Original Article

Effects of floods on infrastructure users in Kenya

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Abstract

Events associated with climate change such as floods increase outages of infrastructure services. Developing countries largely react rather than being proactive in managing the effects of floods on infrastructure. This is clearly demonstrated by inadequate level of preparedness experienced before, during, and after events of floods. This research discusses the effects of floods on infrastructure users in Kenya based on a primary study carried out in 27 counties out of 47 counties in Kenya. The research findings show that events of floods in Kenya disrupt provision of infrastructure services by damaging road networks, energy facilities, buildings, and social facilities. The study reveals Kenya spend huge amount of resources in recovery phase to address the effects of floods. The study notes that local communities play a critical role in responding and recovery from floods. The study also reveals Kenya lacks climate sensitive policies, legislation, and development plans that make reference to resilience in order to protect infrastructure against known and foreseen climate risks. The study recommends that building resilience in infrastructure to respond and withstand the effects of floods demands common vision among different stakeholders.

KEYWORDS

floods, infrastructure damage, infrastructure resilience, infrastructure services

1 | INTRODUCTION

Floods are among the most devastating climate-based risks to physical infrastructures such as roads, communication, buildings, and social amenities. Floods expose infrastructure to more risks of structural damage, wearing out, and aging quickly, thus increasing maintenance and replacement costs. Floods affect the infrastructure by weakening the foundation that hold the structures thus damaging and disrupting the provision of infrastructure services too (United Nations, 1999). Disruption of infrastructural services affect all economic activities relying on the infrastructure and often lead to undesired outcomes such as loss of lives and livelihoods, increased outages of electricity, water, and communication, and ultimately leaving communities vulnerable to floods (Onywere et al., 2011). It is estimated that the larger the area affected by floods, the greater the infrastructure damage and disruption of infrastructural services leading to increase in operational and maintenance costs. The New Climate Economy (2016) report estimated that worldwide investments in infrastructure will need to increase from USD 3.4 trillion per year currently to about USD 6 trillion per year by 2030.

Infrastructure vulnerability to floods is a cause for concern in Kenya. In the recent years, Kenya has...
experienced major episodes of floods leading to high incidents of infrastructure failures and thus socio-economic losses (Opondo, 2013). Floods associated with El Niño phenomenon between 1997 and 1998 were intense, severe, and widespread affecting more than 1.5 million people and damaging properties worth USD151.4 million in Kenya. The floods destroyed and disrupted vital social infrastructure including communication, transport, silting of hydropower dams, destruction of power lines and housing in 46 of 61 districts in Kenya. In addition, the 2010 floods affected North Rift, South Rift, Upper Eastern, South Rift, and North Eastern regions leading to the destruction of 40 bridges, roads, and some of the water infrastructure (Opondo, 2013). The Kenya Institute for Public Policy Research and Analysis (KIPPRA) has conducted a study that reveals that the recent episodes of floods of 2017 and 2018 in Kenya in 27 counties had a far-reaching effect on infrastructure users across different counties.

Planning for the impact of floods on infrastructure is essential in building resilient infrastructure (Deloitte Access Economics, 2012). However, developing countries make little reference to resilience in infrastructure planning and development (Carter & Connelly, 2016). There is an implicit assumption that land use planning, building codes, and standards provide adequate requirements for building robust infrastructure (Merwe et al., 2018). Resilient infrastructure ensures continuity provision of adequate and reliable infrastructure services and ultimately reducing the time and costs spent on repairs and maintenance of infrastructure (UNEP, 2017). As noted by World Road Association (2015), climate variability impacts on the planning, design, construction, and maintenance of infrastructure and therefore effective and targeted actions should be taken towards building resilient infrastructure to minimize the damages and disruptions.

This paper assesses the effects of floods on infrastructure users at the household level in order to establish mitigation measures with ultimate goal of building resilient infrastructure in Kenya. The paper analyzes the effects of floods on infrastructure users; provides lessons from selected projects designed to provide infrastructure services in the events of floods; and reviews the legal and frameworks for infrastructure development. Finally, the paper recommends the need to incorporate resilience throughout the life cycle of infrastructure projects in Kenya.

