Scientific Journal of Engineering, and Technology (SJET)
ISSN: 3007-9519 (Online)
Volume 1 Issue 2, (2024)
https://doi.org/10.69739/sjet.v1i2.139
https://journals.stecab.com/index.php/sjet

Published by
Stecab Publishing

Research Article

Validating the Climate Resiliency Framework for Road Projects in KPK, Pakistan

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About Article

Article History
Submission: August 22, 2024
Acceptance : October 06, 2024
Publication : October 16, 2024

Keywords
Climate Change, Framework, Resiliency, Road Projects, Validating

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ABSTRACT
This study validates a recently developed framework aimed at assessing the climate resiliency of road projects, recognizing the increasing impact of climate change on infrastructure, especially transportation networks such as roads. The framework provides a standardized and systematic approach for evaluating how well road projects can withstand and adapt to climate change impacts, including challenges like flooding, extreme temperatures, and rising sea levels. Conducting the research through a case study approach, we applied the framework to three specific road projects: Drabo Road, Chino Road, and Shahi-Barawal Road. The results revealed the resiliency scores for each project—Drabo Road scored 55.5%, indicating a partially resilient status; Chino Road received a score of 47.9%, signifying an acceptable status with room for improvement, also classified as partially resilient; Shahi-Barawal Road obtained a score of 50.2%, placing it in an acceptable and partially resilient category. This investigation showcases the framework's effectiveness in identifying vulnerabilities and recommending adaptation measures. The research contributes to the development of a practical tool that can assist engineers, planners, and policymakers in making informed decisions regarding the design, construction, and maintenance of road infrastructure in the face of climate change. Ultimately, the goal is to enhance the overall resilience of road projects and minimize potential damage caused by climate change impacts.

Citation Style:
Pathan, I. U., Behsoodi, M. M., & Aslam, M. S. (2024). Validating the Climate Resiliency Framework for Road Projects in KPK, Pakistan. *Scientific Journal of Engineering, and Technology, 1*(2), 19-23. https://doi.org/10.69739/sjet.v1i2.139

1. INTRODUCTION

Natural forces have shaped the Earth's climate throughout its history. However, in the last century, human activities have posed a significant threat, accelerating climate change within a relatively brief timeframe (Swart *et al.*, 2003). Climate change is a complex global problem that requires a comprehensive response, which integrates adaptation and mitigation measures across multiple sectors and scales (UNFCCC, 2018). Resiliency is the ability of individuals, systems, or communities to adapt and recover from adverse events or stresses, such as natural disasters, economic downturns, or personal crises (UNISDR, 2017). Resiliency involves developing strategies and resources that can help individuals or communities bounce back from difficult situations and build a stronger foundation for the future. Resilience can be developed through various means, such as building strong social networks, fostering personal skills and resources, and creating systems and infrastructure that can withstand and recover from shocks or stresses (Hawley & Pescosolido, 2010). "Resiliency in terms of roads refers to the ability of road systems to adapt and recover from adverse events or stresses, such as natural disasters, climate change, or human-made disasters" (FHWA, 2018). A resilient road network can withstand the impacts of extreme weather events, floods, or other hazards, continue to function, and provide access to essential services for communities (OECD, 2019). Resiliency can be achieved through various measures, such as improving road design, construction, and maintenance, incorporating climate risk assessment, and enhancing emergency response and recovery capabilities (World Bank, 2017).

Infrastructure resilience, as defined in the document "Principles for Resilient Infrastructure" developed by the UN Office for Disaster Risk Reduction (UNDRR) is, "the timely and efficient prevention, absorption, recovery, adaptation and transformation of national infrastructure's essential structures and functions, which have been exposed to current and potential future hazards" (UNISDR, 2017).

It is crucial to find the climate resiliency of roads in today's times as climate change is causing more frequent and intense weather events, which can damage and disrupt road systems. As roads are critical infrastructure that supports economic activity and enables access to essential services, their failure can have significant impacts on communities' safety and well-being. By understanding and enhancing the climate resiliency of roads, we can ensure that our infrastructure systems can withstand climate-related stresses and continue to provide reliable transportation services to communities.

2. LITERATURE REVIEW

2.1. Assessment of Climate Resiliency Score for Roads

Resiliency measurement of roads is important for several reasons. First, road infrastructure plays a critical role in supporting economic activity, enabling access to essential services, and ensuring public safety. Disruptions to road networks can have significant economic and social impacts, particularly in the face of climate change, which is creating more frequent and severe weather events. Second, climate change is increasing the vulnerability of road infrastructure to the impacts of extreme weather events, such as floods, landslides, and storms. To ensure the continued functionality and safety of road networks, it is important to measure and enhance their resilience to climate change.

The United Nations Office for Disaster Risk Reduction has emphasized the importance of climate resiliency of roads in its Sendai Framework for Disaster Risk Reduction 2015-2030. The framework highlights the need to "enhance the resilience of new and existing infrastructure, including...transport infrastructure, to disasters, including through developing their capacity to adapt to climate change" (UNDRR, 2015).

