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Analysis of spatial distribution of worship centres using maximum location model in part of Minna, Niger state, Nigeria

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ABSTRACT

The research uses the Maxisum Location Model to determining optimal location of existing worship centres in part of Minna Metropolis with the primary goal of locate p facilities such that the total demand-weighted distance between demand nodes and the facilities to which they are assigned is maximized (i.e. This model was adopted to solve the problem of noise generated from the sound-speaker) used by these worship centres during their services to the nearest neighborhood using 500meters as a distance factor. Since there are no restricted rules governing siting of worship centres it may not be located everywhere optimally, therefore, more areas were affected when a distance less than 500meters criteria was used while some areas are farther from the noise based on their location at optimal distance of 500meters and above. Spatial analysis was carried out on the sufficiency or otherwise of churches and mosques within the study area. Multi-criteria queries were carried out and results revealed that some worship centers need to be relocated because the area they were are too congested and also generate more noise to the environment through sound-speaker used. Recommendations were made to predict future deficiencies if relevant government agencies fail to provide more rules and regulations in siting of worship centers as the population increases.

Keywords:
Facilities, Geographic Information System (GIS), location, residential area, services area, spatial analysis and wards

1. Introduction and Perception

The increases in urban growth, the capacities of developing urban centres and governments to manage the consequences of urban noise level trends decreasing according to Gabriel [5]. Literarily, pollution is been described as to make unhealthily impure as well as a substance that makes air, water, soil among others; dangerously, dirty and thus unsuitable for people to use [11]. It is a substance that adulterates, infects, perverts and vitiates the safety of another substance. Atolagbe, and Tanimowo [1] confirmed that a major factor of environmental hazard in an urban area is

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traceable to pollution. The pollution of an environment occurs in three major ecological components of the environment: air, water and land. And it ranges from solid to sewage wastes, chemical, industrial and nuclear discharges and pollution of water, aquifer and air.

Effective management of these and other environmental pollutants is similar to the maintenance of orderly, clean, healthy crisis-free and sustainable environment. Nearly all the noise sources identify earlier in the study ranging from commercial sources to domestic sources, constitute legitimate human activities.

On the contrary, it is bad enough that people literally go to hell and return in trying to commute from one point to another, given the traffic snarl they grind through daily. Yet it is worse that even at night they are unable to get good hours of sleep owing to the growing amount of noise in the neighbourhood. Such noises are either coming from the generating sets when there is power outage, as is often the case, or from many churches and mosques whose loudspeakers costly blare to the highest decibel [2]. Recently, the Lagos state government shutdown 70 churches, 20 mosques and about 11 hotels, club houses and beer parlors in a move aimed at reducing the noise level in the state [6].

According to the general manager of Lagos State Environmental Protection Agency [2], nobody is allowed to make noise above 55 decibel during the day in the residential area and only 45 decibel is allowed in such area at night. In the industrial areas, 90 decibel of noise is allowed during the day which the noise rate must not exceed 80 decibel at night in such area.''

The right to associate, to freedom of worship, to earn a living, among others; in respect of individuals is guaranteed, not only in the country's constitution; but also in international chatters. All these activities are also carried out or performed by citizens of other nations including the more developed countries of the world where noise pollution is minimal [5].

The unchecked establishment of churches and mosques in residential neighborhoods is a telltale sign of the subversion of law and order in our society [2]. In property planned estates and neighborhoods, religious worship centres are usually designated away from residential areas in such a way that the noise generated from such centres could hardly be a source of nuisance. With the grating noise of many generators, sounding as if they have no exhaust pipes, residential neighbourhoods literally go up in babel of sounds wherever there is power outage in such neighbourhoods, night fall and sleeping become nightmarish yet apart from the loud noise that generating plants from hotels produce, the heavy fumes from their exhausts also pollute the environment in no small measure.

It is very difficult to proscribed or legislated against any of these activities. Corrective efforts should be put in place to moderate these activities in a way that minimum noise is generated. Actually, the problem is not so much with the activities that generated the noise, but rather with the ways these activities are carried out. For instance, the more loudly the speakers mounted on the roof of church during worshiping does not invited more worshipers during service or indicates the effectiveness or sincerity of worship , since religions centres carry enough identity for worshipers to recognize without being concerned with noise [5].

The in discriminate siting of such centres even in residential neighbourhoods is clear affronts on the rights of the residents who have no suffer the effects of the noise they do not generate. Not only does such noise have dangerous impact on the health of the victims, they rob the people of their secular right, as they are in adventently drawn into such worship sessions because loudspeakers are virtually affixed to their home.