2 RELATED WORK

Several studies have predicted that the average global temperature may increase by 1.4–5.8°C by the end of the 21st century thus affecting the global weather patterns including rainfall. Weather variability often leads to increased number of floods that disrupt infrastructure services thus increasing outages of infrastructure services as well as undermining the economic development. Literature indicates that the total economic losses from floods are higher in developed countries, but the relative size of economic impacts and the number of fatalities are more significant in developing countries (UNISDR, 2011).

Most developing countries are located in high-risk areas characterized by regular floods, thus affecting large parts of the population. About 800 million people live in flood prone areas, of which 70 million people experience floods each year (UNISDR, 2011). Droughts and floods account for 80% of the loss of life and 70% of the economic losses in Sub Saharan Africa (SSA) (Bekele et al., 2014). Lack of financial resources coupled with gaps in technical know-how, skills, and data make the developing countries ill-prepared for prevention of floods.

Economic activities of countries and their fiscal positions are vulnerable to climate- and weather-related extreme events. Existing research shows that the fiscal implications are clearly negative (Unterberger, 2018). The existing literature indicate the increased incidents of floods are further constraining national budgets as countries struggle to allocate more resources in response to natural disasters. As suggested by Kiem and Austin (2013), there is a possibility that the frequency, intensity, and duration of floods may increase due to anthropogenic climate change, stressing the need for robust adaptation strategies. To implement successful flood risk management, policy makers have to understand the interaction between hazard, exposure, and vulnerability. Policy makers need to know the factors that contribute to increasing exposure, vulnerability, and eventually flood risk to a geographic area.

The recent past has witnessed unprecedented levels of infrastructural failures due to weather-related shocks thus affecting the provision of infrastructural services. According to Fekete (2019), flood damage is one of the most prominent examples of disaster risk that leads to huge economic losses globally. The author notes that floods severely damage infrastructure thus creating outages of services. Floods damages infrastructure by deteriorating the integral structural components and deforming the ground on which infrastructure is based on. It is important to consider that cascading effects associated with floods on infrastructure because infrastructures exist as large-scale interconnected networks. Understanding the effects of floods extend beyond flood locations and flood catchment areas. Fekete (2019) observes that there are few studies carried out to establish the effects of floods on infrastructure.
Several studies have been conducted to account experiences on effects of floods on infrastructure in different countries. For instance, Shah (1999) described the floods that hit Bangladesh in 1998 for 65 days as the worst in the country with almost two-thirds of the country submerged under water and millions of citizens affected. The floods destroyed basic infrastructure like roads and bridges as well as houses, properties, crops, and livestock. Similarly, according to Mustafa (2002), despite Pakistan’s massive investment in its water sector, the country remained vulnerable to the flood hazard. Pakistan has suffered major floods in 1950, 1956, 1973, 1976, 1988, and 1992, each affecting more than 10,000 lives. In 1987, Pakistan was hit by floods that seriously damaged the infrastructure of riverside towns such as houses, bridges, roads, railways lines, telephone connections, and dams.

Flooding, especially as a result of intense precipitation, is the predominant cause of weather-related disruption across many sectors in various countries. For instance, the transport sector is severely affected by incidences of floods. According to Pregnolato et al. (2017), transport networks underpin economic activity by enabling the movement of goods and people. During extreme weather events transport infrastructure can be directly or indirectly damaged, posing a threat to human safety, and causing significant disruption and associated economic and social impacts. Heavy rain usually causes overland flow that result in drainage systems exceeding their capacity, and therefore increasing the likelihood of being blocked by debris. Other similar studies such as Sultana et al. (2016), Kenley et al. (2014), Winter et al. (2016), and Habiba et al. (2013) further demonstrate the effects of floods on infrastructure in different countries. Damages to infrastructure due to floods have different implications and may have to be repaired quickly, because public infrastructure and buildings provide services the whole population relies on (EOD Resilience Resources, 2016).

In response to the challenges of floods on infrastructure, a wide range of tools and mechanisms have been proposed. Researchers and policy makers are increasingly calling for better solutions when dealing with the uncertainties and complexities of infrastructure risks associated with floods. Traditionally, the solutions mainly focused on technical and engineering responses but the last decades suggest holistic approaches on better ways to build resilience during planning and implementing infrastructure. Unterberger (2018) further suggests that in order to increase resilience with regards to public flood damages, there is need to ensure stricter land use regulation and precautionary measures such as wet- or dry-flood proofing, or to flood insurance.

