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Analysis of Relief Materials Distribution Based on Road Network Connectivity in the North East Nigeria

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ABSTRACT

The connectivity of roads networks plays an important role in ensuring quick delivery of relief materials to the affected population and improves the satisfaction rate. However, unconnected transportation network increases the distances at which relief materials traveled to reach disaster victims. This study analysed relief materials distribution based on road network connectivity in the North East Nigeria. Google map analysis was done on road network using geographical images that actually represent series of vertices (nodes) and set of edges (links). The degree of network connectivity in the North East was done by counting the numbers of nodes and links in the google map. Gamma index was used to calculate the level of the connectivity leading to the identified IDP camps. The result of road network connectivity over which relief materials were been transported to various IDP camps in the zone showed that only the routes from Bauchi to Rindibin Camp and Maiduguri to Biu Camp reflect an average degree of connectivity, while the others show a poor level of network connectivity. Therefore, the study recommended that NEMA should be proactive in its planning to deliver relief materials to the designated location by evaluating several alternative links and utilising various tactics by consulting transportation service providers and other public and private organisations that can help with humanitarian efforts. Lastly, Government should also adopt the use of cashless policy while providing aids instead of distribution of food and material items.

Keywords:*-Distribution, Relief materials, Road network, Road connectivity*

INTRODUCTION

Currently, there are several natural and man-made disasters occurring around the world that pose a serious threat to people's lives and properties in all ways [6]. In 2021, 432 global natural hazard-related disasters were recorded. This led to 10,492 fatalities, affected 101.8 million people, and resulted in economic losses of almost 252.1 billion US dollars [8]. As a continent, people in Africa are vulnerable to a wide variety of calamities, which has significantly increased economic losses and human sufferings from natural disasters and armed conflicts are the main catastrophes that people in African nations

experience, and made the populace completely vulnerable. In Nigeria, the death toll from flooding alone was around 300, compelled more than 100,000 people to leave their homes, and over 500,000 individuals have been affected according to National Emergency Management Agency of Nigeria (2022) while the ongoing armed conflict in North-Eastern Nigeria between Boko Haram and other parties is leading to widespread displacements, food insecurity and several victims of violence. 2,375,846 internally displaced people (IDPs) were counted in the zone as a whole [10].

These individuals are unable to support themselves, necessitating the provision and delivery of a sizable number of relief items to them in their affected areas. However, the effectiveness of rescue activities depends on getting these relief supplies to the impacted areas in a timely manner and moving them to the disaster-affected areas or IDPs' places requires road networks as an illustration for the structures and movements of these materials.

To ensure the secure and timely delivery of aid supplies to disaster areas, interconnectivity or route links are needed. This road networks connectivity are crucial for guaranteeing prompt distribution of relief supplies to the impacted people and raising satisfaction levels. A well-connected transportation system increases the variety of travel alternatives while reducing the distances over which relief supplies must be transported to reach disaster victims [25].

Previous studies on the connectivity of the road network where relief supplies are delivered were scarce especially in Nigeria and North East particularly. Those available literatures regarding road network connectivity of relief materials were from overseas[2]; Jana et al, 2021; Li & Teo, 2019; Hu et al, 2017). It is against this background that this study tends to fill the identified gap by analyzing the connectivity of road networks conditions at which relief materials reach before getting to the affected population especially in the North East Nigeria which was not empirically studied before.

The paper was organised such that part two of the paper was devoted to a literature review, which explains theory connected to road network connectivity and reviews the concept of relief materials, empirically discussed the road network connectivity of relief materials and nature of the disasters in the North East Nigeria. Part three is designed for methodology which covered the study area and method of data analysis. The findings were reported in part four, while the conclusion and recommendations were presented in section five.

LITERATURE REVIEW

Graph Theory

Leonhard Euler, a well-known mathematician, is credited with developing graph theory in 1741. In this unique situation, a diagram is comprised of vertices (otherwise called hubs or focuses) associated by edges (likewise called connections or lines).

