Crisisonomy Vol.16 No.3, 69-79
ISSN 2466-1198 (Print) ISSN 2466-1201 (Online) https://doi.org/10.14251/crisisonomy.2020.16.3.69

Crisisonomy

Examining Spatial Associations of Road Intersections, Traffic Accidents, and Health Facilities in Lagos, Nigeria

HyoungAh Kim+

Institute of Public Policy and Administration, Chung-Ang University, 303-1203, 84 Heukseok-ro, Dongjak-gu, Seoul, Korea

Abstract

The purpose of this study is to suggest a new method to estimate the potential hotspots of road traffic accidents (RTAs) in underdeveloped countries. Due to the lack of infrastructure and experiences, many underdeveloped countries have failed to prepare effective policies to reduce traffic accidents. Considering their fiscal constraints, it would be critical to allocate health and traffic safety facilities with evidence-based methods. This study suggests the method of using road intersections as potential high-risk areas of RTAs when no accurate data are available in underdeveloped countries. Using the data from Lagos State in Nigeria, RTA hotspots were identified based on road intersections and travel distances from the high-risk points to the nearest health facility were calculated. There was a strong spatial correlation between the number of road traffic accidents and road interactions (p〈0.001). It is also found that urban areas had more traffic accidents but crashes were less severe, compared to suburban areas. These results indicate a disproportional allocation of health facilities between urban and suburban areas in Lagos, Nigeria.

Key words: road traffic accidents (RTA), spatial correlation, traffic safety, hotspot analysis, evidence-based method

Ⅰ. Introduction

It is undeniable that Road Traffic Accidents (RTAs) are an urgent global epidemic that requires government interventions (Onyemaechi & Ofoma, 2016). According to a report from the World Health Organization (WHO) in 2013, 1.3 million people died due to road injuries in 2011 (World Health Organization, 2013). RTA was ranked as one of top 10 leading causes of injuries in 2011. For low-income countries, the burdens of RTA are much heavier than developed countries; 93% of injury-related deaths occurred in low- and middle- income counties because of the lack of infrastructure and personnel for effective injury prevention and controls (World Health Organization, 2013; Stevens, *et. al.*, 2013).

The number of road traffic accidents, injuries, and deaths in Africa has increased over the last three decades (Adeloye, *et. al.*, 2016). The WHO African Region reported having the highest fatality rate on traffic roads, with 26.6 per 100,000 people dying in RTAs in 2013

+ Corresponding author: HyoungAh Kim, Tel. +82-2-820-5439, Fax. +82-2-813-7737, e-mail. mode21@nate.com

(WHO Global Status Report on Road Safety). The primary reason for high risk on road traffic accidents in Africa is due to the use of automobiles as a primary form of transportation, especially as they are cheap compared to other forms such as trains and flights (Adeloye, *et. al.*, 2016). Moreover, economic developments in African have caused more people to be exposed to more road injury risks because of the increase in auto-mobile in theses countries (World Health Organization, 2009-2015).

Nigeria has the highest burden of RTIs especially among sub-Saharan African countries. The road fatality rate in Nigeria was 1,042 deaths in a year for 100, 000 vehicles, (Onyemaechi & Ofoma, 2016) which contrast to 15 and 7 in the Unites States and Great Britain respectively[1]. However, effective government interventions cannot properly be made due to a lack of data and capable personnel (Onyemaechi & Ofoma, 2016). Moreover, Nigeria has poor traffic infrastructure, road design and enforcement of traffic rules and regulations, along with the rapid economic and population growth. Thus, comprehensive and robust research is necessary for safe roads in Nigeria (Onyemaechi & Ofoma, 2016).

II. Backgrounds

Nigeria is one of the most promising countries in Africa in terms of economic growth and its potential. According to a Bloomberg News Report in 2014, Nigeria became the economic leader in Africa, overtaking South Africa in GDP. Nigeria is also ranked as the 7th largest population in the world. However, the country suffers from the high fatality rate of road traffic crashes. The major reasons of for this are poor road environments, insufficient alternative mobility methods, unsafe vehicles, uneducated road users, and inappropriate post-crash treatments (Onyemaechi & Ofoma, 2016; Adogu, *et. al.*, 2009; Aworemi, *et. al.*, 2010). Among the reasons, one of most efficient ways to reduce the fatality rate from road traffic accidents is by preparing enough numbers of health facilities so that a traffic victim could be receive medical services in time. Several studies have argued that properly timed treatments after road traffic crashes are one of the most important ways to reduce the fatality rates of RTA (Hazen & Ehiri, 2006; Shaw, *et. al.*, 2017). Lagos, the most dense and populous state in Nigeria, has run an ambulance dispatching system, named “Lagos State Ambulance Service (LASAMBUS)” since 2001. To transport traffic accident victims in time, professional health workers are trained to give immediate urgent care for the victims of traffic crashes (Ibrahim, *et. al.*, 2017; Adewole, *et. al.*, 2012). However, even with the emergency dispatching system, Lagos still suffers from a high number of deaths from road traffic accidents.

