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Review

Interaction between infrastructure and climate change on buildings, roads, and bridges in developed and developing countries: a case of Japan and Mozambique

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ABSTRACT

This research aims to investigate the effects of climate change on roads, buildings, and bridges infrastructures and provide solutions adopted in developed and developing countries to reduce or mitigate the impact of climate change on infrastructures. The methodology applied in this research consists of three parts, first in-depth research was carried out on Japan and Mozambique to assess the reasons these countries have a high-level impact of events generated by climate change, followed by an analysis of possible causes behind the high exposure to events generated by climate change, comparison in terms of temperature, precipitation, storms, earthquakes, floods, droughts and cyclones during the last 40 years, followed by measures adopted in both counties to reduce the impacts on infrastructure. In accordance with the result of the research, geographic location, climate, development, and economic expansion are major elements that may render developed and developing regions more vulnerable to catastrophic disasters. Furthermore, the methods used to combat climate change are mostly determined by the availability of materials, technologies, and cost aspects.

1. Introduction

Climate changes provide infrastructure policymakers with both immediate and long-range issues. Addressing this difficulty in a thoughtful and balanced manner is crucial to the effectiveness of adaptation measures [1]. Environmental impacts, such as environmental pollution and acidification of lakes and reservoirs, erode air and water quality and deplete economically and environmentally significant resources. Climate change is exacerbating these issues by threatening the economy and the environment, as well as forcing irreversible changes in both developed and developing countries [2]. Climate scientists know that social activity is warming the world in ways that will have far-reaching and uncomfortable consequences for natural resources, energy consumption, ecologies, business output, and human well-being. Gas in the atmosphere (GHG) emissions have caused global warming. Decisions made nowadays, especially those relating to the redesign and restoration of existing transport networks or the placement and development of product transport systems, will have a long-term influence on the system's ability to adapt to climate change. Immediately focusing on the problem should help reduce potential future investments and operational disruptions [3]. Roads, buildings, and bridges are vital worldwide assets for countries and businesses. Managing this asset needs effective decision-making that emphasizes economic cost-benefit analysis, often at the expense of external variables like public welfare, environmental costs, and the effects of climate change. In the case of developing countries, this may be a dual challenge and an opportunity [1]. This research concentrates on the interaction between infrastructure and climate change in developing and developed nations, with a particular emphasis on roads, bridges, and buildings in Japan and Mozambique. Furthermore, this research aims to compare natural hazards such as temperatures, precipitation, droughts, cyclones, and floods, together with the adaptation mechanisms used in both countries to respond to severe events. Throughout the analyses, special attention is paid to variations in climate outcomes, with a focus on extreme events such as cyclones, floods, and droughts.

1.1 Impacts of climate change on roads, bridges, and buildings infrastructures

Temperature change difficulties and implications for infrastructure and urban areas center on temperature and weather factors as well as occurrences that are expected to vary in size or frequency as a consequence of changing climate. Variations in average global temperature and extreme heat, together with heat and/or cold waves, changes in precipitation amounts and patterns, along with extreme storms and inundating; changes in weather systems, intensities, and densities; and sea-level rise are all associated with vulnerabilities and risks [4]. The several impacts of climate change on bridges, roads, and buildings will be discussed in this subsection.

1.1.1 Buildings

A changing environment is predicted to have a critical impact on the deterioration of building materials and expedite the process [5]. Damages to buildings in lower portions of rivers induced by direct water influence are often associated with damage and degradation of building material properties as a consequence of lengthy water pressure [6]. In general, structures can be destroyed by high winds if the construction technology and materials are inadequate. The wind has recently damaged roofs with corrugated asbestos-cement roofing sheets and box-rib or corrugated metal roof panels. In both circumstances, lighter materials with an enormous surface area are used [7].