In contrast to directed graphs, which have edges connecting two vertices asymmetrically, undirected graphs have edges connecting two vertices symmetrically.

The idea is essential to this study because it explains how organisations or aid agencies can provide a consistent level of service, for as by identifying alternate pathways when a specific connection is busy or disrupted. A vast network of navigational services is made up of roads and highways. In the event of road

restrictions due to an assault or other natural calamities such as flooding, Google Maps may be the greatest option for finding the shortest path.

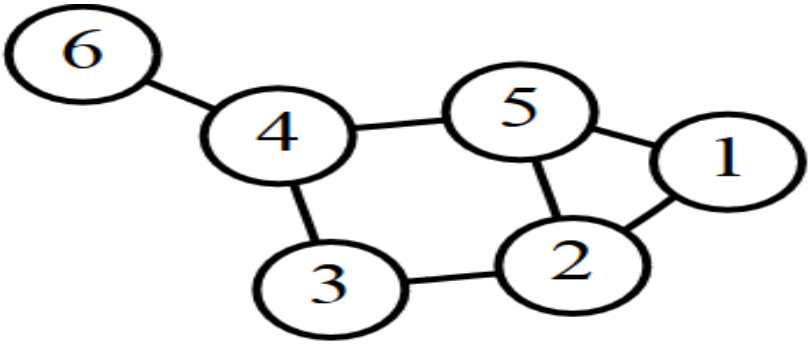

Fig. 1:-*Road Graph*
Source: *Wikipedia (2023)*

Relief Materials or Aid

Different researchers use different terminologies for relief aids, such as emergency relief, disaster relief, humanitarian aid, disaster relief supplies, and humanitarian help. According to the International Federation of Red Cross, relief is the provision of necessary, appropriate, and timely humanitarian aid to those affected by a disaster, based on a preliminary rapid assessment of needs and intended to contribute effectively and quickly to their early recovery. (2021).

According to [7], relief entails satisfying catastrophe victims' immediate needs for food, clothing, shelter, and medical assistance. In the hours, days, and weeks following a tragedy, it gives help to preserve lives and alleviate suffering.

It entails the distribution of a certain quantity and quality of products to a quantifiable group of beneficiaries, based on selection criteria that identify actual needs and the groups least able to meet them. Keeping in mind the panic that emerges during any disaster, it is critical to plan ahead of time to ensure that relief materials distribution is efficient and successful in the early aftermath of a disaster [24].

When paired with an adequate disaster preparedness plan, a successful relief operation becomes more realistic [9]. The government is required to deliver relief items to disaster areas in the event of frequent abrupt disasters.

The term "relief supplies" refers to the materials required for the full emergency response [18, 19]. In the aftermath of disasters and crises, disaster relief supplies (DRS) such as life necessities (e.g., food and drinks), living security items (e.g., clothing and shelters), medical supplies (e.g., medicines and healthcare products), and life-saving tools and equipment (digging tools, emergency lights, and large equipment) play critical roles in saving lives and rebuilding communities.

Various supplies require different management techniques due to differences in material lifetime and demand urgency [17]. First, DRS demand is unpredictably high due to unexpected events occurring in unexpected places in the majority of cases. Second, because of the various damage levels and regional situations, the amount, nature, and urgency of demand are highly unclear. Third, the relief procedure relies heavily on the prompt availability and

transmission of DRS. Finally, the requirement for these materials and equipment is unavoidable, and they have significant social significance [27].
In addition to preventing and enhancing preparedness for such occurrences, humanitarian aid seeks to save lives, alleviate suffering, and uphold human dignity during and after man-made crises and disasters brought on by natural disasters. The manner in which aid is administered to the intended beneficiaries can have a significant impact on their level of vulnerability, allowing them to regain control of their lives and improve their chances of survival.