1. Previous Studies

A certain amount of studies has focused on the RTA and their fatality rates in Nigeria and in the sub-region of Nigeria. In a review of Google and Google Scholar, there were 15 studies on the topic of RTAs since 2010. Most RTA studies in Nigerian regions have the dependent variable being fatality rates (Osayomi & Areola, 2015; Atubi & Gbadamosi, 2015; Atubi, 2015, 2012a, 2012b, 2010; Ibrahim, *et. al.*, 2017). One paper discusses the importance of governmental interventions to reduce the number of RTA (Onyemaechi & Ofoma, 2016), while others conducted empirical analyses with the aggregated of numbers of RTA and death from RTA. Interestingly, it appears that only one person seems to dominant the

1) Economist news article. Driving in Nigeria, Time for a test 2013. https://www.economist.com/news/middle-east-and-africa/21579057-why-nigerias-roads-can-be-terrifying-time-test

Nigeria RTA studies (Atubi & Gbadamosi, 2015; Atubi, 2015, 2012a, 2012b, 2010), meaning that the actual amount studies in Nigeria is not as extensive as originally believed.

The methodologies in these studies are not advanced enough to separate out key factors that affect RTA fatality. Some of them used a variance analysis (Atubi, 2015, 2012a), while others have used time series analysis (Abdulkabir, *et. al.*, 2015), regression analysis (Aworemi, *et. al.*, 2010), and spatial analysis (Victoria, 2016; Osayomi & Areola, 2015). Due to the lack of data availability and technical capacity, there are innate constraints that researchers can use to conduct robust analyses in order to verify complex causal mechanisms of RTAs in the country. Thus, I believe that appropriate analytic models should be implemented, using the same data that has already been analyzed. Table 1 shows a summary of the literature concerning Nigeria RTAs for the last 10 years.

Current research has shown that geographic information systems (GIS) can be used to explore an association between populations and their accessibility to health facilities. Raykar, *et. al.*(2015) found that residing within 2 hours driving distance to health care facilities, particularly to a surgeon, is essential to saving traumatically injured victims from RTAs. This indicates that decreasing transport time to definitive health care facilities is important for RTA victims when they have a traumatic injury (Swaroop, *et. al.*, 2013; Jarman, *et. al.*, 2016).

With currently available data, GIS data and the RTA records obtained from a new media scrapping technique, this study explores the distribution of health facilities in Lagos, Nigeria. Under the assumption that RTA would more likely to occur at road intersections, the distances from each road transactions to the nearest hospital is measured and compared by different levels of road structures and features of traffic accident locations.

2. Hypotheses

From the discussion of background and literature review, this study will focus on the distribution of tertiary hospitals and ambulance stations in Lagos State, Nigeria.

H1: Health facilities are disproportionally distributed by local government areas in Lagos Nigeria.

H2: Health facilities are disproportionally distributed between urban and suburban areas.

H3: The injured people from RTAs in suburban areas travel longer distances to transfer to a hospital than the ones in urban areas.

Ⅲ. Methodology

In many studies of road traffic accidents, actual locations of traffic crashes and their health outcomes are used to conduct statistical analyses so that the findings from the analyses could provide meaningful policy implications. This study, however, could not obtain the data about road traffic accident locations and crash victim's health outcomes. Alternatively, this study uses a structure of road networks in the Lagos state as potential spatial locations of RTAs in the study area. Several studies have exhibited that most vehicle-pedestrian crashes occurred at traffic road intersections or conjunctions compared to other types of road environments and settings (Lee & Abdel-Aty, 2005; Moons, *et. al.*, 2009; Loo, 2009; Shaw, *et. al.*, 2017). Therefore, the statistical analysis in this study uses the locations of road conjunctions as potential crash points. To validate the assumption of potential RTA locations, the aggregated numbers of RTAs and deaths from the RTAs at the local government area (LGA) level are analyzed to determine whether they have correlated each other. If they have a certain amount of correlation, then the locations of road intersections can be used as highly probable spatial points

where RTAs occur. After testing the data validation, a level of points clustering is estimated by Moran's I estimates and a kernel density function.

$$Moran's\ I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \cdot \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i}^{n}(x_j - \bar{x})^2}$$

In addition to *Moran*' I estimates, a kernel density is employed to exhibit high dense areas of road intersections in a map. Kernel density estimation used in this analysis to create a density raster of intersections points (Sheather & Jones, 1991) as highlighting the small areas where many road intersections are located in a map. Through this assumption, these areas are noticed as possessing high risk to have dense RTAs. Thus, hotspots of potential RTAs are marked in a map. Then each spatial points of the risk RTA areas are matched with the nearest the secondary or tertiary health facilities. Afterwards, the distances between a RTA point and the matched hospital are measured. In scrutinizing the maps by measuring travel distances from the hotspots to the nearest health facility, we can discuss the pattern of travel distances by LGA's features.