1.1.2 Roads and bridges

Climate change will almost undoubtedly exacerbate current traffic difficulties and worsen the state of bridges in both industrialized and developing countries [8]. Higher temperatures, greater precipitation and humidity levels in some places, and increasing carbon levels in the environment may all contribute to a higher risk of bridge damage. The principal impact of climate change on roads and bridges are Increased long-term displacements, higher erosion frequency, tumble collapse and avalanche, structure resettlement, rockfalls, snow avalanches, extra pressures on structures, silt contraction and expansion, longer wavelengths impact, increased demand drainage capacity [5]. Premature degradation of road pavement, causing more cracked areas, disruption of access, and infrastructure damage. Porous asphalt deterioration results in spalling, pothole damage, and lost revenue at longitudinal seams. Pavement life is reduced owing to early material and structural deterioration [9].

1.2 Contextualization of the research

To develop the research on the interaction between changes and infrastructure in roads, bridges, and buildings, Mozambique and japan were selected as illustrative cases of developing and developed countries because of their high risk to natural disasters as well as Japan is the most threatened country in the world by climate change mainly due to heavy rains, earthquakes, typhoons, and heat waves. On the other hand, Mozambique, with its location around the Indian Ocean, has been one of the most affected by cyclones in Africa, mainly in the past 20 years. This section attempts to provide an overview of both nations, focusing on their geographical location, climate, and precipitation.

1.2.1 The geographical location of the research area

Mozambique is located on the eastern coast of southern Africa, 11-26 degrees south of the equator, and has a tropical to a subtropical climate that is moderated by its mountainous topography and influenced by the movement of the intertropical convergence zone, El Niño, and surface temperatures in the Indian Ocean, all of which can vary from year to year due to changes in atmospheric and oceanic circulation patterns. This country's rainfall distribution follows a north-south gradient, with greater rainfall around the coast, where the annual average is between 800 and 1200 millimeters (mm). Summer average temperatures near the shore range from 25 to 27º Celsius, while winter temperatures range from 20 to 23º Celsius. Approximately 23 million (estimated - July 2012); rising population growth rate of 2.5%; Moreover 70% of the population lives in rural regions, with agriculture being the most significant major activity [12].

Japan is an archipelago nation located off the East coast of Asia, consisting of four main islands, from north to south: Hokkaido, Honshu, Kyushu, Shikoku, and over 3500 smaller islands. Because Japan covers over 2,360 kilometers, the inhabitants experience a wide range of weather conditions. The winter months in Japan's east are dry. The mountains limit the moisture boundaries; the Pacific side receives less, and the Sea of Japan shore receives tropical showers. Summer in Japan is quite humid. The Japan Current (Kuroshio) ensures a pleasant autumn. Typhoons (hurricanes) with high winds over water make landfall in the southeastern section of the nation around November [13].

2. Methodology

This study was divided up into three stages: the first involved the selection of the developed and developing nations, accompanied by the gathering of data on roads, bridges, and buildings, and finally, the analysis of the data acquired for Mozambique and Japan. To collect data for this study, a platform called Climate Change Knowledge Portal for Development Practitioners and Policymakers (CCKP) was applied, along with Excel, to generate graphics and analyze the data.

2.1 Climate knowledge portal

The Climate Change Knowledge Portal (CCKP) serves as the World Bank Group's central repository for climate-related information, data, and tools (WBG). The Portal provides an online platform for accessing and analyzing extensive data on climate change and development. Climate data aggregates are now available at the national, subnational, and watershed levels. The use of versatile methodologies, relevant information, and instructive techniques that can deliver detailed data to a broad range of users, enabling them to apply research evidence to the design of a project or policy, is often required for the successful integration of scientific information in decision-making. Figure 1 illustrates the geographical location of Mozambique and japan as the case of developed and developing countries.

(a)

(b)

Figure 1. (a) The geographical location of Mozambique [10], (b) The geographical location of Japan [11]

3. Discussion

3.1 Comparisons between Mozambique and Japan

The purpose of this research is to examine severe occurrences in Mozambique and Japan, as well as the strategies used to deal with the consequences of climate change. As a result, this research emphasizes the contrast in terms of precipitation, temperatures, cyclones, droughts, floods, and storms in this section. In addition, a comparison of solutions will be addressed.