Infrastructure vulnerability to climate-related events is a cause for concern. Emerging trends in the engineering suggest that the problem is rooted in the misnomer of achieving a “collapse proof or resilient” structure based on approaches that address a limited range of performance and are unable to cope with slight variability in the initial design assumptions or structural response. The term resilience refers to the ability of an entity to recover, or “bounce back,” from the adverse effects of a natural or man-made threat (Leon & Sunil, 2013). Given the need to preserve building functionality in infrastructure, designers are turning to concepts of resilience which stress the need for a system to resist, adapt to, and recover from exposure to a broad range of hazards.

3 | METHODOLOGY

KIPPRA conducted a research survey in 27 counties that usually experience incidences of floods in Kenya. A total of 1500 households were sampled based on the National Sample Survey and Evaluation Programme V (NASSEP V) which is a household sampling frame developed by Kenya National Bureau of Statistics (KNBS). The primary data were gathered from a survey of 1370 households across the counties. Additional primary data were collected through key informant interviews from key government officials at the national and county governments as well as officials from private sectors and community-based organizations. To gain insights from interventions, the study reviewed documents such as policies, laws, infrastructure development plans, annual reports, and infrastructure evaluation reports from different sources. In addition, the study reviewed secondary sources such as Kenya Integrated Household Budget Survey (KIHBS) data for 2015–2016 to understand the distribution and access of infrastructural services at the household level.

The whole spectrum of questions the paper addresses centers on establishing the effects of floods on infrastructural users (refer to Figure 1). This involves establishing the effects of accessibility and availability of infrastructural services due to floods. It is expected that households usually experience increase in distance and time when accessing infrastructure services such as transport, water, and sanitation and buildings during and immediately after the incidents of floods. In addition, the effects of floods on infrastructure services vary with frequency and magnitude of the weather events. This study is based on the hypothesis that events of floods disrupt the infrastructure services accessed by households. Such infrastructure requires to be repaired or restored appropriately and in a timely manner so that the infrastructural services can resume. The quality of infrastructure determines the
degree to which infrastructures are susceptible to or unable to cope with adverse effects of floods.

Strengthening planning and development of infrastructure is critical in disaster mitigation, response, and recovery as demonstrated by Figure 1. Robust structures to manage vulnerability translate to enhanced resilience of infrastructure. In case of infrastructural damage, it is necessary to put in place measures such as repair and restoration efforts to minimize the disruption of functions. It is expected that planning and development of infrastructure should reference to resilience. In addition, developing and implementing climate sensitive policies as well as drawing critical lessons from the implemented infrastructure initiatives enhance infrastructure resilience.

4 | EFFECTS OF FLOODS ON INFRASTRUCTURE USERS IN KENYA

4.1 | Road infrastructure

The transport sector is one of the most affected sectors by floods and therefore the type of road surface usually determines the quality and durability of the roads in face of adverse weather conditions. According to KIHBS 2015–2016 data, 46% of road surface is earth road, 22% is murrum while tarmac is 7% and this means that most of the roads are prone to the effects of heavy rainfall. It is noted that 24% of the main roads were not passable throughout the year largely because of their unfair conditions during the rainy seasons. KIPPRA study sought to establish the levels of destruction of roads infrastructure due to floods experienced in 2017 and 2018 in various counties and observed that flood prone counties recorded high levels of destruction of road infrastructure due to excess water on the roads and this increased time to access road transport services. In addition, counties that have poor road network density presented fewer alternative routes to access markets and other social amenities thus increasing travel time. Overall, 47.6% of the counties reported an increase of time when accessing transport services during the rainy seasons. Further, it was observed that counties reported destruction of infrastructure, increase cost of accessing products and services and being cut off from other areas at percentages of 20.9%, 18.3%, and 9%, respectively. Other effects due to floods on road infrastructure are shown in Figure 2.