In some cases, distributing vouchers (to be exchanged for a restricted range of critical commodities) or e ven cash to disaster victims, if local marketplaces are able to provide the requisite items, may be a more appropriate, efficient, and successful manner of giving emergency help. This type of help has the advantage of being relatively low-cost to implement, allowing more money to go directly to the recipients (The International Federation of Red Cross & Red Crescent Societies, 2021). Conditional Cash Transfer, for example, was used in Nigeria under COVID-19.

While disasters are catastrophic by definition, causing extensive loss of material things and property, as well as damage and death, disaster assistance is a fundamentally human response. The amount of materials, money or services made available to individuals and communities that have suffered losses as a result of disasters will determine their level of assistance.

Road Network Connectivity of Relief Materials

The extent to which humanitarian actors and relief assistance from one node can reach other nodes either directly or indirectly through another node or a series of nodes before reaching catastrophe victims is referred to as transport network connectivity in the context of relief supply chains. Many short links, many intersections, and few dead-ends characterise a well-connected network. As connectivity improves, travel distances shorten and route possibilities expand, allowing for more direct travel between destinations and increased accessibility.

Vulnerability, robustness, and resilience are commonly assessed using connectivity as the foundation [28,29]. Roads may be damaged or blocked by debris after a natural or man-made catastrophe, and bridges and viaducts may collapse. Some road portions are closed as a result of these common hazards, and the road network may even be disconnected [2]. After a disaster, the connection of post-disaster road networks is critical because they serve as lifelines, providing access to impacted areas and supporting evacuation, emergency response, and long-term rehabilitation operations [4].

The connectedness of a network will vary if some roads and intersections, which represent links and nodes respectively, are disrupted. Disrupting links might cause the shortest pathways between node pairs to be broken, increasing the distance between them. When one node fails, all of the links that are connected to it are disrupted. Furthermore, if a disaster is severe enough to interrupt many nodes and/or links, the original network may be broken up into isolated sub-networks, with no pathways linking some node pairs [29].

According to [2], recent studies on post-disaster recovery have concentrated on enhancing the road network or improving accessibility. Some of these studies focus on selecting road segments to be upgraded or repaired rather than on routing while

some research on road networks includes network connectivity as a limitation in their model.
Kasaei & Salman (2016) investigated arc routing issues in order to remove blocked roadways and restore network connectivity. After a calamity, [2] proposed a technique for producing a timetable for street freedom groups to reestablish network. In the literature, some metrics for evaluating the connectivity of post-disaster road networks have been presented. Three execution measures were used for the post-seismic tremor street network by Chang and Nojima (2001): all out length of organization open, absolute distance-based availability, and genuine distance-based openness. Aydin et al. (2018) used the scale of a sizable connected component to demonstrate the connectivity of post-disaster networks. These connection measures are applied to post-disaster networks that have been determined or evaluated using simulations for various scenarios. Connectivity measures are stated below;
Alfa Index (**α**)
Beta Index (**β**)
Gamma Index (**γ**)

Disasters in the North East Nigeria
Nigeria, like the rest of the world, is vulnerable to both natural and man-made disasters. Drought, desertification, flooding, diseases, coastal erosion, dam failure, building collapse, oil leak, maritime collision or accident, bomb explosion, bus and train collision, communal clashes, fire, air crashes, and boat mishaps are all examples of catastrophes. Insurgency, banditry, farmers/herders confrontations, and the coronavirus, which arrived in Nigeria via an Italian citizen in Lagos, are among the others.

Nigeria is separated into six international zones in particular South, South-East, South-West, North Focal, North-West and North-East. Each of the Zones had experienced natural and man-made disasters at various levels.

Aside from continuous flooding, which is one of the most common natural disasters across Nigeria's zones, Northeast which comprises of Adamawa, Borno, Bauchi, Gombe, Taraba and Yobe States has been plagued by other natural disaster and insurgency attacks known to be Boko Haram.