3.1.1 Temperature

Temperatures have risen in recent decades due to climate change, and many cities have seen high temperatures on both sides, maximum and lowest. The figures below depict temperature changes in Mozambique and Japan during the last 40 years. Figure 2 clearly shows the minimum temperatures measured in both nations showing that the minimum temperature in Japan before the development or growth in factors was over 7º. Ten years later, the lowest temperature increased dramatically, with temperatures over 8º. A relatively similar situation endures to this day, with exponential growth tendencies. Since the 1980s, Mozambique has seen high-low temperatures of 18º. The country had a minor increase in temperature during the decades of 1990 and 2000, with a 1º increase in temperature in 2010 and a temperature that has remained steady till today, with some tendencies to climb slightly in the next years. The same approach can be seen in Figure 3 for maximum temperatures in Mozambique and Japan.

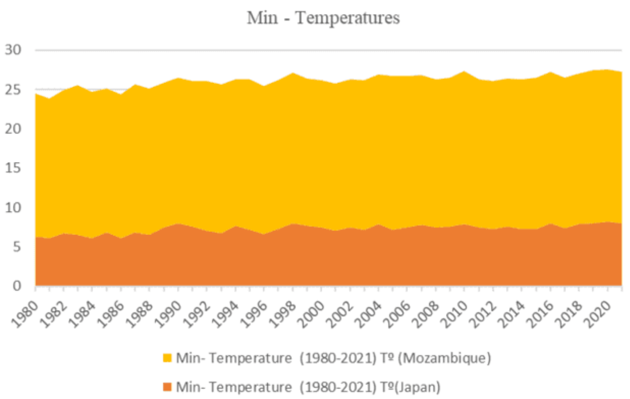

Figure 2. Minimum Temperature in Japan and Mozambique from 1980 to 2020

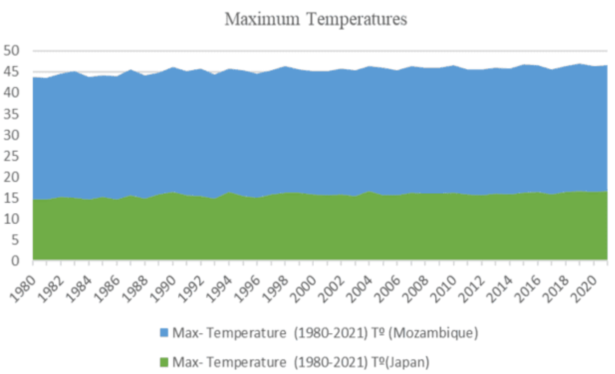

Figure 3. Maximum Temperature in Japan and Mozambique from 1980 to 2020

In Japan, the maximum temperature has increased by 2º during the last 40 years. In the first decade (1980), the temperature was 14º, with some changes during the decade; in the second decade, the temperature increased to 16º, with some oscillations throughout the third decade; this scenario continues to the present day, with a strong propensity to rise in the following years. Mozambique, on the other hand, had slight variations in maximum temperatures during the previous 40 years, with 29º in the early decades and slight swings. This country witnessed a 1º increase in maximum temperature in 2010, followed by several declines until 29º, which remained constant until the actual days, with some tendency to climb slightly in the following years. With regards to Mean Temperature (Figure 4), Japan kept with the same tendency over the last 40 years, with an increase of 2º in its mean temperatures from 10º to 12º, while Mozambique trends an insignificant change over time, with 23º to 24º over the last 40 years.