1. Data

This study used two different types of data to conduct a geospatial analysis. First, geographic information systems (GIS) data such as point, line, and polygon shapefiles were substantially used in this analysis. The shapefiles of Lagos state in Nigeria were downloaded from the website, titled openAFRICA[2]. Additionally, the four different level road networks in Lagos were given by the office of Global Health at the University of Texas Southwestern (UTSW) Medical Center. The road network data include major, minor, tertiary, and residential roads in Lagos. In addition to GIS data of Lagos, the physical addresses of health facilities were provided by the office of Global Health at UTSW. By geocoding the health facility location data, the location of secondary and tertiary heath faculties are depicted in Lagos maps.

The second data used in this analysis were the number of RTAs and fatal RTAs from June 2006 to December 2018. The data were obtained from the Nigeria Watch database[3]. The French Institute for Research in Africa, which hosts the database, has collected all types of human injury data from 15 different Nigerian news media across the country such as Vanguard, Leadership, the Guardian, Sun and so on. After obtaining access to the database, I queried data by the region of Lagos and the type of injury as road accidents. The data subset has a feature of LGA, so the numbers of RTAs and fatal RTAs were aggregated at the LGA level. Although data were not provided by the Lagos state governments, several previous studies have analyzed the data from the Nigeria Watch database (Vitus, 2014; Chouin, *et. al.*, 2014; Nwankwo & James, 2016). Moreover, this study used this RTA data as a check for validation for potential RTAs locations whether the aggravated numbers of potential RTAs are corresponding to the actual numbers of RTAs. Thus, this study argues that the analysis can bear a certain level of noise in data because they are not directly calculated into analysis' results but are rather used for comparing RTA patterns by administrative locations in Lagos.

2. Validity

The results of a multimethodology for a data validation test and spatial analyses will be presented in the following paragraphs.

2) https://africaopendata.org/dataset?tags=Nigeria+LGA+Boundaries, last retrieved on May 2, 2019

3) https://www.ifra-nigeria.org/, last retrieved on May 2, 2019

Table 1. Descriptive analysis of RTAs and road intersections

Statistic	N	Mean	S.D.	Min	25%	75%	Max
RTAs	20	79.3	49.1	23	48.5	103	220
Major-minor inters.	20	41.1	59.3	0	3	55.5	207
Major-tertiary inters.	20	110.9	86.8	1	33.8	160	368
Major-residential inters.	20	302.1	219.4	16	175.2	365.2	1,005
Total road inters.	20	454.1	298.3	21	265.2	586.5	1,267

1) Validity of Potential RTA Locations.

<Table 1> shows the results of a descriptive analysis for the numbers of RTAs and road intersections at different levels in road structures.

The total numbers of RTAs and deaths from the RTAs in Lagos, Nigeria from 2006 to 2018 were 1586 and 4314 respectively. This fact implies that on average, 2.7 people were killed in a single traffic accident. The burdens of RTAs are disproportionally distributed by LGA. For example, while Epe had 23 RTAs, Ikeja had 220 RTAs in the study time period. For the number of road intersections, the largest number of intersections in LGA was 1267 where I assume to have a high likelihood of RTAs compared to the other LGAs. More details of the descriptive analysis about RTAs and road intersections at the LGA levels are shown in <Table 1>.

To check the validity of the assumption that RTAs occur at the road intersections, the correlations between the numbers of RTAs and road intersections aggregated by LGAs are computed as found in <Figure 1>. The RTA variable are positively correlated with the frequency of road intersections, especially the correlation of RTAs and major-minor road intersections and major-residential intersections are statistically significant. Therefore, the assumption that if there are more road intersections in an area, the more RTAs will occur, is validated. Thus I can use a road intersection location as a potential RTA location.