The zone has experienced droughts, which have led to crop failure, poor crop production, household famine, hunger, and mortality, as well as the death of animals [12,26]. In 25 local government areas (LGAs) spanning Borno, Adamawa, and Yobe (BAY) states, more than 2,000 cases of cholera and acute watery diarrhea (AWD), including 76 fatalities, were reported [20].

In the instance of the man-made disaster in North East Nigeria, the violence resulting from the insurgency of non-state armed groups (NSAGs) in the region continues apace. Millions of people have been uprooted as a result of the attacks and insecurity, which have wreaked havoc on agricultural productivity and other livelihoods, cut off crucial services, and triggered a security crisis [20].

In the zone alone, about 3.2 million people have been displaced, including 2.9 million internally displaced persons (IDPs) (unhcr.org). The Boko Haram conflict alone has displaced approximately 2.4 million people in the northeast Nigeria. During displacement, the need for government or other relief agencies to transport relief materials to the needy population is required. What is unknown is the numbers of nodes or links require by

relief materials to reach before getting to the needy especially in North East Nigeria.

METHODOLOGY

Study Area

Nigeria is a federal republic with 36 states and Abuja as the Federal Capital [5]. The states are grouped into six geopolitical zones, the North Central (NC), North East (NE), North West (NW), South West (SW), South East (SE) and South South (SS). Out of all these zones, this study was carried out in North East zone. The zone comprises Adamawa, Borno, Bauchi, Gombe, Taraba, and Yobe state. The zone is home to 23,558,674 people, or 13.5 percent of Nigeria's total population, and occupies just under one-third of the country's total land area [22]. According to the United Nations Office for the Coordination of Humanitarian Affairs [21], the humanitarian situation in North East Nigeria is one of the world's most complicated humanitarian disasters.