The UNDRR recommends several measures to enhance the climate resiliency of road networks, including improving road design and construction, incorporating climate risk assessments into planning and design, enhancing emergency response and recovery capabilities, and improving maintenance and monitoring of road infrastructure. The importance of resiliency measurement of roads lies in the need to ensure the continued functionality and safety of road networks in the face of climate change and other hazards. The UNDRR emphasizes the importance of enhancing the climate resiliency of road infrastructure through various measures to ensure that they can adapt and recover from adverse events or stresses. The literature on climate resiliency of roads highlights the importance of developing road networks that can withstand the impacts of climate change, such as increased precipitation, sea-level rise, and extreme weather events. The following is a brief overview of the key findings from some recent research papers in this field.

In a study published in the Journal of Cleaner Production (JCP), researchers evaluated the climate resiliency of a road network in Quebec, Canada, using a risk-based approach. They found that the road network was vulnerable to the impacts of climate change and recommended measures such as improving road drainage and increasing the height of culverts to enhance resiliency (Li & Dessouki, 2021).

Another study published in the Journal of Transportation Engineering examined the impact of climate change on road maintenance costs in Canada. The authors found that climate change could increase road maintenance costs by up to 50% over the next 20 years, and recommended that road authorities adopt proactive measures to enhance the climate resiliency of road networks (JTE ,2020).

In a review published in the Journal of Infrastructure Systems (JIS), the authors highlighted the importance of incorporating climate risk assessments into road planning and design. They argued that climate resiliency should be integrated into all phases of road development, from site selection and design to construction and maintenance (JIS, 2020).

A study published in the International Journal of Disaster Risk Reduction (IJDRR) examined the impact of Typhoon Haiyan on the road network in the Philippines. The authors found that the road network was vulnerable to the impacts of the typhoon and recommended measures such as enhancing road drainage, strengthening bridges and culverts, and improving emergency response and recovery capabilities (IJDRR, 2019).

Overall, these studies suggest that climate resiliency of roads is an increasingly important issue, given the growing impacts of climate change on road infrastructure. To enhance climate resiliency, road authorities should adopt proactive measures, such as incorporating climate risk assessments into road planning and design, improving road drainage and culverts, and strengthening emergency response and recovery capabilities.

2.2. Resiliency

"Resiliency refers to the capacity of a system to maintain its function and integrity in the face of such disruptions and to recover from them quickly and effectively" (Smith & Eisenman, 2011).

Resiliency can also be defined as "the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure" (UNISDR, 2009). This definition highlights the importance of resiliency in the face of hazards and the need for systems to be able to adapt and maintain their core functions and structures. Resiliency is not just about bouncing back from a shock or stress, but also about the ability to learn from and adapt to changing conditions.

Another way to understand resiliency is through the concept of "transformative resilience," which involves "using a crisis as an opportunity for rethinking and transforming the system" (Folke *et al.*, 2010). This perspective emphasizes the potential for crises to lead to positive change and transformation, rather than just returning to the previous state.

In summary, resiliency involves the capacity of a system or entity to adapt and maintain its core functions and structure in the face of shocks, stresses, and changing conditions, with the potential for transformative change. In conclusion, Resiliency also involves a shift towards more resilient practices and technologies that reduce environmental impacts and promote social and economic well-being. Resiliency is a complex concept that involves balancing economic, social, and environmental factors to ensure long-term viability. It requires a shift towards more resilient practices and technologies and a collaborative effort from all stakeholders to work towards a more resilient future.

2.3. Framework for Climate Resiliency of Roads

An integrated framework for assessment of climate resiliency of roads is important because, as stated by the United Nations Framework Convention on Climate Change (UNFCCC), "climate change is a complex global problem that requires a comprehensive response, which integrates adaptation and mitigation measures across multiple sectors and scales" (UNFCCC, 2018). In this context, roads are a critical component of infrastructure that supports economic, social, and environmental activities, and their resilience to climate impacts is essential for the well-being of communities and the sustainability of societies.

An integrated framework for assessment of climate resiliency of roads can provide a systematic and holistic approach to evaluating the multiple dimensions of resilience, including physical, social, economic, and environmental factors. As noted by the International Road Federation (IRF), "road infrastructure needs to be resilient to climate change impacts, but also needs to support the sustainable development goals by promoting social, economic, and environmental sustainability" (IRF, 2021). Therefore, an integrated framework can help ensure that the assessment of climate resiliency of roads considers not only the technical aspects of their design and construction, but also their social and economic functions, as well as their potential environmental impacts.

Furthermore, an integrated framework can facilitate the communication and collaboration among different stakeholders involved in road development and management, including engineers, planners, policy makers, and local communities. As highlighted by the World Bank, "the development of resilient road infrastructure requires the participation of multiple stakeholders, from national governments to local communities, in order to ensure that the infrastructure meets the needs of all stakeholders and contributes to sustainable development" (World Bank, 2020). In summary, an integrated framework for assessment of climate resiliency of roads is important because it can provide a comprehensive and collaborative approach for evaluating the multiple dimensions of resilience, ensuring the road infrastructure to be more resilient, and promoting the well-being of communities and societies.