4.2 | Energy infrastructure

KIHBS 2015–2016 data reveal that 31.67% of the households used electricity connection from grid for lighting purposes. Only 16.11% use solar energy to light their households while 37% of the households use paraffin which is a nonrenewable energy. The data further reveal that 92.9% of the main electricity comes from the main power distributor Kenya Power Lighting Company (KPLC) and only 6.4% comes from solar-based sources. In terms of electricity connections per counties, KIPPRA study indicates that the urban-based counties show high connection rates to the main power grid while rural-based counties had the least connections to the grid. KIPPRA study reveals that counties experienced increased power outages during the floods periods. This is particularly due to weak installation and poor maintenance of electric poles and power transformers that are easily destroyed and swept away by running water. Further, during the rainy seasons, dams that support generation of hydro-electricity fail to handle huge volumes of water. There are several instances of water overflow in the dams leading to disruption of power provision thus increasing the number of power outages.

It was observed that when outages of the electricity occur due to incidences of floods, respondents resulted to...
using alternative sources of energy for lighting. Candles and paraffin accounted for about 81% while use of solar stood at 6.22%. It was noted that only 12% of the households have installed solar panels in their dwellings. In addition, KIPPRA study indicates that counties with highest levels of solar panels ownership per households were due to aggressive campaigns for households to adopt the solar energy. However, urban-based counties recorded lower ownership of solar since most households are connected to the power grid.

4.3 | Building structures

KIPPRA study reveals that the dominant roof material was iron sheet for household dwellings. It was observed that grass roofing for household dwellings was common in some drought prone counties due to the availability of the grass material as well as cultural practices. Similarly, iron sheet roof was dominant for health centers, schools, and market structures. The study reveals that level of destruction due to floods experienced in 2017 and 2018 brought different levels of destruction to building structures across counties. Largely health centers, schools, and market structures were minimally affected by the weather conditions. However, flood prone counties recorded highest levels of destruction of building structures. Similarly, the study reveals that counties that have semipermanent housing structures recorded highest levels of household destruction due to floods and households reported increased cases of property damages and death of human and livestock. According to KIHBS 2015–2016 data, 55% of household dwellings have mud as predominant material for wall. Other households have bricks, grass, and woods as predominant material for wall. Such materials generally may not be able to withstand the strong winds and heavy rains experienced during the rainy seasons.

4.4 | Repairing of damaged infrastructure

Repairing or replacing infrastructure after occurrence of a disaster is one of the practices carried out to address the damage. However, this is often very difficult, costly and slow. In addition, the actors responsible for repairing the infrastructure in various counties lack technical and financial resources to adequately restore the infrastructure services. Generally, the post repair and restoration of infrastructure due to floods have huge cost implication. Generally, 95% of critical infrastructure in the developing world is government-owned, and governments bear the responsibility to repair damaged infrastructure. In Kenya, both national and county governments have responsibilities of repairing the publicly owned and to some extent the privately owned infrastructure and this further exert pressure on available resources allocated for infrastructure restoration.

As noted earlier in KIPPRA study, building and maintaining certain infrastructure such as roads is usually costly. Table 1 provides a breakdown of how the government of Kenya has allocated funds to road agencies for different types of roads over the last 4 years. Generally, trunk and primary roads are expensive to build and maintain. More funds were allocated for maintenance in 2018/2019 following the floods that destroyed road infrastructure in 2017 and 2018. It was estimated that Kenya required USD 79.4 million to repair roads that have been damaged by heavy rains experienced in the country. A relatively significant amount of the funds come from the Roads Maintenance Levy Funds (RMLF).

In addition, there are other similar efforts carried out to restore transport services in Kenya. For instance, the Road Sector Investment Programme 1 (RSIP1) for 2010–2014 estimated that about USD 650 million was required annually for the maintenance of the entire road network. This did not however include the backlog maintenance.
This continues to demonstrate that the amount of resources allocated for maintenance is inadequate. In addition, creation of alternative road routes would be critical to ensure availability of transport services. Data from the State Department for Kenya indicates that an expansion of certain types of roads such as superhighways has not been carried out in the last 4 years largely due to the large cost of construction. However, minor roads have significantly increased since 2014 due to relatively lower cost of construction as well as increased demand to open up the rural areas for economic growth and development. Similarly, the total number of roads increased gradually from 2014 to 2018, an indication that the development of transport infrastructure is key in supporting the economic activities in the country.