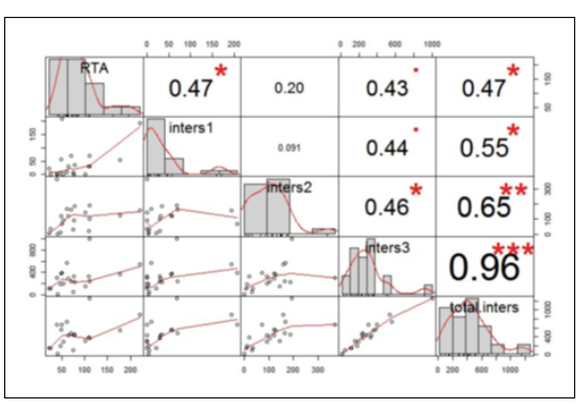

Figure 1. Correlations between true RTA numbers and road intersections at the LGA level

3. Results

1) Spatial Clustering of Road Intersections

The level of intersection clustering is first measured by Moran's I (Moran, 1948).

Table 2. Morn's I estimates by the level of road intersections

Road intersections	N	N in hotspot	Moran's I	p-value
Major-minor	882	320	0.065	<0.001
Major-tertiary	2218	573	0.026	<0.001
Major-residential	6042	678	0.095	<0.001

<Table 2> shows the estimated coefficients of Moran's I. The values of Moran's Is are positively statistically significant at less than 0.1% level although their magnitudes are relatively small. In the Moran's I calculation, the frequency of road interactions are aggregated by LGAs, so an actual clustering of interaction points crossing LGA's boundaries were ignored in cluster

measurement. Therefore, this study, thus a Kernel density estimation for mapping hotspots of road interactions rather than Moran's I estimates. The total numbers of each road intersection were also counted. There are 6042 intersections between major and residential roads, 2218 intersections between major and tertiary roads, and 882 intersections between major and minor roads. Among those intersections 678 points, 573 points, and 320 points are estimated as hotspots of the road intersection for major-residential roads, major-tertiary roads, and major-minor roads respectively. It should be noted that the hotspots estimations were done by Kernel density functions. More details about how road interactions, meaning potential RTA locations are illustrated with hotspot maps by each level of road interactions.

2) Hotspot Analysis

(1) Results of hotspot analyses

<Figure 2> depicts the hotspot areas of the major and minor road intersections. Since the center of Lagos state is in a highly dense area, the hotspots of potential RTAs at major and minor interactions concentrate in the central part of Lagos. In addition to the road intersections, health facilities are more closely located with each other in the center compared to the other peripheral areas of the state.

The estimated travel distance from the hotspot points to the nearest health facilities is 1146.3 meters on average. This indicates that RTA victims need to travel around 1 kilometer if the RTA happens at major-minor road intersections.

<Figure 3> shows the hotspots distribution of major and tertiary road intersections. Similarly to the previous map, most hotspots concentrate in the center of the state where highly dense areas are located. The pattern of hotspots allocations is different, spreading out wider than the ones of major-minor road intersections. It is because