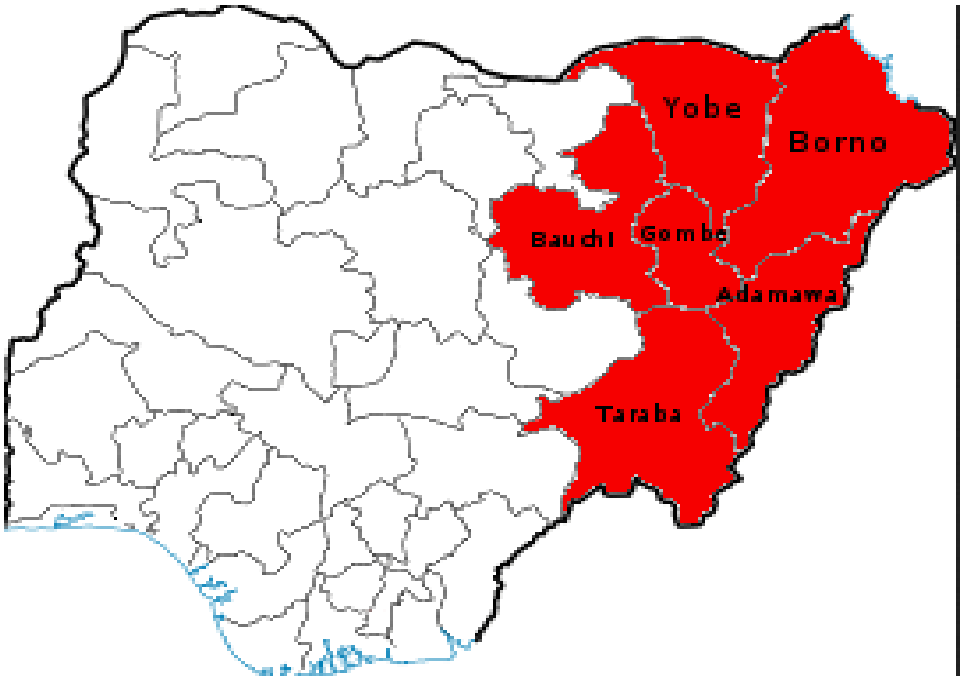

***Fig. 2:**-Map of North Eastern States, Nigeria*
Source: Wikipedia (2016)

Method of Data Analysis

For this study, secondary data which is Google map was used to obtain data on road network connectivity by identify the links and the nodes connection. Various measurement tools have been developed for measuring the extent to which links and nodes maximum connectivity, which requires the existence of a direct link between each node (Kansky, 1963). These indices are all based upon the relationship between the number of edges and vertices in a network which is regarded as a topological graph. Among the indices used for measuring road network connectivity are Beta, Gamma and Alpha Index. Since the road networks that are used to transport commercial goods are also used to transport relief supplies in the North Eastern region, alpha, beta and gamma indices were also used to assess the connectivity of the road networks in the communities where various IDP camps were located. North East zone is made up of Adamawa, Bauchi, Borno, Gombe, Taraba, and Yobe States with 309 IDP camps according to the Displacement Tracking Matrix [10]. Only Gombe state

has no records of IDP camps (no record of those living in camps) whereas Borno State has the highest with 245 IDP camps, followed by Adamawa State with 28 IDP camps. With the exception of Gombe State, each locality where an IDP camp is located was taking from the other states in the zone.

The study considered the road network from each state capital to the community where the camp is located while gamma index only was used. Duan & Lu [11] also used gamma index in their study to evaluate the roads connectivity of a community. Therefore, roads with a high gamma index value were considered to be well connected. As acknowledged from crafted by [23], the availability level that is under 49% means that low degree of street network availability, half addresses a typical degree of network and 60% or more indicate elevated degree of street network availability. The formula for Gamma index of network connectivity is specified as;

$\gamma = e/3(v-2)$
Where;
y= Gamma index
e= edges or links
v= vertices or nodes

FINDINGS

For Yola-Fufore: The numbers of links are 4 and nodes are 5.

$= \frac{4}{3(5-2)} \quad = \frac{4}{3(3)} \quad = \frac{4}{9} = 0.44$

For Bauchi- Kangyare/ Turun: The numbers of links are 18 and nodes are 14.

$= \frac{18}{3(14-2)} \quad = \frac{18}{3(12)} \quad = \frac{18}{36} = 0.50$

For Maiduguri-Biu: The numbers of links are 19 and nodes are 14.

$= \frac{19}{3(14-2)} \quad = \frac{19}{3(12)} \quad = \frac{19}{36} = 0.53$

For Jalingo- Mayo Goi: The numbers of links are 33 and nodes are 26.

$= \frac{33}{3(26-2)} \quad = \frac{33}{3(24)} \quad = \frac{33}{72} = 0.46$

For Damaturu- Damaturu Central: The numbers of links are 7 and nodes are 7.

$= \frac{7}{3(7-2)} \quad = \frac{7}{3(5)} \quad = \frac{7}{15} = 0.47$

Table 1:-*Number of Road Edges and Vertices of selected communities in North-East Nigeria*

Variables	**No. of Links (Edges)**	**No. of Nodes (vertices**	**Gamma**	**Remark**
Yola- Fufore	4	5	0.44	Low
Bauchi- Kangyare/ Turun	18	14	0.50	Average
Maiduguri-Biu	19	14	0.53	Average
Jalingo- Mayo Goi	33	26	0.46	Low
Damaturu- Damaturu Central	7	7	0.47	Low
Average Gamma Score			**0.48**	

Source: Authors' Computation (2023)