Locating a facility in the best location is a decision making problem. The best place depends on criteria like the optimal distance, the capacity of the facility, population of demand, population density etc. However, the objectives to be considered in decision making can be distinguished by many factors because the presence of facilities can produce different kinds of effects. If these effects are considered positive by customers, facilities are defined "desirable" [7]. It is the case of many services (public or private) such as schools, public offices, shopping centers, metro stations. On the other hand, if facilities are source of risks and/or damages, they are considered “undesirable or obnoxious”: examples of this kind are landfills, nuclear reactors, chemical plants, military installations and worship centres etc.

If facilities are desirable, the decision maker aims at positioning them as close as possible to the customers. When facilities are considered "undesirable" or "obnoxious", customers aim at avoiding their presence and try to keep such facilities far away from them. Therefore, they will be located in the area with the smallest number of customers. A possible objective to describe this problem is the maximization of the distance between facilities and their assigned customers (MaxiSum problems). In order to assist appropriate government agencies in the state to determine areas where certain facilities are causing more noise pollution or otherwise, this research therefore used Facility locational criteria and Maxisum Location Model for querying the coverage and service areas of the churches and mosques in the research area.

In other word, this work is not responsible for the political, religious, racial or partisan in any correspondence conducted. Therefore, any such opinion expressed, whether explicitly or implicitly, in any said correspondence is not to be interpreted as that of the Authors neither attempt to investigate the structural stability of the facility or the road network, but investigated the appropriateness of the location wherein the facilities are sited and their corresponding spatial distribution (Euclidean distance from potential users within the research area.

1.1 Objectives of Facility Location Problems

Objectives to be considered in decision making can be distinguished by many factors because the presence of facilities can produce different kinds of effects. If these effects are considered positive by customers, facilities are defined "desirable" [7]. It is the case of many services (public or private) such as schools, public offices, shopping centers, metro stations. On the other hand, if facilities are source of risks and/or damages, they are considered “undesirable or obnoxious”: examples of this kind are landfills, nuclear reactors, chemical plants, military installations.

If facilities are desirable, the decision maker aims at positioning them as close as possible to the customers. In other words, customers attract ("pull") the facility to them (pull objectives). In order to obtain this kind of solution, it is possible to use efficiency measures such as the minimization of the distance between facilities and their assigned customers (MiniSum problems). Figure 1 shows an example of location based on pull objectives. There is a set of potential sites and a set of demand points in a given location space where the decision maker wants to locate two facilities. Each potential facility is pulled by customers through a sort of “attractive force” (represented by the arrows in the Figure 1). Consequently, the facilities will be located in the area with the largest number of demand points. When facilities are considered "undesirable" or "obnoxious", customers aim at avoiding their presence and try to keep such facilities far away from them (push objectives). In Figure 2 customers push them away through "repulsive forces".

Therefore, they will be located in the area with the smallest number of customers. A possible objective to describe this problem is the maximization of the distance between facilities and their assigned customers (MaxiSum problems).

However, the adoption of this measure would contribute to locate the facilities too far (in theory as far as possible) and the resulting solution would be not realistic in terms of efficiency. For this reason, solutions should be selected considering a trade-off between two conflicting objectives: for efficiency reasons facilities should be not too far from the area they serve but, at the same time, they should be far from the customers. In addition, further location problems have been defined pursuing the objective of the "equality" of distances between demand points and the set of facilities (balancing objectives).