4.5 | Role of communities and households

Local communities played a significant role in building and maintenance of community infrastructures such as roads, bridges, market, and school structures. KIHBS 2015–2016 data reveal that the willingness of local communities to make cash contributions to community projects has become better (47%) hence critical for community infrastructure development. Similarly, the data show that the number of self-help community initiatives is higher. Indeed, the level of participation of communities in local projects has become better (40%). In addition, it is observed that local communities participated in maintaining community infrastructures such as roads, buildings, and sources of water. Forty-four percent of the respondents believed that the level of maintenance of community infrastructure had improved. Further, the data reveal that the community programs, NGOs, house owners, and landlords largely funded the establishment and building of water resources. Similarly, the data reveal that different actors run community programs to maintain various sources of water.

4.6 | Time taken to repair damaged infrastructure

KIPPRA study established that different infrastructure took different time to be repaired.Damages on electricity grid, piped water, and own houses took less than 1 month to be repaired while damaged bridges and roads took relatively longer to be repaired. Restoring the services associated with basic needs took less time while other infrastructure services took relatively longer time. Infrastructure services that are costly to repair and initially funded by the government tended to take more time since the maintenance kit is usually inadequate as illustrated in Table 2.

5 | REVIEW OF SELECTED INFRASTRUCTURE PROJECTS IN KENYA

Different types of infrastructure projects are implemented with objectives of ensuring the availability of infrastructure services before, during, and after the events of floods. There are several projects implemented to provide infrastructure services in the events of floods in order to build resilience for different communities. Some interventions focused on restoring infrastructure services that have failed, damaged, or disrupted while others on new infrastructure. Some interventions are targeted towards long-term adaptations through entrepreneurial support from the households in order to support their livelihood sources during and after events of floods, while other interventions act as short-term mitigation measures to ensure smooth provision of infrastructure services during and after events of floods.

It is noted that technology has potential to increase the resilience levels for communities in need of water during the floods periods by improving efficiency, accountability, responsiveness, and transparency of water service providers. For instance, Majivoice is a platform for two-way communications between citizens and water providers using affordable, accessible, and user-friendly technologies. The application is built to strengthen dialog between citizens and water service providers and to ensure timely and transparent resolution of consumer concerns in case of any disruptions during the dry and rainy seasons. Similarly, MajiData application provides the water sector with the information required to measure impact and progress towards the achievement of the Sustainable Development Goals as well as targets set by Kenya’s Vision 2030. In Kibera (informal settlement in

| TABLE 1 | Kenyan Government funds allocation for maintenance and repairs of road infrastructure |
|----------|------------------------------------------|
| Funds allocation for maintenance and repair of roads in USD (millions) | 2014–2015 | 2015–2016 | 2016–2017 | 2017–2018 | 2018–2019 |
| 238.81 | 235.15 | 559.90 | 498.43 | 616.94 |

Source: State Department for Infrastructure and Kenya Roads Board.
the capital of Kenya), SODIS application has successfully facilitated access to water and more so to safe drinking water by use of solar technology. Families can save on fuel that was previously used to boil drinking water during flood and drought seasons. Other related projects supported by mobile technology include M-Maji that provides water information to empower the underserved communities with better information about water availability, price, and quality. The Trilogy Emergency Relief Application (TERA) is a SMS platform allowing its users to send geographically targeted messaging for communities to prepare for potential flooding situations. While some drought prone counties have developed water investment plans with an objective of tapping water during the flood periods and such water is used during the drought periods (Hilda et al., 2012).

The Kenya Off-Grid Solar Access Project (K-OSAP) is a flagship Project of the Ministry of Energy, financed by the World Bank for 6 years since July 2017 to June 2024. It aims to increase access to modern energy services in 14 underserved counties and when completed the project targets 277,000 households and facilitate the provision of 150,000 clean cooking stoves (REREC, 2021). To strengthen community resilience, various development partners are working together to promote the programs through Integrated Risk Management (IRM) approach to strengthen and protect livelihoods of vulnerable communities in Kenya during floods.