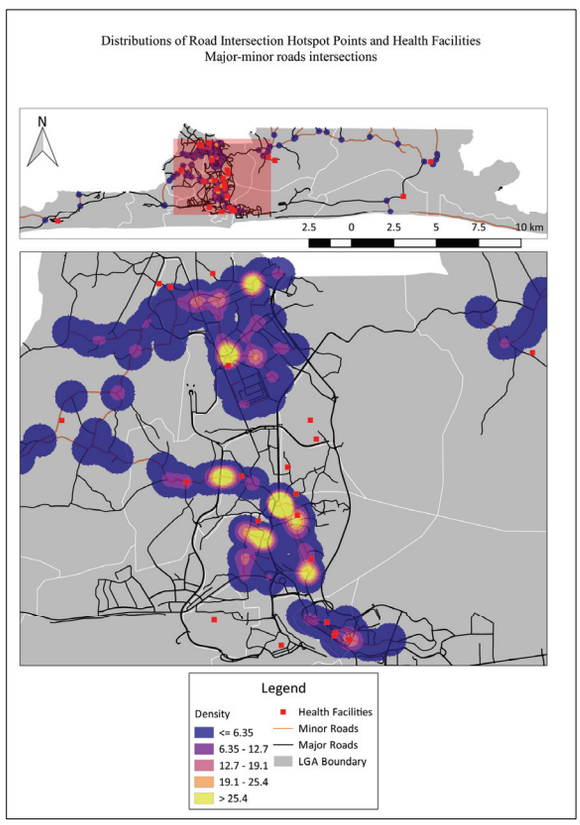

Figure 2. Hotspots of major-minor road intersections

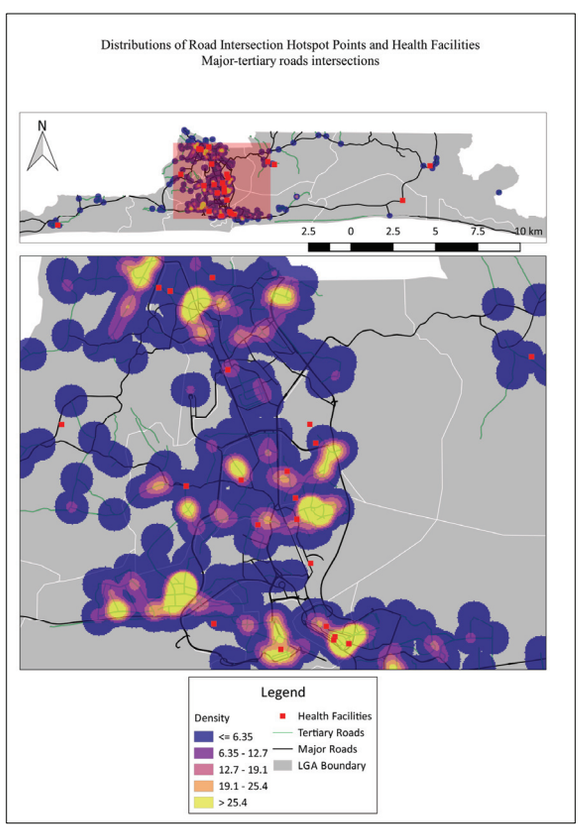

Figure 3. Hotspots of major-tertiary road intersections

tertiary roads are more widely stretch out than minor road in Lagos. The estimated average travel distance from hotspot points to health facilities is 1780 meters. As the number of potential RTA points that reach broader areas at the tertiary road level increases, the longer distance RTA victims in the major-tertiary intersections travel around 1.7 km.

<Figure 4> displays the hotspot of road intersections between major and residential roads. As residential roads reach much wider areas of the state as found by green lines in the map, the broader areas are selected as hotspots for potential RTA areas, along with major roads. Because of the greater numbers of hotspots, the travel distance is longer than the other two types of road intersections. The average estimated travel distance from the hotspot points of major-residential road intersections to the nearest health facilities is 2342 meters. The victims of RTAs occurred at the residential road intersections would travel

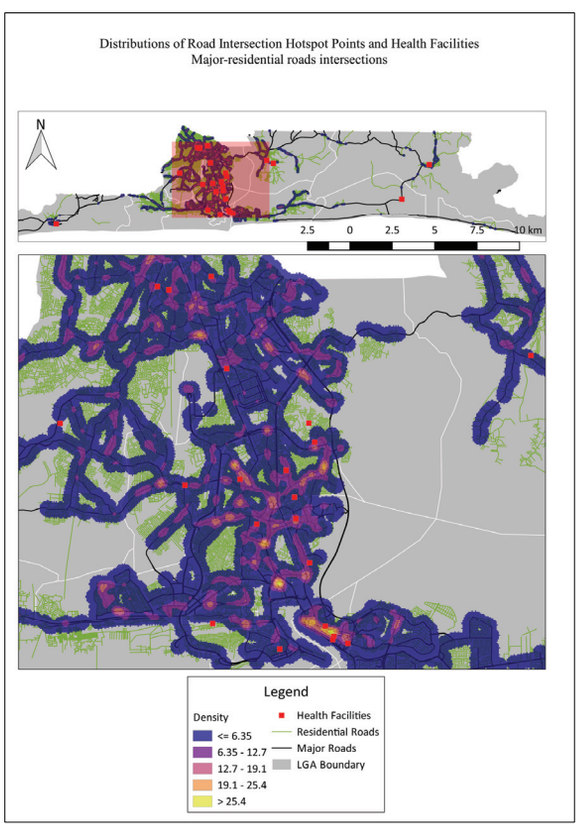

Figure 4. Hotspots of major-residential road intersections

2.3 km to get medical services, thus being more likely to receive late health treatments compared to the others who might have traffic crashes at the upper level of road structures.

(2) Travel Distance Comparison between Urban and Suburban Areas

As found in the previous subsection, most potential RTA points and health facilities are located in the center of Lagos. Meanwhile, the peripheral areas in the state are less dense and have fewer health facilities. To detect the different patterns of travel distances and RTAs between the central and the peripheral areas, I have coded the LGAs by urban and suburban areas. If a LGA is located in the center and is introduced as a urban area in government websites, the LGA is remarked as urban. Before comparing the other features of RTAs, the average travel distance from every intersection point to the nearest health facility within a LGA is depicted in <Figure 6>. As expected, the average travel distances from the road intersections to the nearest hospitals vary by LGAs. The LGAs in central Lagos explicit shorter distances compare to the LGAs in suburbs. RTA victims in Lagos Island would travel 670 meters to go the nearest hospital, but the ones in Ibeju/Lekki would travel 30 times longer distance as of 20 km to reach the nearest hospital. I found that the travel distances between urban and suburban areas are substantially different because of numbers of health facilities nearby.