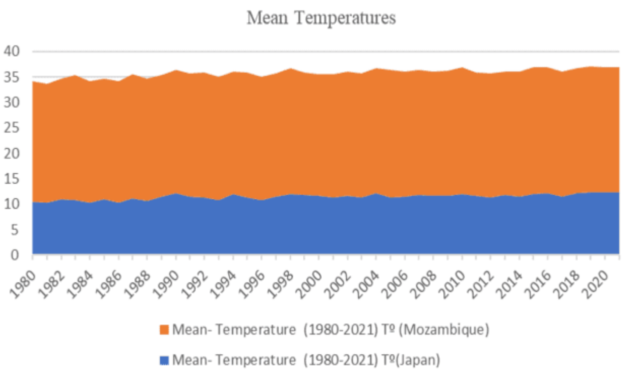

Figure 4. Mean Temperature in Japan and Mozambique from 1980 to 2020

3.1.2 Precipitation

In recent years, Japan has received the highest proportion of precipitation compared to Mozambique. This country had the most precipitation in the first decade, with 1919 mm, compared to 953 mm in Mozambique. Over the second decade, precipitation in Japan fell to 200 mm, compared to 100 mm in Mozambique. While Japan suffered another decline in precipitation of more than 400mm in the third decade, Mozambique witnessed a rise of 200 mm, representing the greatest value of precipitation reached by this nation, with around 1200 mm to the current day. However, Mozambique's precipitation has decreased over the previous two decades, with 100mm in the third decade and 200mm in the fourth. Meanwhile, Japan has seen a 200 mm rise in the previous two decades. Figure 5 reveals the quantities of precipitation in Mozambique and Japan over 40 years.

3.1.3 Cyclones

Compared to Mozambique, Japan has a record of one or more cyclones yearly, signifying the highest number of cyclones over 40 years. However, Mozambique had followed Japan's pattern of having more than one cyclone each year, with high concentrations in coastal regions, such as in 2022, when Mozambique was hit by three cyclones in less than six months. The storm was followed by high winds, floods, and heavy rain, destroying Mozambique's central and northern coastal cities. Figure 6 demonstrates the occurrence of cyclones in both countries over 40 years.

3.1.4 Floods, landslides, and storms

The graph (Figure 7) compares the incidence of Floods, droughts, earthquakes, and storms in both nations; it is feasible to understand that Japan is heavily affected by storms with the largest quantity compared to Mozambique. Earthquakes and landslides are very common in the nation. As a result, Mozambique has the greatest record of flood incidence when compared to Japan. Furthermore, this country has undergone droughts during the previous few decades.

