Transportation planning and resilience in countries with high risks of natural disasters: The case of Haiti

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Abstract

The purpose of this study is to uncover Haiti's existing transport infrastructure, the challenges that it has endured in the disaster response process, the strategies for disaster response that have been put in place, and the plans for transportation and resilience in the face of natural disasters. The case study design was adopted for the research, with the data obtained from official documentation and archival records. The analysis of the data reveals that transportation diversity is limited in most locations, the inaccessibility of some areas by road remains an obstacle to disaster response, and that Haitian sectoral laws, along with the activities of international organizations, have enhanced the government's capacity for natural disaster response. Recommendations for practice are presented in light of these findings.

Keywords: Transportation, planning, resilience, natural disaster, recovery, response, relief

1. Introduction

Natural disasters are inevitable occurrences around the world, especially with the rise in climate change being a contributory factor. According to Guo and Quayyum (2020), many small countries are highly vulnerable to natural disasters and the negative impacts it has on human lives, property, and the economy in general. The island nations in the Caribbean and Pacific are among the most vulnerable to natural disasters. One of the nations is Haiti, which has suffered a series of natural disasters that devastated the economy, led to massive losses of lives, and destroyed the infrastructure. For instance, Hurricane Jeanne hit the nation in 2004, taking more than 4,000 lives. In 2007, Tropical Storm Noel caused mudslides and

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flash floods in Western Haiti, with 66 losing their lives and 15,000 homes getting destroyed (World Bank, 2016). The 2008 hurricane season also caused severe damages, but the 2010 earthquake was the most devastating disaster the nation endured as it led to the loss of more than 200,000 lives, left 1.5 million homeless, and generally affected more than three million people.

The occurrence of disasters such as hurricanes, earthquakes, floods, and tsunamis does not only cause disruption to human life but also greatly affects the critical infrastructure systems of the affected regions (Zhu et al., 2021). One of the infrastructure systems that get adversely affected by natural disasters is the transportation network. The transport network is a necessity for disaster response and recovery. As Zamanifar and Hartmann (2020) explained, the efficient operation of a transportation network is critical for the socio-economic functions of individuals, enterprises, and critical services. According to Aydin et al. (2018), the breakdown of a transportation system after the occurrence of a natural disaster severely disrupts the activities of rescuing affected individuals, delivering supplies to affected regions and communities, and conducting recovery efforts.

The transportation networks are needed for performing emergency search and rescue, provision of emergency medical care services, and firefighting (Nikoo, et al., 2018). Thus, any disruption to the network could be disastrous to the humanitarian response after an earthquake, landslide, flood, tsunami, or any other man-made disaster. Various cases highlight the transportation problem that some regions encounter after the occurrence of natural disasters. Ramli et al. (2018) highlighted the challenge that a broken-down transportation system poses through the case of the 2014 *Bah Kuning* flood in Malaysia. During the flood, the victims who had been evacuated to various shelters received little support from donors and other agencies because of the lack of supporting transportation infrastructure for disaster relief (Ramli et al., 2018). As Nikoo et al. (2018) explained, the situation is similar to what occurs in many developed countries that suffer from natural disasters which can destroy several cities – such as Haiti.

There is, therefore, a need for effective management of the operational and logistical networks for regions that are at high risks of seismic hazards. As Aydin et al. (2018) noted, such management efforts and transportation planning activities are necessary to ensure the optimal utilization of limited resources, especially in developing nations. The creation of plans for the actions to take in the event of a natural disaster enhances a transportation network's resilience and capability to recover from the devastation that a natural disaster introduces (Zamanifar & Hartmann, 2020). However, the implementation of such plans is hampered by the complexity of infrastructure reconstruction projects whose success is dependent on multiple social, political, economic, and technical factors (Ghannad & Lee, 2020). As IFRC (2015) reported, the same challenge existed in Haiti, where the plans were not effectively matched with execution strategies.

1.1 Problem Statement

Haiti is one of the island nations in the Caribbean that are highly vulnerable to natural disasters. Its recent history has shown the debilitating impacts that natural disasters, including earthquakes, storms, and hurricanes, have had on its population. The major disasters that it has suffered over the past two decades occurred in 2004, 2007, 2010, 2016, and 2021. With every natural disaster comes the need for humanitarian support to all the affected populations regardless of their locations. However, since the disasters affect the transportation networks, there is a need for a robust transportation system with multiple alternative modes of transport to enable relief agencies to reach all affected citizens and to enable the restoration of transport infrastructure after the debilitating impacts of a disaster. This need can be met by a robust transportation and resilience plan from the government. The problem, however, is that there is little information regarding the Haiti government's transportation and resilience plans in its disaster management strategies and policies.

