevation terrain, steep slopes, high topographic relief, tectonic activity, and erosion." Hence, the international workshop on "CPEC Natural Hazards Risk Assessment and Mitigation and Silk Roads Disaster Risk Reduction" held in Islamabad concluded that there is a need for collaboration

between Chinese and Pakistani Disaster Risk Management and Infrastructure Specialists to formulate a mechanism and provide disaster risk reduction strategy for the infrastructure projects under the China Pakistan Economic Corridor (ECOSF, 2017).

What is particularly worrisome is that four (Gilgit, Karachi, Peshawar, and Quetta) out of the eleven cities identified as major nodes of CPEC in the Long-Term Plan of CPEC have been identified by the National Disaster Response Plan of 2019 as the most vulnerable districts in terms of earthquakes. Gwadar is also located in the region along Pakistan's coastal belt, which is prone to high seismic hazards. Similarly, six (Dera Ismail Khan, Gilgit, Gwadar, Karachi, Peshawar, and Sukkur) out of the eleven node cities of CPEC are listed by Pakistan's National Disaster Management Authority (NDMA) as the most vulnerable districts in terms of floods and flash floods. Gilgit is most vulnerable to avalanches as well. Moreover, Gwadar, Karachi, and Peshawar are extremely vulnerable to more than one category of natural hazards.

Similarly, at least one major city, Rawalpindi, the twin city of Islamabad, is also listed as the most vulnerable city. Islamabad is also one of the significant nodal centers of CPEC development. The proximity of a central CPEC node right next to a highly vulnerable city in terms of natural hazards can affect the long-term progress of CPEC projects based in the capital city, which is, in effect, the nerve center and the central clearing house for all CPEC planning and development. Significant portions of the central route of CPEC also pass through the regions of Pakistan identified as high-risk flood areas. At least two node cities of CPEC, namely Gwadar and Karachi, are at a high and medium drought risk. Gwadar, Karachi, and Thatta are also most vulnerable to cyclones and tsunamis (National Disaster Response Plan, 2019). It must be mentioned that four major wind power projects and two additionally planned wind power projects under CPEC are in Thatta. Bahawalpur, the site of the massive 1000 MW solar power project under CPEC, is identified as the most vulnerable to droughts.

The 884 MW Suki Kinari hydropower project under CPEC is in Mansehra, which has been identified as one of the districts most vulnerable to floods and flash floods (CPEC Secretariat, 2021). Moreover, the mega energy projects of CPEC are coal-based power plants, i.e., coal power plants in Sahiwal, Hub, Karachi, and Thar. Coal-based power plants have severe environmental implications, releasing tons of greenhouse gases (GHG) into the atmosphere. These GHGs, in the long term, will cause climate-induced natural

disasters in Pakistan. These risks further increase CPEC infrastructure's vulnerability and jeopardize the megaproject's long-term viability.

In contrast, renewable energy projects emit less carbon emissions, improving environmental quality and sustainable development. The potential of renewable energy has been explored in ASEAN countries and can be implemented in Pakistan (Wu *et al.,* 2021). A study (Zhang *et al.,* 2020) investigated the consumption and energy efficiency pattern concerning economic growth in developing countries. The study's findings revealed that developing economies have high energy intensity and low energy efficiency. Pakistan follows the same scenario with severe line losses and poor transmission channels. In addition to natural hazards vulnerability assessment, having the agenda of sustainable development, environmental conservation, and significant investments in renewable energy projects can enhance the disaster resilience of CPEC.

Incidentally, Karachi and Lahore are also identified as highly vulnerable to industrial hazards, which a natural hazard event can cause. It is easy to imagine the magnitude of the impact of a potential major natural hazard event in these cities either separately or in two or more of these districts. Urban droughts are becoming a stark possibility for big cities suffering water stress due to the impact of urban anthropogenic carbon emissions and accelerated global warming on the hydrological cycle. Also, in Asian metropolises, "choked water bodies and urban drainage systems increase the vulnerability to floods" as well as heightening the "frequency and intensity of water-related disasters like floods and droughts under climate change impacts, hindering development prospects" due to the spatial concentration of "water demand of millions into a small area." Key CPEC node cities like Gwadar, Karachi, Lahore, Peshawar, and Quetta are vulnerable to the urban drought phenomenon (Ray and Shaw, 2019).

Along with a range of infrastructure projects, two critical Phase II projects aiming at industrial development are in these regions: Moqpondass Special Economic Zone (SEZ) in GB and Gwadar Free Zone (CPEC Secretariat, 2021). These two projects are critical to the transformation of CPEC as envisaged in the joint Long-Term Plan for CPEC (2017-2030). Gwadar represents a comprehensive port city development complex consisting of multiple projects across different domains of urban, business, educational, health, industrial, marine, trade, and transport development, and in this sense, it serves as the microcosm of CPEC itself. Natural hazards can also thwart the transition from one stage of development to another. For a country like

Pakistan, which has been locked into the stages of semi-industrialization for some decades now, natural vulnerability poses a greater risk to development gains than newly industrialized countries with the resources and the know-how to minimize the losses incurred due to natural hazard events and disasters. This finding is backed by studies that have explained how developing countries like Pakistan are less responsible for GHG emissions, a significant factor behind recent climate changes, but the adverse impacts are higher on developing nations. Natural hazards like the recent forest fires in Balochistan and the extraordinary nationwide heat wave where the maximum temperature was recorded to be 51 degrees centigrade in March are foreboding natural hazards that have the potential to disrupt the development of not only CPEC projects but also any other community, rural, or urban development initiatives (Youmatter, 2020).