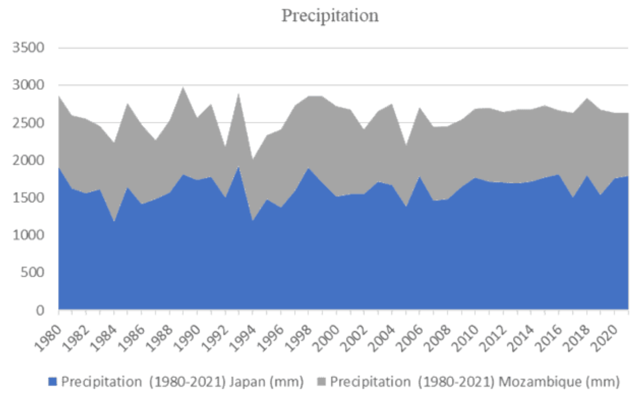

Figure 5. Precipitation in Japan and Mozambique from 1980 to 2020

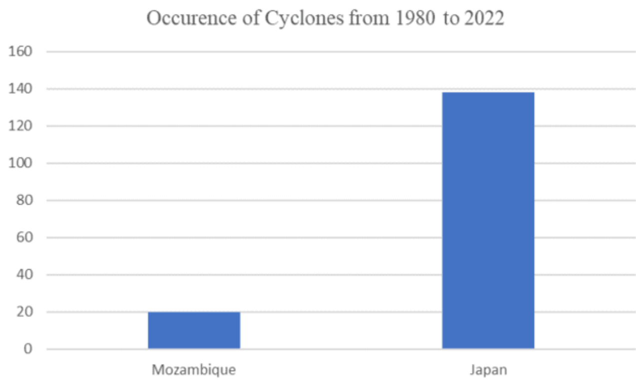

Figure 6. Occurrence of Cyclones in Mozambique and Japan from 1980 to 2022

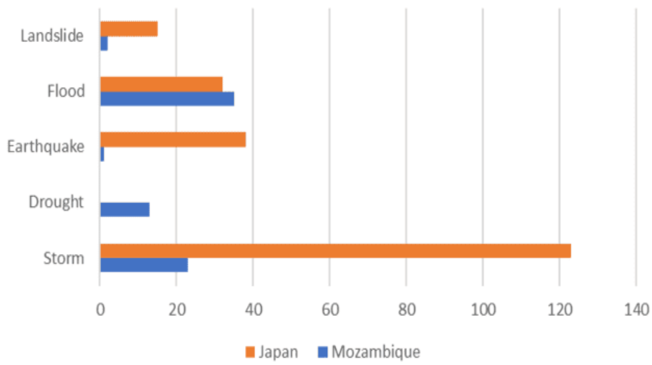

Figure 7. Floods, droughts, and storms occurred from 1980 to 2021

3.1.5 Solutions adopted in Mozambique

Mozambique, in particular, is a country rich in natural resources, from its soil to its large forests, passing through its big rivers and even its vast mineral deposits. It also gives simple access to natural construction resources. Ref [14] argued that traditional housing materials are the most sensitive to weather impact since they are used in their original condition. Using materials in their natural condition becomes a more ecological, less polluting alternative, as well as under numerous sustainable characteristics that may be summarised, such as boosting the energy efficiency of buildings. However, one of the most challenging challenges in the building industry has been to match the notions of sustainability with the disposition of the material desired. The materials most used in Mozambique for construction, especially in rural areas, are zinc, bamboo, stone, clay, and timber.

- **Buildings:** To alleviate the impacts of climate change, Mozambique developed stilted buildings (Figure 8) to allow inhabitants to reach their homes even during extreme occurrences such as floods or heavy rains. This method comprises towering pillars at a height higher than the ground, often 3 m, depending on the purpose of the building and the slope of the land. In this nation, the major materials utilized in this technology were Bamboo for the structure (columns, beams, roof structures, and wall structures) and reinforced concrete for the foundations. This solution was implemented in the North and center of Mozambique in rural areas, where the populations have no access to conventional materials as well as they don't have enough information related to construction. Additionally, this solution provides numerous vantages for the population, mainly because it is low-cost contrition, and 90% of the materials employed for this kind of house can be found in nature. Bamboo is a robust, fast-growing, and extremely sustainable material that has been utilized architecturally in many regions of the world for thousands of years. As seen by several visually spectacular contemporary projects, it has the potential to be an aesthetically beautiful and low-cost alternative to more traditional materials such as timber [15]. Bamboo has a highly strong fiber as a building material. Bamboo has double the compressive strength of concrete and a tensile strength comparable to steel. Bamboo fiber has a higher shear stress than wood. Bamboo has a longer lifespan than wood. Bamboo may also be bent without breaking. Bamboo is regarded as one of the strongest building materials, with tensile strengths greater than and less than 28,000 N per square inch, as opposed to steel, which has a tensile strength of 23,000 N per square inch [16]. Bamboo can withstand greater strain than compression. Bamboo fibers run axially and are made of a highly elastic vascular bundle with high tensile strength. These fibers have a higher tensile strength than steel, but it is impossible to build connections that can convey this tensile strength. Slimmer tubes are also superior in this regard. Axial parallel elastic fibers having tensile strengths of up to 400 N/mm^2 can be detected inside the silicate outer skin. In comparison, particularly strong wood fibers may withstand tensions of up to 50 N/mm^2. Bamboo as a construction material has the following advantages and disadvantages: it is the most rapidly increasing renewable natural construction material, the material is easily accessible and environmentally friendly, as an independent construction material, bamboo is a feasible alternative to steel, concrete, and masonry, it is inexpensive and simple to use, it may be readily bent, shaped, and provided with joints to fit the building, its incredible flexibility makes it an excellent construction material in earthquake-prone locations. Locally accessible materials are used in certain regions to preserve the local tradition and vernacular architecture, durability- Because bamboo is susceptible to insects, untreated bamboo is regarded as transient with a lifespan of fewer than 5 years, jointing- despite the fact that numerous joints are used, structural efficiency is low, inadequate design advice and codes [17].
- **Roads & Bridges:** In Mozambique, the roads and bridges were reconstructed using the same technologies, with great attention to extreme events, due to emergencies applying modular designing (Figure 9) to bridges made of steel modular structures to help in the restoration of the transportation and rapid adaptation of the country, and maintenance. A modular building is a pre-engineered steel structure, which implies that its components, or modules, are created in a factory setting to the same regulations as traditional structures. Commercial trucks deliver the completed modules to a building site, where they are assembled by a function Object. Each module is placed to create a self-supporting structure capable of supporting another modular unit on top. While this can be advantageous for segmented vertical construction, it has limitations for large-scale structures. This is especially true for structures broader than a semi-truck bed. This solution has the following benefits, which were grouped into five categories: a project schedule, project cost, labor safety, project quality and productivity, and environmental [19]. The restrictions were also explored and grouped into five areas based on existing literature: project planning, transportation, public and expert acceptability, establishment cost and cost owing to complexity, and coordination [20].