1.2 Study Purpose

The purpose of this study is to explore archival records and official documentation on Haiti's transportation in light of the country's vulnerability to natural disasters to uncover its existing transport infrastructure, the challenges that it has endured in the disaster response process, the

strategies for disaster response that have been put in place, and the plans for transportation and resilience.

1.3 Research Questions

- What is the status of Haiti's transportation planning and resilience with regards to the natural disasters that it has faced and its high risk of undergoing intense disasters in the future?
- How can transportation planning and resilience in the country be improved to ensure efficiency in recovery, restoration, and relief following the occurrence of an earthquake, storm, hurricane, or another natural disaster?

2.0 Review of Previous Research

2.1 Transport Network Challenges During Disasters

Various researchers have explored the challenges that encumber transport networks after the occurrence of a natural disaster. Cantillo et al. (2019), after explaining the degradation of transport system functionality after a disaster and its impact on relief activities and human suffering, assessed the vulnerability of transport networks for response operations. The authors then developed a model for performing transport network vulnerability assessment that considered lack of access, deprivation costs, and critical links for disaster response. The findings of their test of the model on a coffee-producing region in Colombia demonstrated the usefulness of performing network vulnerability assessment in making disaster response plans (Cantillo et al., 2019).

Apart from the lack of access, deprivation of services, and failures in critical links during disasters, other challenges to the transport networks after natural disasters exist. According to Rouhanizadeh and Kermanshachi (2020), the major challenges are the lack of resources for reconstruction and the presence of debris on the transport networks. The authors identified these challenges after conducting an in-depth review of literature on the reconstruction of transport infrastructures following natural disasters. The reconstruction process itself is also marred by obstacles such as lack of organization in mass relocations following disasters, high traffic

volumes following natural disasters, inadequate maintenance of transport infrastructures, and a lack of resources including materials, workers, funds, and contractors (Rouhanizadeh & Kermanshachi, 2020).

The concept of transport network resilience in the face of a multiplicity of challenges has received a lot of interest among researchers. Serdar et al. (2021), after conducting a systematic review of literature on urban transport network resilience, explained that transportation networks need to be well maintained to support recovery efforts following disturbances and hazards. The reason is that a resilient transportation network enables the resilience of other critical systems and services, including repairs, relief efforts, transportation of people and goods, and efficient disaster response (Serdar et al., 2021). Some of the indicators of resilience include the performance of the road network over time, suitability of the network for connecting diverse locations under different circumstances, reliability during disasters, and cost-effectiveness for recovery efforts. According to Koren and Rus (2019), on the other hand, resilience can be measured through the ability of the network to regain pre-disaster performance levels in the shortest time possible.

2.2 Resilience Models

Researchers have explored various strategies for planning for and ensuring transportation resilience after the occurrence of natural disasters. Aydin et al. (2018) performed a study that tested a methodology for evaluating the strategies that are in place to ensure a restoration of road network connectivity after the occurrence of an earthquake or a landslide triggered by an earthquake. The methodology incorporated the steps of identifying the strategies in place, determining a graph-based metric for representing the road network, using Monte Carlo simulation to analyze the strategies, and analyzing the recovery time to determine the resilience of the network and the strategies. The authors tested the methodology on the case of the Nepalese district of Sindhupalchok, which was adversely affected by earthquake Gorkha in 2015 (Aydin et al., 2018). Their findings highlighted the usefulness of the methodology for evaluating a region's transport network resilience in the face of a natural disaster and the effectiveness of its transportation plan.

From a study on disaster recovery and reconstruction planning, Zamanifar and Hartmann (2020) proposed an optimization-based decision-making model for the planning process. The researchers explored various models that have been developed for Disaster Recovery Planning of Transportation Networks (DRPTN) and studied their applicability in real-world disaster occurrences. The ensuing model that they proposed incorporated a decision support system, traffic management models that are integrated with recovery problems, uncertainty avoidance, and subjectivity reduction in the disaster recovery models (Zamanifar & Hartmann, 2020). The authors suggested that in the development of pre-planning models and algorithms, there is a need for efforts to identify the local complexity and convexity of the transportation problem.