The review of various initiatives to improve access to infrastructure facilities and services demonstrate positive feedback in addressing challenges associated with floods and thus building resilience in infrastructure. The lessons drawn from the implementation of the infrastructure initiatives include: Technology plays a critical role in facilitating the success of various initiatives by generating resources such as funds, data, ideas, and exploration which are critical in building infrastructure resilience. It is critical to ensure initiatives involve the right actors and target the local problems. This will ensure projects fast implementation, adequate support from partners as well as buy-in from the government and local communities. It is important to promote cooperation and sharing of information regarding the initiatives at the county and sub county levels on shared resources such as water catchment areas.

### TABLE 2

| Repair time                        | Responsibility           | Roads (%) | Bridges (%) | Electricity grid (%) | Piped water (%) | Own house (%) | Market structure (%) | School structures (%) | Communication facilities (%) | other |
|------------------------------------|--------------------------|-----------|-------------|----------------------|-----------------|---------------|----------------------|--------------------------|--------------------------------|-------|
| Less than 1 month                  | Local community          | 6         | 5.9         | 26.6                 | 24.8            | 7             | 5                    | 6.2                      | 6.2                            | 57    |
| Less than 6 months                 | County government        | 13        | 6.5         | 3.9                  | 6.5             | 5             | 3                    | 2.4                      | 2.4                            | 13    |
| More than 6 months                 | National government      | 11        | 6.7         | 3.7                  | 1.2             | 5             | 0                    | 0.1                      | 0.1                            | 11    |
| More than 1 year                   | NGOs                     | 13        | 2.5         | 0.7                  | 1.2             | 1             | 1                    | 0.3                      | 0.3                            | 13    |
| None (never repaired)              | Family/self              | 47.7      | 6.7         | 11.3                 | 4.7             | 12.2          | 1                    | 0.9                      | 0.9                            | 47.7  |
|                                   | Others                    | 33.2      | 11.3        | 3.9                  | 7.7             | 1.2           | 2                    | 3.9                      | 3.9                            | 33.2  |
| Source: KIPPRA survey.             |                          |           |             |                      |                 |               |                      |                          |                                |       |

6 | REVIEW OF THE LEGAL AND POLICY FRAMEWORK FOR INFRASTRUCTURE IN KENYA

Developing countries invest significant resources into infrastructure to upgrade existing systems, facilities and
to build new networks and structures to support economic growth. However, all types of infrastructure, including energy, transport, and buildings are affected by climate change. As earlier noted, rising temperatures, increased flood risk, and other potential hazards threaten the reliable and efficient operation of these infrastructure, and hence likely to have large economic and social impacts (Unterberger, 2018).

Human led factors have continued to contribute to climate variability in developing countries which in turn weakens the existing infrastructure to absorb the shocks of floods. Practices that expose infrastructure to more harm include but not limited to inadequate rural and urban planning, delayed repairs, destruction of forests and water catchment areas, building houses along river banks, use of poor building materials leading to nonresistant structures and foundations that cannot withstand the running waters and thus putting high risks on infrastructure (Opere, 2013). Therefore, planning, implementing, and maintenance of various infrastructure projects should incorporate vulnerability component and how to deal with the increasing weather risks. Incorporating resilience in infrastructure would assist in reducing the extensive damage usually reported due to floods.

Infrastructure assets are generally capital-intensive, long-lived, and interdependent across many sectors. Decisions made about the location, planning and design, technology and materials used, type of operation, and maintenance of the infrastructure determine their longer-term resilience to the effects of climate change (Deloitte Access Economics, 2012). Strengthening resilience in infrastructure is an essential component of climate adaptation, particularly since adequate, reliable infrastructure underpins growth. Taking infrastructure resilience into account can protect investment returns, support business continuity, and meet regulatory requirements. Vallejo and Mullan (2017) identify common barriers in building resilient infrastructure such as lack of awareness or information, short-termism, and misaligned regulatory incentives. This calls for developing countries to formulate appropriate legal and policy frameworks that guide the policy makers on building infrastructures that are resilient to climate change.