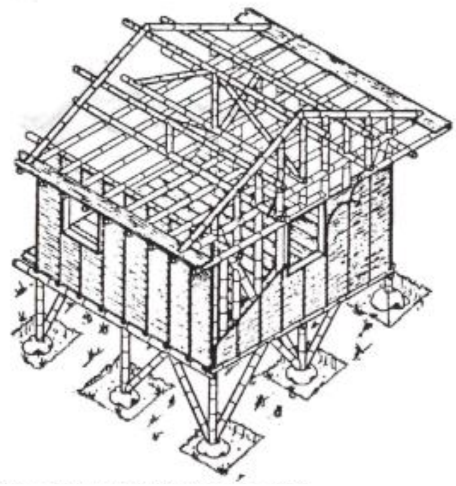

Figure 8. The solution adopted in Mozambique in the most affected areas (rural areas) to withstand climate change [12]

Figure 9. The bridge was reconstructed by using a steel structure to withstand climate change impacts in the North of Mozambique [18]

3.1.6 Solutions adopted to Japan

Rapid development has resulted in the eradication of agricultural areas and woods, which naturally help to collect and absorb rainwater. As a result, the quantity of surface runoff pouring into the river has increased, increasing the likelihood of floods [21].

- **Buildings:** To resist the worst floods, japan devised a new form of construction called pilotis structures, which includes reinforcements like pillars, supports, or piers that lift a structure above land or water. A grid of slender reinforced concrete pylons that sustain the structural weight of a structure. Figure 10 shows the application of pilots in Japan as a solution to combat the impact of climate change on buildings. Figure 10 illustrates a pilotis structure implemented in japan residential buildings. This solution was implemented in Yokohama city. The climate of Yokohama is moderate, with pleasant, sunny winters and hot, humid, and wet summers. The city, like the rest of Japan, is influenced by the monsoon circulation: in winter, northwest cold currents predominate, while in summer, hot and humid tropical currents take their place. Yokohama is located in Tokyo Bay, close to the Japanese capital. Given the relatively low latitude and the shelter of the mountain, the Siberian currents are felt little in winter, resulting in a reasonable number of sunny days and temperatures that are not too chilly [22].