3. METHODOLOGY

The nature of resiliency is multi-criteria and requires an integrated framework for its measurement. Various approaches are available in the literature to provide guidelines for the measurement of the resiliency of infrastructure of different types; however, a specific framework to measure the climate resiliency of roads was recently developed (Aslam *et al.*, 2022) based on the Analytic Hierarchy Process (AHP) and Multi-Criteria Analysis (MCA) techniques. Relative weightage for criteria, related factors, and sub-factors was calculated based on stakeholders' inputs in a Google Form survey was conducted and responses were collected from stakeholders from different backgrounds i.e. technical, social sciences, and economics. Data was analyzed by applying the AHP method, using MS Excel program for calculations.

For this study, field visits were arranged to proposed (Drabo, Chino, and Shahi-Barawal) roads in KPK of Pakistan to record the observed status of sub-factors by using performance for the measurement of sub-factors. We have added the values for observing the status of sub-factors by qualitative and quantitative measurements (0%, 25%, 50%, 75%, and 100%) in the mentioned framework.

4. RESULTS AND DISCUSSION

4.1. Results

The selected three roads have been visited. Required data was collected via the developed framework and proforma during the field visits. Then the collected information was inserted into the MS Excel sheet and the calculations for every criterion resiliency score have been calculated for all three roads. The observed status for each status of sub-factor is here inserted, and a complete framework with all required inputs was put in the framework having factors and sub-factors related to the five criteria of resiliency and sustainability (technical, environmental, social, economic, and institutional).

The traffic signal model or weightage model for the assessment of resiliency and sustainability shows the score of sustainability. To have more visual representation, the traffic light signal model is used as given below. This model was used by Aslam *et al.* in 2016, SC (Bouabid & Louis, 2015), and CFA to calculate the weight of the likelihood of sustainability. Based on this grading criteria, the system obtains above 70% score will have a greater likelihood of sustainability. The WASH system obtains a score of less than 40% is not sustainable and will not be recommended for implementation. The category of partial sustainability ranges from 41- 49% is accepted with improvement in project design (Behsoodi *et al.*, 2023).

Table 1. Grading Criteria of Sustainability/Resiliency Assessment with Traffic Light Signal

Overall Grading	Accumulative Resiliency Score	Traffic Light Signal	Accumulative Resiliency Score (%)	Likelihood of Resiliency	Remarks
A	Excellent	● (green)	85-100	Resilient	
B	Good	● (green)	70-84	Resilient	
C	Acceptable	● (blue)	50-69	Partially Resilient	
D	Acceptable with Improvement	● (yellow)	41-49	Partially Resilient	
E	Not Acceptable	● (red)	1-40	Not Resilient	

As mentioned before we have assessed the climate resiliency of three mentioned roads in KPK, Pakistan, and the results for every road are shown separately in the following Table 2.

Table 2. The Climate Resiliency of Roads

No	Name of Road	TLS	Total Score for Resiliency (%)	Situation	Resiliency
1	Drabo road	(50-69)%	55.5	Acceptable	Partially Resilient
2	Chino road	(41-49)%	47.9	Acceptable with improvement	Partially Resilient
3	Shahi- Barawal road	(50-69)%	50.2	Acceptable	Partially Resilient

4.2. Discussion

The tested climate resiliency framework for road projects in KPK, Pakistan received positive feedback on its usability and effectiveness. Drabo Road scored 55.5%, indicating an acceptable and partially resilient status. Chino Road received a score of 47.9%, signifying an acceptable status with room for improvement, and also classified as partially resilient. Shahi-Barawal Road obtained a score of 50.2%, placing it in an acceptable and partially resilient category. Users praised its clean and clear interface, simple language, and easily understandable inputs. The methodology was transparent, allowing users to comprehend the calculation of climate resiliency scores and the factors involved. The framework's avoidance of technical terms made it accessible to a broad audience, including those without a climate science or engineering background.

5. CONCLUSIONS

The climate resiliency framework, tested on three roads in KPK, Pakistan, proved effective and user-friendly. The transparent methodology, clear language, and accessible interface garnered positive feedback. Results for Drabo, Chino, and Shahi-Barawal roads indicated varying degrees of acceptability and partial resilience. The framework's holistic assessment and visual representation through a traffic light signal model facilitated easy interpretation. Overall, the framework emerges as a valuable tool for stakeholders, offering actionable insights for climate-resilient infrastructure decisions in the region. Its holistic assessment of various factors impacting climate resiliency provided a comprehensive view of road projects. Users found the results easy to interpret, with clear explanations and appreciated the inclusion of explanatory criteria, factors, and links to additional resources. In conclusion, the tested framework proves to be a practical and user-friendly tool, making it valuable for diverse stakeholders engaged in climate-resilient infrastructure assessment.

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