<Figure 5> shows a comparison of the numbers of RTAs, fatal RTAs, and the travel distance to a hospital between urban and suburban areas. While the average travel distance in urban areas is around 2 kilometers, suburban areas are around 7 kilometers (see the gray bar in <Figure 5>). A particularly interesting finding is that urban areas have greater numbers of RTAs compared to

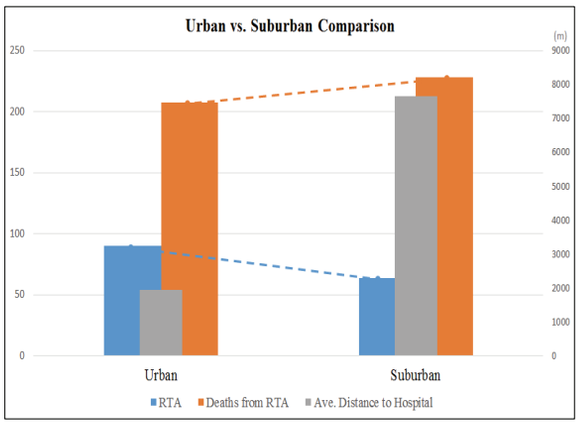

Figure 5. Comparison of urban and suburban areas in Lagos

suburban areas, but the number of fatal RTAs is smaller than compared to suburban areas. There could be several reasons for this difference in patterns for RTAs and the numbers of deaths from the RTAs. First, the most urban areas locate in the center of Lagos where high populations and vehicle registration rates, so a chance of traffic accidents becomes higher than compared to less populated areas. Second, the urban areas usually have strict traffic policies or more safety patrols, so the behaviors of road users are more likely to be careful compared to road users in suburban areas. Fatal traffic accidents are, therefore, less likely to occur in the urban areas. Lastly, in the context of travel distance, there is a possibility of an association between long travel distances to medical facilities and high numbers of deaths as compared in <Figure 5>. The data of fatal RTAs were collected from news media that did not specify that when and where the victims of RTAs died. Thus, the result found in <Figure 5> suggests that there could be an association between the longer travel distance traveled to the medial facilities and RTA fatalities. However, further support this correlation, further analyses would be needed that includes more information of RTA victims, how they transfer, and the health outcomes.

Ⅳ. Conclusion

By assuming that road intersections would have road traffic accidents in the study area, the average distance from the RTA locations to the nearest hospitals were estimated by each LGA, the central, and peripheral areas of Lagos. This study found that RTA victims at major-minor road intersections need to travel around 1 kilometer, would travel 1.7 kilometers at major-tertiary road intersections, and would travel 2.3 kilometers at major-residential road intersections. This finding implies that most of the secondary and tertiary health facilities in Lagos are located near the major roads and urbanized areas. This is also verified by a comparison of travel distances between urban and suburban areas. While the average travel distance in urban areas was 2 kilometers, this average increased in suburban areas to 7.5 kilometers. This shows that the RTA victims in the suburban areas would travel 3.75 times longer than those in urban areas. Interestingly, the number of deaths from RTAs in suburban areas were greater than ones in urban areas, as shown when contrasting the burdens of RTAs in both areas (see <Figure 7>). This finding indicates that the RTAs in suburban areas was less frequent but were more severe than the RTAs in urban areas. This finding may imply that a longer travel distance could result in a greater number of deaths from road traffic crashes in suburban areas.

Overall, the average travel distances in Lagos was relatively shorter than those in other African regions. For example, the estimated travel distance from the RTA locations to the nearest health facility in Nairobi, Kenya was 6.8 kilometers (Shaw, *et. al.*, 2017). Therefore, this study can conclude that the health facilities in Lagos Nigeria are relatively well located than when compared to those in Nairobi. However, this direct comparison of

travel distances with other African regions may not be an appropriate way to evaluate the allocation of health facilities. Due to a variety of traffic road environments and settings, specific risk factors reside in particular regions should be explored (Aworemi, *et. al.*, 2010; Onyemaechi & Ofoma, 2016). Yet, some imperative points can be generalized, providing meaningful implications to policy makers in Lagos State. As shown in the this study, shorter travel distances will decrease the rate of RTA fatalities in Lagos. Therefore, an increase in either more health facilities or better medical capacity in suburban areas should be considered to minimize risk to die from road traffic accidents.