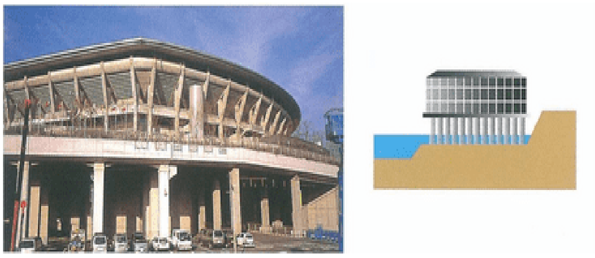

Figure 10. Pilotis structure employed for Nissan Stadium [21]

Pilotis are a type of vernacular architecture created using traditional techniques and materials such as bamboo, timber, straw, etc. High buildings as being those in which the foundation is not immediately lying on the ground but is raised with structural pillars or columns of different heights, typically more than two meters. In other terms, the pillars or columns are the structures that hold the structure together [23]. The Sob-Pilotis solution offers the following benefits and drawbacks [24]: Ease of construction on unstable and sloping terrain; When built on water, they give the impression of floating;

- Acceptability in areas with rough and muddy terrain; Acceptability in wetlands;
- It is possible to construct beneath embankments; it has an ecological aspect because no soil waterproofing is required; it prevents pathological issues;
- Protection against a potential flood;
- Buildings' environmental effects must be reduced.

- **Roads and Bridges:** To reduce the impacts of climate change, mainly due to flooding, Japan adopted the above technique as an opportunity to reduce runoff volume by helping the water in filtering into the soil, decreasing urban heating, and reducing flash floods. Fig.10 illustrates the permeable pavement in Taipei city. Permeable pavements are often made of permeable concrete, asphalt pavements, permeability interlocking concrete paving modules, or grid-type systems installed across an accessible base/subbase layer. Permeable pavements filter and remove pollutants, minimize peak flows, and enhance groundwater recharge. Permeable pavement systems, regardless of surface, contain three design techniques. First and foremost, they are intended to encourage complete or complete penetration of rainwater into the soil subgrade. Second, where soil subgrade infiltration rates are limited, partial infiltration occurs, and the remaining water departs via underdrains. Third, for designs that do not need infiltration, permeable pavement solutions are encased in a geomembrane that keeps detained water from entering the soil subgrade and allows it to depart through underdrains [25].

4. Conclusion

Climate change is expected to have an influence on roads, bridges, and road infrastructures by altering the pattern of extreme climatic events such as temperature, precipitation, floods, earthquakes, droughts, and storms. Considering everything in the effort it is possible to conclude that despite their dissimilar economic realities, Mozambique and Japan face the same challenges in battling climate change. As a developed country, Japan has stronger technological and economic resources to adapt and respond to climate change, and the urban areas are the most affected by extreme events. In contrast, Mozambique has the most people and is the most exposed to catastrophic occurrences in rural regions. Moreover, the country has a set of deficient infrastructures, which gradually contributes to the increase of the consequences of these events on the population, economic power, and technologies, which do not facilitate the collection, processing, and production of solutions that can help to battle these events in the long term and effectively, reducing the number of losses in major infrastructure, economic resources, and human terms. Additionally, geographic location and climate are important factors that may render individuals more vulnerable to catastrophic disasters as well as development and economic expansion are critical elements in both increasing and mitigating different losses caused by climate changes. Furthermore, the methods used to combat climate change are mostly determined by the availability of materials, technologies, and cost aspects.

Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere.

Data availability statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflict of interest

The authors declare no potential conflict of interest.

References

[1] Schweikert et al. (2014). The infrastructure planning support system: Analyzing the impact. Journal of transport policy, 35(2014)146-153. DOI: 10.1016/j.tranpol.2014.05.019

[2] Andrea, T., & Michael, C. (1986). Climate impacts threatening Japan today and tomorrow.WWF. https://www.wwf.or.jp/activities/lib/pdf_climate/environment/WWF_NipponChanges_lores.pdf.