The decision-making model for infrastructure reconstruction following a disaster is necessary because of the multiple factors affecting the process and the limitation in government resources required for a successful response and recovery process (Ghannad & Lee, 2020). Ghannad and Lee (2020) uncovered this fact based on their research on the prioritization of post-disaster reconstruction, from which they proposed the use of a resource allocation analysis to evaluate the optimal priorities for the transportation network wrecked by a disaster. Ghannad and Lee (2020) further proposed a model that enables decision-makers to optimize the goals of post-disaster recovery, incorporate their experiences based on the local scenario, and ensure the goals are optimally sustained.

2.3 Transportation Plans for Disaster Response

Research by Ramli et al. (2018) identified the most feasible locations for evacuation centers and the transportation modes for disaster relief. The authors identified these logistical options after conducting a study on disaster relief options for Malaysia's Kelantan region, which had experienced a flood in December 2014. They used a geographical information system (GIS) and the HEC-RAS to simulate the flood then performed a suitability analysis to establish the locations that are best suited for helipads and transport routes for accessing various evacuation centers (Ramli et al., 2018). Their study highlighted the role that air transport plays in aiding ground-based disaster response and recovery options.

One of the options for enhancing transportation resilience is diversity in transportation, especially through the deployment of an emergency transportation network. From Rahimi-Golkhandan et al.'s (2021) study of intraurban mobility, transportation is defined as the availability and distribution of different modes of transport within a region or community. The implementation of a diversified transport network promotes the functionality of other infrastructure and services after hazards (Rahimi-Golkhandan et al., 2021). Nikoo et al. (2018) conducted a study aimed at analyzing the emergency transportation network design problem whose objective functions include route length, travel time, and the number of paths for emergency vehicles or planes to use. The study findings presented a branch-and-cut solution method that minimizes the vulnerability of the transport network by creating an optimal emergency network.

The emergency transport network can have diverse modes of transport to ensure that all the population needs are met. Nia and Moghimi (2017) conducted a study to investigate the modalities of transporting injured people to care facilities following a disaster, using a genetic algorithm to identify the most feasible solutions. The three transportation scenarios that the researchers analyzed included the direct transfer of casualties to a maser medical facility, two-stage transfers of casualties by road, and two-stage transfer using road vehicles and air transport (Nia & Moghimi, 2017). Based on the algorithm results, Nia and Moghimi (2017) reported that the combination of road and air transport is the most feasible for a region whose urban transport infrastructure has suffered a severe hit.

Governments, policymakers, and other responsible authorities can implement plans for enhancing transportation following a natural disaster. According to Rouhanizadeh and Kermanshachi (2020), the governance and planning strategies that need to be put in place include a revision of outdated policies and codes, regular evaluation of the reconstruction process, prioritization of important transportation infrastructures, identifying backup transportation infrastructures, and specifying the roles of individual stakeholders in the response strategy. The authorities also need to implement coordination and cooperation strategies, including resource tracking and monitoring, organization of workforce for transportation reconstruction and

optimizing the allocation of resources (Rouhanizadeh & Kermanshachi, 2020). According to the Victoria Transport Policy Institute (2016), a resilience plan should ensure that the system has diversity, efficiency, redundancy, autonomy, and strength to ensure its accommodation of variable and unexpected conditions.

However, as Zuofa (2020) wrote in a book on the master planning for infrastructure management projects, disaster preparedness in transportation network planning is grossly inadequate, with many governments lacking preparedness for natural or man-made disasters. As Rahimi-Golkhandan (2020) also noted from a study of the transportation mobility and resilience in the case of New York City, the regions or zones with the highest vulnerabilities for natural disasters do not have the needed levels of transportation diversity. The author noted that the low transportation diversity in such areas undermines their post-disaster mobility (Rahimi-Golkhandan, 2020). The same phenomenon could be true for low-income countries that lack diversity in their transportation infrastructures and are still vulnerable to natural hazards. For instance, Yabe et al. (2020) noted that the island nations in the Caribbean, which are highly vulnerable to natural disasters, do have limited resources to promote recovery from natural disasters, meaning that their transport networks are not diverse or resilient.