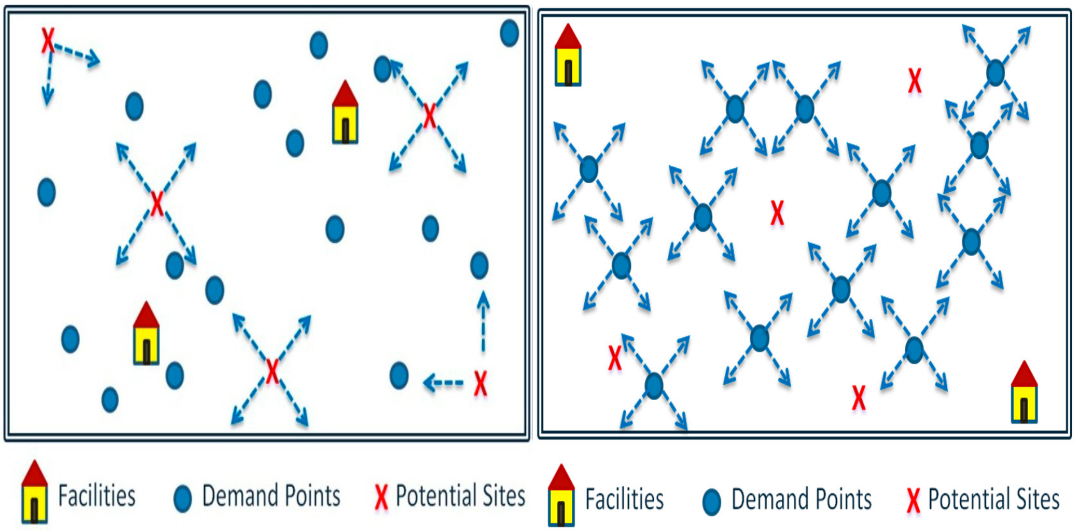

Fig. 1. Example of location based on pull objectives

This type of objectives is used, for example, when the location of public facilities must take into account not only the achievement of efficiency targets but also the more complex concept of "equity". We consider push objectives when facilities are defined as undesirable, i.e., customers wish as one of their objectives to “push” facilities as far from them as possible. Without any restrictions, push objectives will attempt to locate the facilities toward infinity.

1.2 Maxisum Location Problem Concept

One of problem class having a push objective is maxisum location problem. The maxisum location problem seeks to locate p facilities such that the total demand-weighted distance between demand nodes and the facilities to which they are assigned is maximized. Given this constraint, these models seek to maximize the distance between any barrier that wants to occur between the customer and the facilities (i.e. maximize the distance to be covered by the demand points to the facilities) in or to prevent dissatisfaction between them [3].

Thus, by solving the location set covering problem over a range of values of distances, it is possible to develop a cost-effectiveness curve from the pairs of numbers (maximal service distance S, minimum number of facilities to cover). Examination of the cost-effectiveness curve reveals that for a given number of facilities, there may be many location solutions which fulfill the requirement of coverage. However, for a desired level of expenditure then (e.g. fixed number of facilities), one may wish to determine the solution with the smallest maximal service distance [10].

It could happen that the distance value obtained in this manner is much larger than the desired distance S. If it is, the decision maker may shift his attention to concern with the total population covered within S. Having realized that his resources (facilities) are affecting the beneficiary to enjoy the facilities or to achieve total coverage within his distance goal, the decision maker may seek to cover as many people as possible within S using those limited resources by preventing them from any undesirable effect the facilities might want to bring to the beneficiary to enjoy it.

In short, when a decision maker faces the reality of number of facilities causing undesirable or obnoxious": examples of this kind are landfills, nuclear reactors, chemical plants, military installations, environmental factors such as noise etc., he may want to cover the maximum population possible within the desirable distance but ensure at the same time that no one is less than a distance I (where I < S) to his closest facility. Insistence on total coverage within T may be included in order to provide some degree of equity to those not served within the shorter and more desirable service distance S. The closer I can come to the desirable distance S, the fairer the solution is to the people covered within S. [10].

2. Materials and Methods or Study Area Description

2.1 Material

Both spatial and other attribute data, primary and secondary data, necessary for the description and effective analysis of the spatial information were collected. Table 1 gives an overview of the sources of the datasets used for this research.

Table 1
Data and their sources

Data	Source
Worship Centers i.e. Church and Mosques locations	Field observation using Garmin Handheld GPS
Road Network	Office of the Surveyor General of Niger State – GIS Department
Base Map (Landsat Satellite imagery of 30m resolution)	Geography Department, Federal University of Technology, Minna, Niger State
Worship Centers Attribute Data (such as name of churches and mosques in each ward and the effect of the worship center to the entire environs)	Personal interview of the researchers
Population /Estimated Population	-ditto-

2.2 Methods

ArcGIS 10.2 software was used to map the existing worship centres locations and their demand points; along with other constrains and siting determinant factors (e.g. population, etc.). This thus served as a basis using the model builder for modeling the suitability or otherwise of the existing worship centers and the possible need for siting more worship centres at other locations or re-locate them if noise generated from the sound speaker based on 500 meters distance factor criteria imposed on the facility will not have effect on their location to the neighbourhood.