There are some limitations in this study. Due to the lack of data accessibility, the RTA locations were presumed by the road intersection locations based on arguments from previous studies (Lee & Abdel-Aty, 2005; Moons, *et. al.*, 2009; Loo, 2009; Shaw, *et. al.*, 2017). Thus, the estimation for road distance may contain some observational bias. To reduce this bias, the numbers of road intersections and the number of RTAs at the LGA level were compared and verified to determine levels of correlations. Another limitation in the analysis was not being able to account for traffic conditions in Lagos in measuring travel distances. The travel time can vary by population density, traffic volumes, and other road conditions, so this study could not estimate accurate travel time in real road contexts. Although travel distances are relatively short, the travel times can be elongated because of bad road conditions and traffic congestion. Better information about the way of RTA victims dispatching, treatments and health outcomes is necessary to support the policies that make reduce the travel distance from RTA locations to a health facility

Acknowledgement

This study is a part of the author's doctoral dissertation, titled "Three Essays on Traffic Crashes: Global Health Burdens and Policy Implementations" at the University of Texas at Dallas in 2019.

References

Abdulkabir, M., R. S. Tunde, and U. A. Edem. 2015. Trend Analysis on Road Traffic Accident in Nigeria. *Science Innovation*. 3(5): 52-57.

Adeloye, D., J. Y. Thompson, M. A. Akanbi, D. Azuh, V. Samuel, N. Omoregbe, and C. K. Ayo. 2016. The Burden of Road Traffic Crashes, Injuries and Deaths in Africa: A Systematic Review and Meta-analysis. *Bulletin of the World Health Organization*. 94(7): 510.

Adewole, I. O., F. Kayode, S. O. Giwa, M. O. Shoga, A. O. Adejumo, and S. A. Ademiluyi. 2012. Ambulance Services of Lagos State, Nigeria: A Six-year (2001–2006) Audit. *West African Journal of Medicine*. 31(1): 8-13.

Adogu, P., A. L. Ilika, and A. Asuzu. 2009. Predictors of Road Traffic Accident, Road Traffic Injury and Death Among Commercial Motorcyclists in an Urban Area of Nigeria. *Niger Journal Medicine*. 18(4): 393–397.

Atubi, A. 2012a. Dominant Injuries from Road Traffic Accident Cycles in Lagos State, Nigeria. *Academic Journal of Interdisciplinary Studies*. 1(2): 237–252.

Atubi, A. 2012b. A Monthly Nalysis of Road Traffic Accident in Selected Local Government Areas of Lagos State, Nigeria. *Mediterranean Journal of Social Sciences*. 3(11): 47–62.

Atubi, A. 2015. Modelling Deaths from Road Traffic Accidents in Lagos State, Nigeria. *American International Journal of Social Science*. 4(5): 119–213.

Atubi, A. and K. Gbadamosi. 2015. Global Positioning and Socio-economic Impact of Road Traffic Accidents in Nigeria: Matters Arising. *American International Journal of Contemporary Research*. 5(5): 136–146.

Atubi, A. O. 2010. Road Traffic Accident Variations in Lagos

State, Nigeria: A Synopsis of Variance Spectra. *African Research Review*. 4(2): 197-218.

Aworemi, J. R., I. A. Abdul-Azeez, and S. O. Olabode. 2010. Analytical Study of the Causal Factors of Road Traffic Crashes in Southwestern Nigeria. *Educational Research*. 1(4): 118-124.

Chouin, G., M. Reinert, and E. Apard. 2014. Body Count and Religion in the Boko Haram Crisis: Evidence from the Nigeria Watch Database. *Islamism, Politics, Surity and the State in Nigeria*. 213.

Chun, Y., Y. Kim, and H. Campbell. 2012. Using Bayesian Methods to Control for Spatial Autocorrelation in Environmental Justice Research: An Illustration Using Toxics Release Inventory Data for a Sunbelt County. *Journal of Urban Affairs*. 34(4): 419-439.

Hazen, A. and J. E. Ehiri. 2006. Road Rraffic Injuries: Hidden Epidemic in Less Developed Countries. *Journal of the National Medical Association*. 98(1): 73.

Ibrahim, N. A., A. W. O. Ajani, I. A. Mustafa, R. A. Balogun, M. A. Oludara, O. E. Idowu, and B. A. Solagberu. 2017. Road Traffic Injury in Lagos, Nigeria: Assessing Prehospital Care. *Prehospital and Disaster Medicine*. 32(4): 424-430.

Lee, C. and M. Abdel-Aty. 2005. Comprehensive Analysis of Vehicle-pedestrian Crashes at Intersections in Florida. *Accident Analysis & Prevention*. 37(4): 775-786.

Loo, B. P. 2009. The Identification of Hazardous Road Locations: A Comparison of the Blacksite and Hot Zone Methodologies in Hong Kong. *International Journal of Sustainable Transportation*. 3(3): 187-202.

Moons, E., T. Brijs, and G. Wets. 2009. Identifying Hazardous Road Locations: Hot Spots Versus Hot Zones. *In Transactions on Computational Science VI*. Berlin Heidelberg: Springer. 288-300.