The Infrastructure sector in Kenya is served by various laws and policies in the regulatory and institutional framework (Kenya Law, 2021; KIPPRA, 2021). The existing legislations provide for numerous guidelines for the development and management of infrastructure. The existing legal and policy framework guide the development of the infrastructure in various stages but do not clearly indicate how resilience is achieved and guaranteed. Generally, the legal and policy frameworks for Kenya were developed at different times by different actors to spell out the scope, functions, and the responsibility owners for various infrastructure. For instance, the Physical Planning Act (Kenya Law, 2021) spells out clearly how the planning of infrastructure is carried out but does not clearly guarantee the embedding of resilience aspects during the planning phase of infrastructure. As noted earlier, infrastructure resilience should be reflected from the planning phase to the design, development, and maintenance of infrastructure (Deloitte Access Economics, 2012). Kenya lacks comprehensive and up to date climate data collected over time from adequate and reliable sources and analyzed over time to accurately inform the design and development of physical infrastructures (Kenya Law, 2021).

Large part of the existing infrastructure in Kenya is based on outdated technologies, standards and codes that are prone to climate risks (Kenya Law, 2021). For instance, most of the infrastructures particularly roads and buildings are based on outdated building codes and standards developed in 1960s (NCA, 2021). This largely explains why most of the infrastructure is not able to withstand the effects of floods resulting to massive destruction of the infrastructure. Some existing policies on infrastructure have not been updated many years since their approval and do not reflect the aspects of resilience (Kenya Law, 2021; KIPPRA, 2021).

The development of infrastructure too is influenced by the regional and international frameworks that are ratified by Kenya (EAC, 2021; The African Union Commission, 2021). For instance, regional programs such as Africa Regional Strategy for Disaster Risk Reduction and Disaster Risk Management Programme outline clear vision of managing risks. However, effective implementation of the regional strategies, policies, and treaties on risk management for infrastructure is a challenge. Thus, the vision of risk managed approach being aligned to the local policies for development of resilient infrastructure is critical. In addition, well-designed and locally specific regulations that translate to a set of rules and laws are central to this effort. Regulations that translate safe practices for design and construction and specify minimum agreed levels of safety and resilience for infrastructure are critical.

7 | CONCLUSION AND POLICY RECOMMENDATIONS

Climate change induced events such as flooding continue to threaten the reliable and efficient operation of infrastructure services, causing major socio-economic disruptions. Due to outages associated with floods, the majority of the infrastructure users in developing countries
experience increased time and distance as well as cost to access the infrastructure services. Despite the existence of laws, policies, regulations, and strategies, Kenya has not succeeded in building resilient infrastructure to withstand the effects of floods.

To build resilient infrastructure there is need to develop and implement climate sensitive policies, legislation, and infrastructure development plans to address the growing risks arising from weather-related events. Priority actions include adopting resilience engineering into the infrastructure planning, development, and maintenance based on appropriate building standards and codes. Enforcing and strengthening the adoption of the new building codes and standards can significantly reduce the effects of floods on infrastructure. Proper choice of location for infrastructure coupled with the use of climate-based data to inform the choice of climate resistant materials should be considered when planning and developing infrastructure. It is essential to build up a second line of defense in case the first defense line fails. Consideration for warning systems that target popular communication methods such as social media and are in local languages should be made. Rescue measures, installed in flood prone areas focusing on the main flood events should also be put in place. In addition, expenditure flexibility and a responsive budget process should support infrastructure reconstruction by acting as a form of fiscal buffer. The budget should include contingency spending items that are only activated in the event of disasters.

The analysis of KIPPRA study revealed that communities have increased their level of participation in community projects. Local communities in some counties participated in good time and were responsible in maintaining and repairing of the roads, bridges, and building structures. Therefore, there is need to strengthen and raise awareness on the role of local communities and county governments in maintaining and repairing of the damaged infrastructure across various counties. Adopting effective methods of early engagement of stakeholders and establishing their roles is critical in building infrastructure resilience.

It is important to promote and strengthen the usage of renewable sources at the household level such as solar power. This reduces reliance on hydro-based power which is negatively affected by overflowing and silting of water dams during rainy seasons. Adopting solar power at household level would also mean less destruction to environment through activities such as charcoal burning.

Finally, building a common vision on resilience in regard to infrastructure demands support across different stakeholders. It is critical to build strong institutional and cross-coordination thus facilitating effective communication and fostering of synergies, and mobilize national and international communities, including private sector to strongly and consistently invest adequate resources to protect infrastructure against known and foreseen climate risks.

**DATA AVAILABILITY STATEMENT**

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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