2.4 Natural Disasters in Haiti

Haiti is one of the nations that has been worst hit by natural disasters over the last two decades. As Yabe et al. (2020) highlighted, Haiti is one of the island communities that have to cope with repeated cycles of natural disasters in the form of earthquakes. One of the most intense disasters the country suffered was the earthquake of January 12, 2010, that killed 223,000 individuals, injured 300,000, and left more than two million people homeless (Haver, 2011). In 2016, the country also endured Hurricane Matthew, which led to the displacement of 140,000 families (Center for Disease Philanthropy (CPD), 2021). On August 14, 2021, the country endured a 7.2-magnitude earthquake that killed 2,200 people and injured 12,260 others (UNICEF, 2021). Historically, the Haitian Departments of South, Nippes, and Grand'Anse have been the worst affected by the earthquakes.

2.5 Summary and Research Gaps

The study by Aydin et al. (2018) highlighted the usefulness of a framework for evaluating the recovery potential for a road network and assessing the planners' preferences for improving the resilience of the network after a natural disaster. Similarly, Zamanifar and Hartmann (2020) identified the efficacy of a decision-making model that supports successful planning and implementation of a recovery effort after a natural disaster. After identifying the difficulties in decision-making regarding the aspects of post-disaster recovery that are to be prioritized, Ghannad and Lee (2020) proposed a model for creating a workable plan for transportation recovery and optimal resource allocation. Thus, research supports the use of decision-making algorithms and models for promoting transportation planning and post-disaster recovery.

Research also reveals the need for a diversified transportation infrastructure incorporating air, water, and other ground transport options in case of a natural disaster (Ramli et al., 2018). The implementation of evacuation centers is also a necessity for robust disaster response and resilience strategies (Ramli et al., 2018). Transportation to and from these evacuation centers can be implemented through an optimum solution combining road and air transport (Nia & Moghimi, 2017). Research also reveals some of the practical approaches that can be implemented to enhance the resilience of transport infrastructures. According to Rouhanizadeh and Kermanshachi (2020), there are governance, planning, coordination and cooperation, and awareness strategies that should be put in place to enhance transport network resilience and promote recovery.

However, Zuofa (2020) noted that many governments do not have sufficient plans for the preparedness of their infrastructures for natural disasters. As Rahimi-Golkhandan (2020) also observed, the zones which are the most susceptible to natural disasters have the lowest levels of transportation network diversity as compared to the zones that have the lowest susceptibility levels. The gap in research, therefore, is the inadequacy of research on the preparedness and resilience in transportation networks among the most vulnerable low-income countries for natural disasters. The present study addresses this gap by exploring the case of Haiti, its transport

infrastructure, the challenges it experiences when it undergoes a disaster, the strategies that the government has in place, and transport planning and resilience activities and opportunities.

3.0 Methodology

The case study design was used in the process to gain an in-depth understanding of the natural disaster experiences in Haiti, how they have affected the public and transportation infrastructure, and how the country has responded in terms of planning and resilience. The design is qualitative in nature, allowing the researcher to obtain information regarding the specific case. The holistic approach was used in the study because it allows the researcher to obtain data from diverse sources to answer the research questions conclusively (Yazan, 2015). The design was implemented after the performance of a literature review of the topic of interest and the identification of the theoretical propositions that address the elements of the case study.

3.1 Instrumentation

The case study of Haitian transportation planning and resilience following the occurrence of natural disasters was conducted using two major instruments, namely documentation, and archival records. The two instruments were used both for the acquisition of data and the performance of triangulation.

3.2 Data

The archival data for the case study was obtained from various databases on the occurrence of natural disasters in Haiti. The databases included Berman's (2015) Haiti Earthquake Data published by Harvard Dataverse and the Humanitarian Data Exchange (HDX)'s (2021) databases focusing on Haiti. The documentation data used in the analysis, on the other hand, included reports from various agencies on the recovery plans and processes following the occurrence of various disasters. The documents included Haver's (2011) earthquake response report, Unicef's (2021) humanitarian situation report, UN's Office for the Coordination of Humanitarian Affairs (OCHA)'s reports as presented by various authors, the Center for Disaster Philanthropy's (2021) disaster report, the International Federation of Red Cross and Red Crescent Societies (IFRC)'s

(2015) report on Haiti's disaster response, and the World Bank (2021) report on Haitian transport and infrastructure.

3.3 Data Analysis

A topographical analysis approach was used to identify the regions that are most affected by natural disasters and the infrastructures in place. The topographical analysis focused on the roads and road networks that serve different regions, with the map of the network compared to the map indicating the road obstacles that were witnessed after Hurricane Matthew (2016). The analysis also focused on the air transport locations for disaster response.