The result of road networks connectivity over which relief materials were been transported to various IDP camps was depicted in Table 1. It was discovered that the road network between Yola and Fufore camp in Fufore includes 4 edges and 5 nodes, and the gamma connectivity value of 0.44 (44%), 18 edges and 14 nodes make up the road network from Bauchi to Rindibin Camp in Kangyare/Turun and the gamma connectivity value of 0.50 (50%), there are 19 edges and 14 nodes in the road network that connects Maiduguri to Biu Camp and the gamma connectivity value of 0.53 (53%), 33 edges and 26 nodes make up the road network from Jalingo to Jauro Gbadi Primary School Camp in Mayo Goi, and the gamma connectivity value of 0.46 (46%) and finally, the road network from Damaturu to Bukar Abba camp in Damaturu Central includes 7 edges and 7 nodes, and the gamma connectivity value of 0.47 (47%). From the analysis, only the routes from Bauchi to Rindibin Camp and Maiduguri to Biu Camp reflect an average degree of connectivity, while the others show a poor level of network connectivity in the North East.

CONCLUSION AND RECOMMENDATION

From the findings, only Bauchi to Rindibin Camp and Maiduguri to Biu Camp have average levels of connectivity in the sampled zone. This indicated that the majority of the IDP camps in the North East have low level of road networks connectivity, making it more difficult to transport relief materials to those camps in the zone. The outcome of the result was in contrast to that of Abbas & Hashidu [1], who found that there had been a significant improvement in road connectivity in North-East Nigeria between 1961 and 2011. Their study took into account the road network connectivity throughout two distinct years, whereas this study took into account the road network connectivity over which relief materials are transported to IDP camps in the zone.

Given that distribution of relief materials depends on the connectivity of roads, therefore, the study recommended that NEMA should be proactive in its planning to deliver relief materials to the designated location by evaluating several alternative links and utilising various tactics by consulting transportation service providers and other public and private organisations that can help with humanitarian efforts. Lastly, Government should adopt the use of cashless policy while providing aids instead of distribution of food and material items over unconnected road networks in the North East Nigeria. This will not only allow beneficiaries to choose the goods and services that are most appropriate for their personal needs but also will reduce time spent on the road to reach various IDPs in an unconnected networks. The scope of this study was only on five IDP camps, and the data were analyzed using the gamma index. This shows that more research is required. Future research should be extended beyond the scope of this study. This will provide more details about the IDPs and IDP camps in the North East. Finally, future study can adopt shimbel and connectivity Index to determine the centrality of the IDP, accessibility and connectivity of the settlements in relation to the IDP camps.

REFERENCES

1. Abbas, A. M., & Hashidu, R. B. (2019). Transportation network analysis, connectivity and accessibility indices in North East, Nigeria. *J. Res. Hum. Soc. Sci*, *7*, 60-66.
2. Akbari, V., & Salman, F. S. (2017). Multi-vehicle synchronized arc routing problem to restore post-disaster network connectivity.