2.3 Formulation of Mathematical Model of the facilities to the Neighbourhood

Figure 3 illustrated the mathematical formulation used in solving the Maxisum location-allocation problem within the study area with notations adopted to domesticate the original "set theory" based formulations in "Spatial Based" Algebraic form [10].

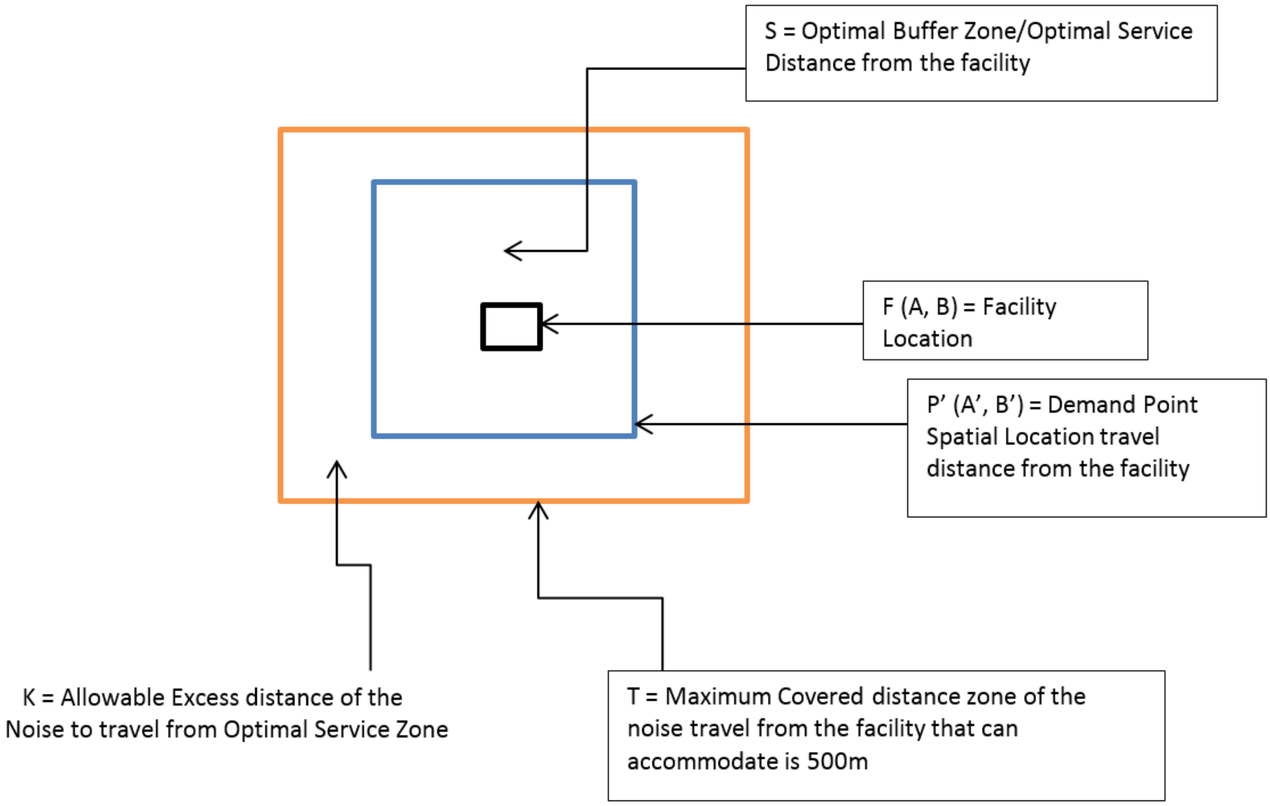

Fig. 3. Formulating Maxisum Location Problem algorithm (Authors' research, 2016)

Location–Allocation solves the problems of matching supply and demand by using sets of objectives and constraints. A location-allocation analysis matches the distribution facilities and the demand while meeting both the objective and the constraint.

Hence, to obtain optimal location of the worship centers from the demand nodes i.e. residential area:

$$F(A, B) = P'(A', B') + S \quad (1)$$

Where: F (A, B) = Optimal Spatial Location of Facility, P' (A', B') **=** Demand Point Spatial Location, and S = Optimal Service Distance between Demand Point Spatial Location and Facility Spatial Location.

However, if the effect of the noise coming out from the existing facilities as more effect on the residential areas in such that Equation (1) cannot hold, i.e. the intensity of the noise is higher on demand nodes (i.e. people to enjoy the facilities), then Maximum Covered distance zone of the noise to travel from the facility (T):

$$T = S + K \quad (2)$$

where: K = Allowable Excess distance of the Noise from optimal service zone (S).