The document analysis involved the thematic examination of the reports described in the previous section. The thematic analysis involved three steps, namely familiarization, theme review and analysis, and deduction of evidence. The familiarization step involved skimming through the content of the reports to uncover the main points and evidence to answer the research question. The theme review and analysis involved the search for the pieces of information in the article that expound on the pre-defined themes of transportation network infrastructure, transportation challenges during disasters, resilience, and planning strategies.

4.0 Results and Discussion

4.1 Haitian Transportation Infrastructure

Haiti has been devastated by earthquakes and hurricanes over the years, all of which have had a negative impact on the transportation infrastructure. From the HDX (2021) database, natural disasters cause bridge damages, road damages and blockages, landslides, and floods that become obstacles for transportation. Figure 1 shows a summary of the comparison of the obstacles by frequency of occurrence after a disaster. The frequencies could be useful in performing risk management for the road networks during natural disasters.

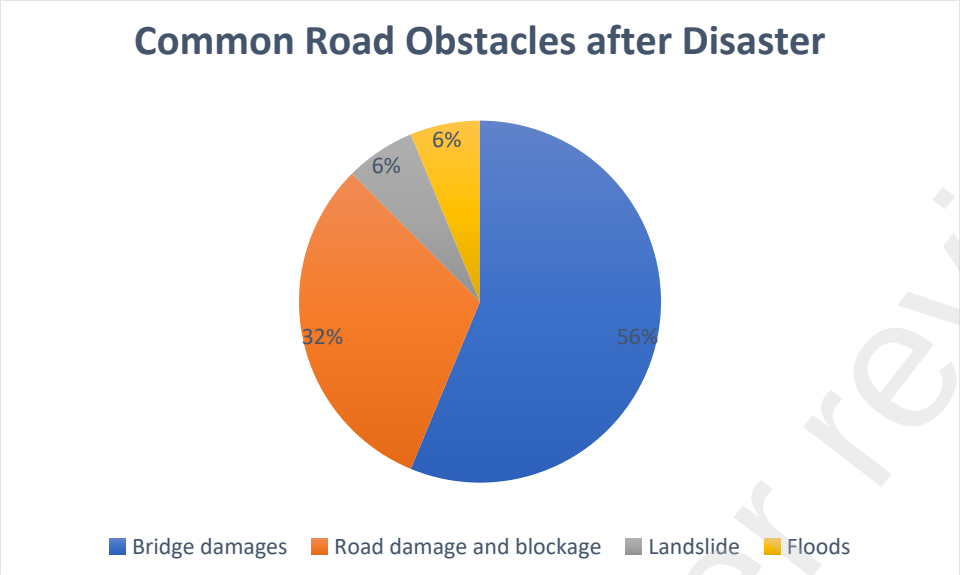

Figure 1: Road network obstacles by frequency

HDX (2021) reports that the obstacles limited humanitarian access to the affected regions. As the data reveals, some of the places that suffered the worst cases of road obstacles have single road networks, with a case in point being Petite Riviere de Nippes, which suffered a massive flood that blocked the only major road passing through the town. The maps show a distribution of similar cases of areas with no alternative transport networks that suffered serious road obstacles (Appendix A). Similarly, during the 2021 earthquake, a massive landslide blocked the Jeremie-Les Cayes highway, limiting transit between the two towns for the delivery of relief (CPD, 2021).

In the regions with low densities of road networks, especially in the regional Departments of Grand d'Anse, Nippes, and Sud, there is a high concentration of helicopter landing sites that are served by the United Nations Humanitarian Air Service (UNHAS), which facilitates the delivery of supplies and aids to affected communities (Appendix C). It is notable that these departments are among those that have been worst hit by earthquakes and hurricanes. Accessibility to the resources, however, remains low because of the limited expanse of the road network.

Each of the 10 Departments in Haiti has at least one airport, meaning that there is an availability of air traffic infrastructure to aid response missions (HDX, 2021). The dataset reveals diversity in

the transport infrastructure across the country but also indicates that many cities and towns lack transportation diversity. Moreover, the country's poor infrastructure planning is one of the leading reasons behinds its vulnerability to the adverse effects of natural disasters. According to the Pan American Health Organization (PAHO), the country lacks solid infrastructure and urban planning.