4. EVOLVING PAKISTAN-CHINA DISASTER RISK REDUCTION (DRR) MECHANISM

In the wake of recent wildfires that raged across the Sulaiman Mountains in Pakistan, China, and Pakistan have agreed to establish a joint monitoring system for forest fire early warning, mitigation, and response utilizing modern technologies like satellite imaging and information and resource sharing in the event of a future emergency (CPEC Secretariat, 2022). An earlier understanding between the two countries regarding disaster management collaboration was already reached in February 2022 (Siddiqi, 2022).

Such collaboration would be based on a detailed hazard' analysis for the comprehensive monitoring and evaluation system based on many distinct but related analyses, namely, seismic hazard vulnerability analysis, landslide hazard analysis, forestation and reforestation analysis, snow and debris hazard analysis, environmental hazard analysis, land erosion analysis, and impact analysis of climate change on glaciers. The types of data that could be required would consist of data on environmental degradation, inland and cross-border traffic volume, capacity, and flow, geotechnical and geological changes like landslides and avalanches, area-specific satellite imaging, meteorological conditions including precipitation rates, water level including inflow and outflow of rivers and reservoirs (Afzal and Naseem, 2018). What is also required is to involve the urban and rural communities and small, medium, and large enterprises operating near and adjacent to crucial CPEC projects in natural hazard risk reduction and mitigation activities. Social, business, and

government players should create an early warning system of natural hazards and risks peculiar to any given area or region where CPEC projects are based. Moreover, education and innovation can contribute significantly to climate change mitigation and developing the DRR framework for CPEC. The role of academia and researchers in shifting the trend towards renewable energy consumption and better environmental practices in OECD countries has been acknowledged (Li *et al.,* 2023). Hence, there is enormous potential for researchers from Pakistan and China to contribute to developing a collaborative DRR framework to make CPEC climate resilient.

It is of the essence to develop a natural hazard vulnerability index for specific regions or areas of CPEC coverage. It is also essential to recognize that CPEC is a continuum and requires uninterrupted operations across the continuum to produce optimal benefits for national, regional, and local development. Without such a comprehensive risk index, it can be said with some degree of certitude extrapolating from the existing data that no significant area of CPEC operationalization is entirely free from natural hazard risks. A CPEC-specific natural hazard risk index would determine the level of risk to which CPEC as a whole and individual CPEC projects are exposed. As part of the formulation of the proposed index, there is a further need to disaggregate district-wise multi-hazard vulnerability and risk assessment for all districts in which CPEC projects are located or through which CPEC transport infrastructure projects pass, in the same manner in which Pakistan's National Disaster Management Authority (NDMA) has prepared such assessments for a few districts of Pakistan, with the only difference that CPEC natural hazard vulnerability and risk assessment should be tailored to the specific needs of planning, development, execution, and operations of CPEC projects (NDMA, 2021). The great work being done by NDMA should also involve increasing sensitivity to CPEC development, including increasing the developmental sophistication of its future phases.

This risk assessment should also include multiple humans, social, economic, geographical, cultural, community, and industrial development risks. The risk assessment effort should also be categorized according to the five major domains of CPEC development. How the devastation caused by a natural hazard event is further exacerbated by non-natural factors like explosive population growth, urban sprawl, haphazard industrialization, rural-urban migration, high reliance on agricultural dependence, poverty traps in hazard-prone regions, poor disaster risk reduction institutional capacity, unregulated land use planning should also be studied for each of the significant node cities

of CPEC as well as other districts home to key CPEC projects (Yu *et al.,* 2018). The inestimable value of predictive forecasting and scenario-based planning should be fully leveraged for natural hazard risk reduction in CPEC nodes and the surrounding regions. It is essential to study and analyze the natural hazard vulnerability of the Chinese section of CPEC before it enters Pakistan and then collate the data and information thus gathered with the natural hazard vulnerability of the Pakistani section of CPEC in order to set up a comprehensive early warning monitoring and evaluation system to contain losses and setbacks to CPEC investments, human resources, natural resources, and lives and property of communities inhabiting the regions of CPEC coverage.