[3] Busalacchi et al. (2008, june). Pontential Impacts of Climate Change on U.S. Transportation. Washington, D.C., United States of America: National Research Council. https://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf

[4] Backus et al. (2012, February 29). Climate Change and Infrastructure, Urban System, and Vulnerabilities. U.S. Departament of Energy. https://www.esd.ornl.gov/eess/Infrastructure.pdf

[5] Nasr et al. (2019, September 26). Bridges in a changing climate: a study of the potential impacts of climate change on bridges and their possible adaptations. Journal of Structure and Infrastructure Engineering. vol 16, 738-749. https://doi.org/10.1080/15732479.2019.1670215

[6] Wilk, K. (2018). Hazards for buildings and structures caused by flood conditions. E3S Web of Conferences 45, 00101 (2018). https://doi.org/10.1051/e3sconf/20184500101

[7] Kusar, D. (2017, May 04). The Impact Of Natural Disasters On Buildings Architectural Styles. Acta geografica Slovenica. DOI: 10.3986/AGS48104

[8] AECOM. (2015, November). Incorporating Climate Change Adaptation In Infrastructure Planning And Design. USAID. https://www.climatelinks.org/sites/default/files/asset/document/OVERARCHING_METHODOLOGY_CCA_ENGINEERING_DESIGN.pdf

[9] Abreu et al. (2022, July 20). Climate Change Impacts on the Road Transport Infrastructure: A Systematic Review on Adaptation Measures. Sustainability. https://doi.org/10.3390/su14148864

[10] https://en.wikivoyage.org/wiki/Mozambique

[11] https://www.whereig.com/japan/map-political.html

[12] Ramsbottom, D., & Lumbroso, D. (2017, October 15). Sustainable Flood Risk Management strategies to reduce Rural communities Vulnerability to flooding in Mozambique. Journal of Flood Risk Management. DOI: 10.1111/j.1753-318X.2008.00005.x

[13] Petry, A. (2003, July). Geography of japan. Japan Digest. http://www.indiana.edu/~japan/Digests/geo.html

[14] Chinowsky, P., Schweikert, A., Strzepek, N., Strzepek, K., & Kwiatkowski, K. (2012, December). Infrastructure and Climate Change: Impacts and Adaptation for south Africa. United Nations University. http://hdl.handle.net/10419/80906

[15] Kaminski et al. (2016). Structural use of Bamboo: Part 01: Introduction to Bamboo.https://www.researchgate.net/publication/305808084_Structural_use_of_bamboo_Part_1_Introduction_to_bamboo

[16] Nurdiah, E. (2015, September). The Potential of Bamboo as Building Material in Organic Shaped Buildings. Procedia. http://dx.doi.org/10.1016/j.sbspro.2015.12.004

[17] Raj, D., & Agarwal, B. (2014, August). Bamboo as a Building Material. Journal of Civil Engineering and Environmental Technology. http://www.krishisanskriti.org/jceet.html

[18] https://www.afdb.org/en/news-and-events/press-releases/mozambique-african-development-bank-purchases-temporary-bridges-replace-infrastructure-destroyed-cyclones-42587

[19] https://gensteel.com/building-faqs/building-comparisons/versus-modular-buildings/

[20] Subramanya et al. (2020). Modular Construction vs. Traditional Construction: Advantages and Limitations: A Comparative Study. https://www.researchgate.net/deref/https%3A%2F%2Fdoi.org%2F10.3311%2FCCC2020-012

[21] Ikeuchi, K. (2012, March 13). Flood Management in Japan. Water and Disaster Management Bureau. https://www.mlit.go.jp/river/basic_info/english/pdf/conf_01-0.pdf

[22] https://www.climatestotravel.com/climate/japan/yokohama

[23] Greissler et al (2007). Palafitas Tipologias Habitacionais em Áreas Costeiras de Frianópolis. VII Seminário Internacional da Lares, São Paulo. https://dx.doi.org/10.15396/lares_2007_t082-geissler_oliveira

[24] https://timberarquiteturaeengenharia.wordpress.com/2018/02/26/terreno-acidentado-dicas-para-projeto-em-aclive-e-declive/

[25] Cheng et al. (2019, December 13). Field Testing of Porous Pavement Performance on Runoff and Temperature Control in Taipei City. MPDI. https://doi.org/10.3390/w11122635