4.2 Disaster Response Challenges

Following the occurrence of natural disasters, various organizations teamed up to undertake humanitarian activities. The Haver (2011) earthquake response report explained that the agencies and organizations participating in the response programs after the 2010 earthquake encountered huge logistical challenges such as the inaccessibility of the populations in need, and their efforts were hampered by the enormity of the disaster. Serious damages to the transportation sector hindered the promptness of access and response to some regions (World Bank, 2021). In 2021, the humanitarian response efforts were also hindered by armed clashes in Port-au-Prince, which prevented road access from the north to the South Department, which was affected the most by the 2021 earthquake (UNICEF, 2021). Furthermore, there were areas that were completely cut off from access from the outside, which hindered the provision of relief assistance (OCHA, 2021). Thus, security constraints and the inaccessibility of some areas by road or air proved to be major obstacles in the disaster response process.

4.3 Strategies for Disaster Response and their Impacts

Haiti has sectoral laws that regulate the planning, construction, and environment sectors, among others. The IFRC (2015) reported that the laws have provisions and policies that support disaster response and preparedness, but they are not matched with effective implementation and enforcement strategies. Since the year 2001, the country put in place the National Risk and Disaster Management Plan and the Emergency Response Plan for managing disasters and risks, with the Ministry of the Interior and the Directorate of Civil Protection (DPC) being the authorities to coordinate the activities of various actors in the implementation process (IFRC, 2015).

International organizations have contributed to the strategies for disaster response and preparedness in Haiti. After the 2010 earthquake, the World Bank undertook the Disaster Risk Management and Reconstruction project to support the country's capacity for disaster response and enhance the resilience of its transportation infrastructure (World Bank, 2021). Through the disaster risk management element of the project, the organization created a framework incorporating earth observation, remote sensing, and hydrological risk modeling to enhance risk assessments. Through the project's transportation element, the organization created solutions for building resilient road networks and enhancing post-disaster response with the aid of hydrological modeling and multi-hazard mapping.

4.4 Transport Planning and Resilience

According to the IFRC (2015), Haiti's national strategy for disaster response and recovery is focused more on the preparation for and response to disasters as opposed to long-term planning for resilience. The plans in place serve the purpose of getting the government and international partners organized to optimize resource allocations for quick and effective responses to at-risk populations following disasters. An integral element in the plans is the preparation for the annual hurricane seasons, with specific details made for logistics, evacuation, and general coordination (IFRC, 2015). However, with the aid of other stakeholders, the government has improved the resilience of its transportation network.

The World Bank (2021) report demonstrated the success of the Disaster Risk Management and Reconstruction project in building the country's national capacity to enhance the resilience of critical transport infrastructure. After the 2010 and 2016 earthquakes, the organization successfully improved the resilience of road networks that could serve 150,000 individuals and rehabilitated roads and damaged bridges. In the report, World Bank (2021) detailed that the national government used the improved capacity to clear roads and gravel in response to the 2021 earthquake, mount a strong emergency response plan, and assess damaged buildings for the purposes of recovery.

5.0 Conclusions

The study aimed at uncovering the status of Haiti's transportation planning and resilience with regard to natural disasters and recommending strategies for improving the planning and resilience. An analysis of official documentation and archival records on the country's history of natural disasters, disaster response, and disaster management plans revealed four major findings. First, many cities and regions around the country lack transportation diversity, meaning that the occurrence of bridge damages, road damages and blockages, landslides, and floods severely affects transportation from one location to another, thereby impairing relief and recovery efforts. Secondly, security constraints and the inaccessibility of some areas by road or air are the major obstacles in the disaster response process. Third, Haitian sectoral laws that put in place strategies for disaster response have not been adequately matched by implementation and enforcement strategies, leading to a reliance on international organizations such as the World Bank for support in disaster response and recovery. Fourth, with the aid of the World Bank and other international organizations, the country's government has an improving capacity for transportation resilience, with plans in place for disaster preparation and response.

5.1 Study Limitations

The case study approach was used to uncover evidence for transportation planning and resilience in Haiti. The first limitation, therefore, was that there was difficulty in uncovering and acquiring official government documentation on transportation plans and disaster response strategies. Therefore, the researcher had to rely on third-party data on the country as the sources of evidence for resolving the research questions. The second limitation was that the case study design did not involve the collection of first-hand data from government officials or persons with authority in the country, leading to a reliance on secondary data.