The natural hazard vulnerability of CPEC projects and the areas and regions of their location should be conceived in the context of the totality of the natural and social environments of which they are a part. It should be mainly remembered that these environments are different in spatial and social terms, marked by unequal distribution of opportunities and hazards, that both the opportunities for work, progress, and development and hazards of different types are conditioned by socioeconomic processes that determine status and access to resources, that this access remains unequal at best, that class, gender, ethnicity, age group, physical and mental health as well as immigration status play an essential part in determining access to resources. Lastly, social systems, political systems, and economic systems at local, national, and international levels affect the ability of people, communities, and even authorities to deal with the impact of natural hazards (Wisner *et al.,* 2015). The ability of the country to deal with natural hazards and the consequent losses will depend upon the degree of preparedness and the level of socioeconomic development of the countries in question (Yu *et al.,* 2018). Concerning natural hazard vulnerability related to CPEC coverage, such a nuanced approach is essential to meet the seven targets and four priorities of the UN Sendai Framework for Disaster Risk Reduction 2015-2030 (Center, 2015).

5. CRITICAL DETERMINANTS OF CHINA-PAKISTAN DRR COLLABORATION

In the context of China-Pakistan collaboration on natural hazard monitoring, evaluation, and mitigation, at least four challenges can be identified, that is, "lack of common geological and meteorological background on natural hazards" with lack of information sharing and coordination, presentation by natural hazards of "new characteristics in terms of formation,

triggering criteria and mobility," lack of detailed "hazard and risk assessments" from the starting point of CPEC in China and its end point at Gwadar in Pakistan, and the probable difference in China and Pakistan in "design codes, procedure, technologies and practices of hazard assessment and mitigation." These challenges will be reinforced with the four significant modeling constraints in risk assessment: limited availability of data and heterogeneous data reflecting differences in format, scale, mapping parameters, and terminology use (Yu *et al.,* 2018). Here, it is necessary to mention that it is essential to collaborate regarding information sharing with other countries in the region, given the likelihood that natural hazards may have cross-border impact, too. At least four strategies can be identified for dealing with natural hazard risk reduction along CPEC, namely, "collection of strategic information about past disasters in a central archive" set up through China-Pakistan collaboration, availability of "long-term data sharing by local authorities and institutes" in CPEC node cities, on project sites and surrounding regions, such as the China-Pakistan Joint Research Center on Earth Sciences (CPJRC), conducting "investigations on natural hazards and risk assessments (both ground- and remote-based and shared protocols and guidelines in mitigation practices." A two-pronged effort consisting of "aggregation, homogenization, standardization of existing datasets and implementation of lacking data" would be required on the one hand, and "the development of a new and unique dataset developed according to shared protocols and validated by the existent datasets (Peng *et al.,* 2017)."

What is essential to recognize further is that apart from the technical-scientific challenges of natural hazard risk assessment, natural hazard and disaster risk reduction require an approach sensitive to some other factors. Since the goal of natural hazard risk assessment is fundamentally to enhance the resilience of CPEC as a whole, including its constituent projects, node cities, passage regions, and the five functional zones identified in the Long-Term Plan, it is worthwhile to note that resilience is seen and understood differently for different stakeholders and that this difference depends upon the "type of hazard" such as the category of natural hazard, the scale of hazard, that is, cross-border, local, city-based, project-based, community-based, "the type of society and its developmental stage," that is, whether it is an underdeveloped, developing or developed society, "time frame," and the cognitive and disciplinary standpoint of stakeholders (Yokomatsu and Hochrainer-Stigler, 2020).

6. LIMITATIONS AND WAY FORWARD

The study mainly investigated secondary data and conducted a qualitative risk assessment of CPEC. Community-based risk assessment, questionnaires, interviews, and focus group discussions are separate from the study due to the extensive study area and reasonable financial and time constraints. Future research studies in this area should focus on quantitative risk assessment of CPEC in Pakistan. The use of specific GIS tools and remote sensing techniques for natural hazard vulnerability mapping should be conducted for quantified risk evaluation. Future studies should focus more on area and natural hazard-specific risk assessment of critical CPEC routes and projects. Community-based disaster management studies at a smaller scale can be a way forward for better understanding and management of natural disasters in Pakistan.

7. CONCLUSION

Because of the vulnerability of the development and operationalization of CPEC to multiple natural hazards, a bilateral multi-dimensional, multi-sectoral, and staggered stage-wise approach to natural hazard risk assessment that takes into account regional, project, developmental, procedural and technique, operational, spatiotemporal, and natural hazard typological diversity of CPEC development will be able to provide assurances and guarantees of robust disaster risk reduction and mitigation in the event of single or combined natural hazard outbreak. For this approach to succeed, there is a need to promote sustainable public-private partnerships in natural hazard risk assessment exercises. Community and business perspectives must be aligned with the requirements of resilience disaster risk reduction in CPEC development. The possibility of non-natural risks like political and security risks aggravating natural hazard risks should not be underestimated. The effect of political polarization and terrorism on reduction and mitigation efforts should be understood clearly by various stakeholders.

Provincial coordination efforts are significant in modeling end-to-end natural hazard risk assessment for the entire CPEC. Regular information and resource sharing between China and Pakistan and within Pakistan are equally essential to ensure the successful operationalization of the prospective bilateral natural hazard monitoring and evaluation mechanism. Periodic reviews and updates, triangulation of data for different types of natural hazards, and building

scenarios of natural hazard events along any given node of CPEC can further consolidate the bilateral risk assessment efforts.

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