European Journal of Operational Research, *257*(2), 625-640.
3. Akbari, V., Sadati, M. E. H., & Kian, R. (2021). A decomposition-based heuristic for a multicrew coordinated road restoration problem. *Transportation Research Part D: Transport and Environment*, *95*, 102854.
4. Altay, N., & Green III, W. G. (2006). OR/MS research in disaster operations management. *European journal of operational research*, *175*(1), 475-493.
5. Anyamele, O. D. (2020). Disparities and Inequality in Infant and Child Mortality among the 36 states and Federal Capital Territory (FCT, Abuja), Nigeria. *Journal of Health Care for the Poor and Underserved*, *31*(3), 1166-1190.
6. Below, R., Guha-Sapir, D., Vos, F., & Ponserre, S. (2011). Annual disaster statistical review 2010. *Centre for Research on the Epidemiology of Disasters*.
7. Cain, D. S., & Barthelemy, J. (2008). Tangible and spiritual relief after the storm: The religious community responds to Katrina. *Journal of Social Service Research*, *34*(3), 29-42.
8. Centre for Research on the Epidemiology of Disasters-CRED, EM-DAT (2021): The international disaster database. https://public.emdat.be/data. Accessed on: 10 Feb. 2020.
9. Chowdhury, S., Emelogu, A., Marufuzzaman, M., Nurre, S. G., & Bian, L. (2017). Drones for disaster response and relief operations: A continuous approximation model. *International Journal of Production Economics*, *188*, 167-184. Hope Bridge (2021). Relief kits and goods. https://relief.or.kr/eng/business/relief.php
10. Displacement Tracking Matrix (2023). Nigeria — Displacement Report 43 (February 2023) | Displacement Tracking Matrix (iom.int)
11. Duan, Y., & Lu, F. (2013). Structural robustness of city road networks based on community. *Computers, Environment and Urban Systems*, *41*, 75-87.
12. Eze, J.N., Aliyu, U., Alhaji-Baba, A. & Alfa. M. (2018). Analysis of farmers' vulnerability to climate change in Niger state, Nigeria. *International Letters of Social and Humanistic Sciences.* 82: 1–9.
13. Global Humanitarian Assistance Report (2017).
14. Hu, H., Fu, X., Cheng, Y., & Zhang, Y. (2017). Relief Supplies Delivery Based on Path Connectivity Reliability. *Journal of Engineering Science & Technology Review*, *10*(6).
15. International Federation of Red Cross and Red Crescent Societies (2021). Services for the disaster-affected:Relief.
16. Jana, R. K., Sharma, D. K., & Mehta, P. (2021). A probabilistic fuzzy goal programming model for managing the supply of emergency relief materials. *Annals of Operations Research*, 1-24.
17. Kovács, G., & Falagara Sigala, I. (2021). Lessons learned from humanitarian logistics to manage supply chain disruptions. *Journal of Supply Chain Management*, *57*(1), 41-49.
18. Liu Y, Cui N, Zhang J (2019) Integrated temporary facility location and casualty allocation planning for post-disaster humanitarian medical service. Transport Res Part E: Logist Transport Rev 128:1–16.
19. Li, S., & Teo, K. L. (2019). Post-disaster multi-period road network repair: Work scheduling and relief

logistics optimization. *Annals of Operations Research*, *283*(1-2), 1345-1385.

20. OCHA (2021). Northeast Nigeria: Flash Update #1 - Cholera outbreak and AWD cases in Borno, Adamawa and Yobe (BAY) states (As of 3 September 2021)
21. OCHA (2022). Nigeria Humanitarian Needs Overview 2022 (February 2022). https://reliefweb.int/report/nigeria/nigeria-humanitarian-needs-overview-2022-february- 2022
22. Okunade, S. K. (2019). Cross-border insurgency and the coping strategies of border communities in North-eastern Nigeria (Doctoral dissertation).
23. Olawale, T. N., & Adesina, K. I. (2013). An assessment of the relationship between road network connectivity and tourists' patronage in Lokoja Metropolis, Kogi State. *Journal of Natural Sciences Research*, *3*(9), 1-11.
24. Perry, R. W., Lindell, M. K., & Tierney, K. J. (Eds.). (2001). *Facing the unexpected: Disaster preparedness and response in the United States*. Joseph Henry Press.
25. Sheller, M. (2013). The islanding effect: post-disaster mobility systems and humanitarian logistics in Haiti. *cultural geographies*, *20*(2), 185-204.
26. Shiru, M.S., Shahid, S., Alias, N. & Chung, E.S. (2018). Trend analysis of droughts during crop growing seasons of Nigeria. *Sustainability* 10 (871): 1–13
27. Ye, Y & Yan, H (2020). Disaster Relief Supply Management. Disaster Relief Supply Management DOI: http://dx.doi.org/10.5772/intechopen.94008
28. Zhou, Y., & Wang, J. (2017). Critical link analysis for urban transportation systems. *IEEE Transactions on Intelligent Transportation Systems*, *19*(2), 402-415.
29. Zhou, Y., Wang, J., & Yang, H. (2019). Resilience of transportation systems: concepts and comprehensive review. *IEEE Transactions on Intelligent Transportation Systems*, *20*(12), 4262-4276.