5.2 Future Work

Future research can address the two limitations to improve the understanding of transportation planning and resilience in a country such as Haiti. The first recommendation is the acquisition of more official documents from the responsible authorities to have first-hand information on the plans and compare them with other third-party data to determine the appropriateness of the plans.

The second recommendation is the conduction of a study with the use of interviews, questionnaires, or focus groups as the data collection approaches to obtain the views of government officials, policymakers, planners, and other authorities on the country's transportation planning and resilience.

5.3 Recommendations for Practice

The analysis of archival records and documentation gave insight into the answers to the research questions. The first research question was on the status of the country's transportation planning and resilience. From the evidence, the country has a national strategy for disaster response and recovery, detailing the logistical, evacuation, and coordination plans to put in place in the case of a disaster. The national strategy also has detailed plans to prepare the country for the annual hurricane season (IFRC, 2015). The challenge, however, is with the implementation and enforcement of the plans has been wanting, meaning that most of the efforts of recovery and restoration are led by non-government international organizations such as the World Bank.

The second research question inquired how the country can improve its transportation planning and resilience. The literature search revealed various strategies that the country's government can adopt to enhance planning and resilience. The first recommendation is the implementation of a diversified transportation network in the locations that have the highest vulnerability. Diversification encourages functionality and continuity of services despite hazards, with the existence of emergency transportation modes and paths helping the recovery process (Rahimi-Golkhandan et al., 2021; Nia & Moghimi, 2017; Nikoo et al., 2018). The second recommendation is the development of a coordination and cooperation strategy to optimize the response of the transportation systems during natural disasters. The strategy should incorporate workforce organization for reconstruction, optimization of resource tracking and allocation, and decision-making to identify the most suitable modes of transport for specific locations (Rouhanizadeh & Kermanshachi, 2020; Ghannad & Lee, 2020). Finally, based on the recommendation of the Victoria Transport Policy Institute (2016), there should be plans to promote the diversity, efficiency, redundancy, autonomy, and strength of the country's transport

network, with sufficient allocation of financial resources to promote the achievement of the resilience goals.

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7.0 Appendices

A. Road Obstacles after Hurricane Matthew

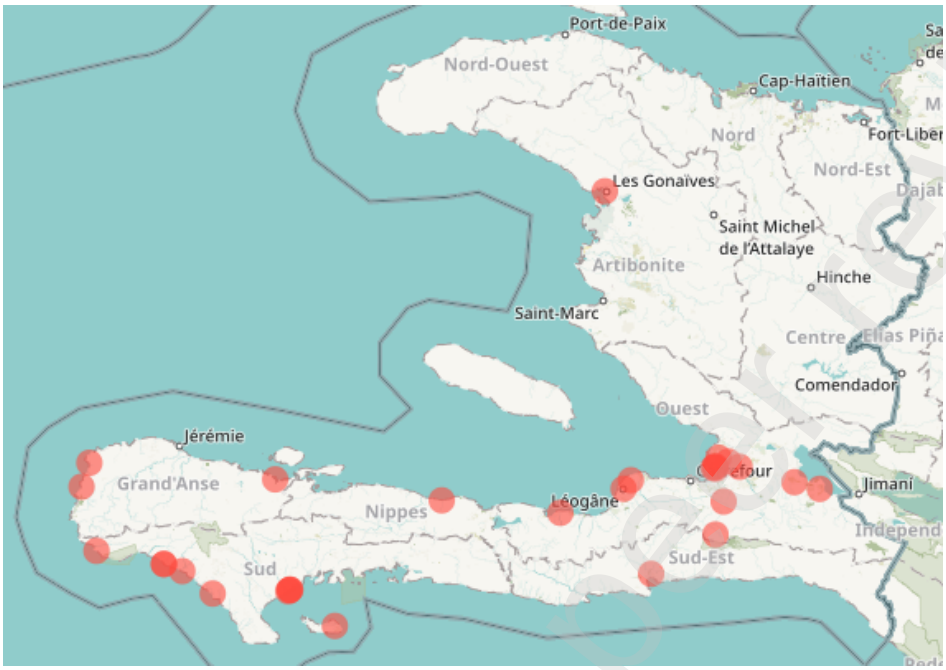

Figure 2: Map showing roads with blockages, traffic, bridge damages, landslides, and floods following Hurricane Matthew (HDX, 2021)