Moran, P. A. 1948. The Interpretation of Statistical Maps. *Journal of the Royal Statistical Society: Series B (Methodological)*. 10(2): 243-251.

Nwankwo, U. V. and O. O. James. 2016. Prevalence of Lethal and Non-lethal Crimes in Nigeria. *Journal of Advanced Research in Humanities and Social Science*. 3(1): 10-25.

Onyemaechi, N. and U. Ofoma. 2016. The Public Health Threat of Road Traffic Accidents in Nigeria: A Call to Action. *Annals of Medical and Health Sciences Research*. 6(4): 199-204.

Osayomi, T. and A. A. Areola. 2015. Geospatial Analysis of Road Traffic Accidents, Injuries and Deaths in Nigeria. *The Indonesian Journal of Geography*. 47(1): 88.

Shaw, B. I., A. A. Wangara, G. M. Wambua, J. Kiruja, R. A. Dicker, J. M. Mweu, and C. Juillard. 2017. Geospatial Relationship of Road Traffic Crashes and Healthcare Facilities with Trauma Surgical Capabilities in Nairobi, Kenya: Defining Gaps in Coverage. *Trauma Surgery & Acute Care Open*. 2(1): e000130.

Sheather, S. J. and M. C. Jones. 1991. A Reliable Data-based Bandwidth Selection Method for Kernel Density Estimation. *Journal of the Royal Statistical Society: Series B (Methodological)*. 53(3): 683-690.

Stevens, K. A., F. Paruk, A. M. Bachani, H. H. Wesson, J. M. Wekesa, J. Mburu, J. M. Mwangi, H. Saidi, and A. A. Hyder. 2013. Establishing Hospital-based Trauma Registry Systems: Lessons from Kenya. *Injury*. 44(Suppl 4): S70-S74.

Victoria, O. 2016. Spatio-temporal Analysis of Road Traffic Accident Black Spots Kaduna State, Nigeria. Ph.D. Dissertation. Ahamadu Bello University.

Vitus, N. 2014. Trends and Patterns of Fatal Road Accidents in Nigeria. *IFRA-nigeria Working Papers Series*. November. 35.

World Health Organization. 2009. Global Status Report on Road Safety: Time for Action.

World Health Organization. 2013. *Pedestrian Safty: A Road Safety Manual for Decision - Makers and Practitioners*. http://apps.who.int/iris/bitstream/10665/79753/1/ 9789241505352_eng.pdf?ua=1.

World Health Organization. 2015. Global Status Report on Road Safety 2015.

Received: Jan. 31, 2020 / Revised: Feb. 26, 2020 / Accepted: Feb. 26, 2020

교통사고와 도로 교차로의 지리적 상관관계 및 보건시설 배치의 과학적 방법연구

- 나이지리아 라고스를 중심으로 -

국문초록 아프리카 등 제3세계 국가와 같이 사회 인프라가 낮은 지역은 데이터 및 연구시설의 부족으로 증거기반(evidence-based) 교통안전 정책 마련에 어려움을 겪기가 쉽다. 특히 저개발 국가일수록 재정적 어려움으로 인해 선진국보다 더 효율적인 방법을 사용하여 안전시설을 배치해야 하는데, 교통사고 위치와 같은 중요데이터가 없는 경우가 많아 안전시설의 과학적 배치가 어려운 실정이다. 이 논문은 저개발 국가를 위해, 교통안전 정책마련 시 도로의 교차점을 사고다발지역으로 가정하고 핫스팟 분석(Hotspot analysis)을 통해 사고 위험성이 높은 지역을 유추한 후 교통안전시설 배치를 위한 방법을 제안하는 데 목적이 있다. 나이지리아의 라고스(Lagos) 주를 연구대상으로 계산한 결과 도로교차점과 사고 수가 통계적으로 상관관계가 높다는 사실 및 도시지역이 비도시 지역보다 사고의 수가 많지만, 사고의 심각성(severity)은 낮다는 사실을 밝혀냈다. 이 논문에서 제안한 방법이 다른 아프리카 도시 및 지역에도 확대・적용되어 도로 안전 수준을 높이는 데 기여하길 바란다.

주제어 : 교통안전, 저개발 국가의 교통안전, 핫스팟 분석 (Hotspot analysis), 지리적 상관관계, 증거기반정책

Profiles **HyoungAh Kim :** She received her Ph.D. degree in Public Policy and Political Economy at the University of Texas at Dallas in 2019. Her research interests are public health, environmental sustainability, risk management, and program evaluation with the methods of a big data analysis and machine learning. She is a senior researcher in the Institute of Public Policy and Administration at Chung-Ang University in Seoul, South Korea(mode21@nate.com).