B. Road Networks, Updated 2018

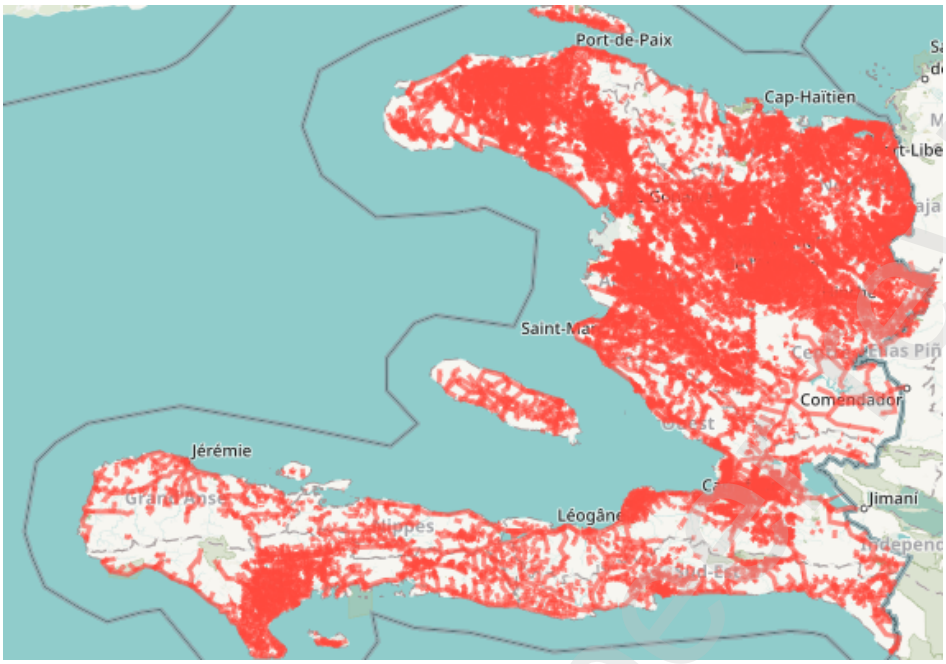

Figure 3: Map showing road networks in Haiti, 2018 (HDX, 2021)

C. Helicopter Landing Sites Served by UNHAS

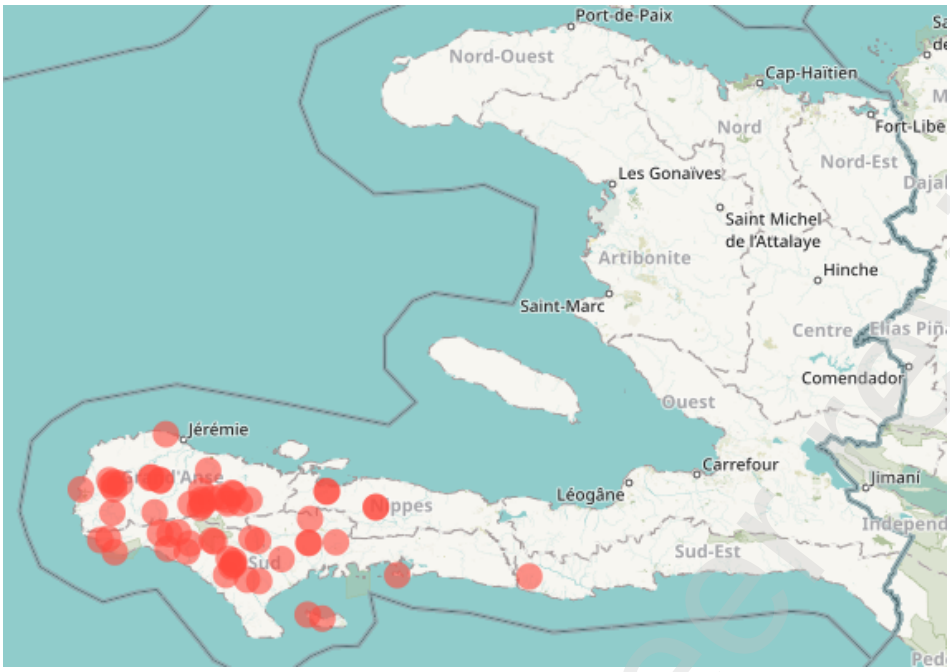

Figure 4: Map showing locations with UNHAS landing sites, marked with red circles (HDX, 2021)