Therefore, the above models were used to determine whether the public facilities, worship centers, were optimally located to serve people located within S or T using 500meters distance without any effect of noise barrier.

Hence, this formula was also used in computing the intensity of the noise of the speaker to each neighbourhood: $I = P * n(A, B)\, D/2D$ [8].

$$I = P * n(A, B)\, D/2D \tag{3}$$

where;

$D1 = D2 = D$

I = Intensity

X = Facility/Source of Sound

$D1$ = Region of Low Intensity

$D2$ = Region of High Intensity

P = Power of each Speaker

n = number of worship centres (A, B) ((i.e. Churches(A), Mosques(B))

2.4 Study Area Description

Minna capital City is represented as a polygon feature, which is shown in Figure 4 of this study. Therefore, lies between latitude 090 37’ 00’N to and longitude 060 33’ 00’ E respectively and it covered an area of 884 hectares. Minna consists of two local Government Areas (i.e. Bosso and Chanchanga Local Government Area). Minna comprises of many neighborhoods based on 2006 census data, population of Minna was approximately to be 348,788 (See Figure 4).

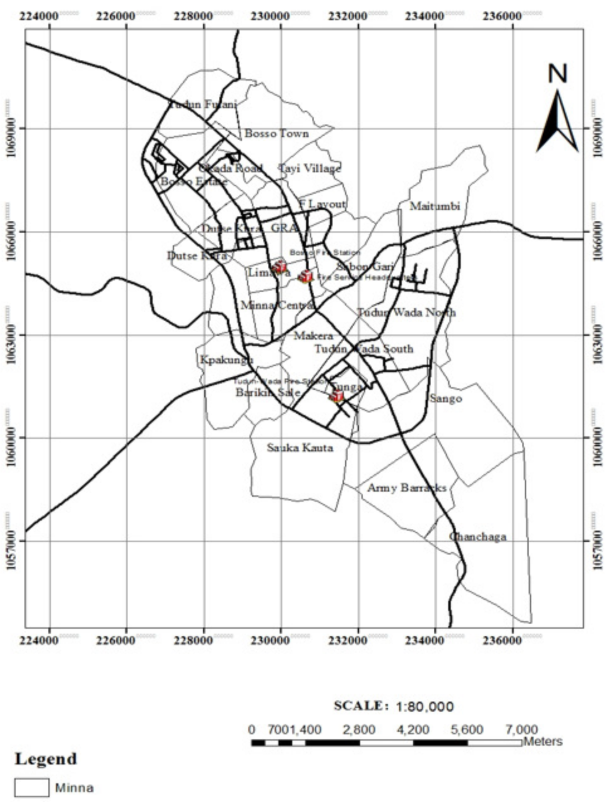

Fig. 4. The map of the study area [4]

3. Experiment/ Tests Conducted

3.1 Maxisum Location Model Application to Worship Centers (Authors' Research, 2016)

To evaluate potential public facilities sites and support decisions concerning the location of additional public facilities areas, certain criteria must be identified. The following criteria were identified in respect to the public facilities, worship centers (i.e. churches and Mosques):

a. Distance of noise travel from the speaker to residential buildings during the service programme of these worship centers should be such that will not affect the comfort of the people meant to enjoy it.

b. It is expected that the travel distance of the noise from the speaker to the residential buildings should not be less than 500meters for the beneficiary to enjoy the facilities.

c. In order to enhance easy assimilation of the worship centers, the church and mosque should be located in an environment in such way that will not result to noise pollution.

In this work, the Optimal Buffer Zone of the noise to travel from the facility (S) and Maximum Covered distance zone of the noise to travel from the facility (T) were used.

3.2 Population Estimation

From the personal interview a population of 500 people requires a worship centre, A place designated for worship must be housed on landed property of minimum area of one hectare, At least 250 persons should make a place of worship , Traffic congestion should be one of the factor to forbid when siting a place of worship centres and Minimum of 15minutes to two (2) hours maximum should be allowed from any worship centre to hold their services due to the Noise pollution generated from the loudspeakers.

Therefore, based on the above population estimate, the authors came up with a Model as follows:

Let Z = minimum population a worship centre should occupy which has a constant of 250 persons;

A= churches;

B= mosques;

Given that $i = 1 \ to \ p$ (p = number of churches)

And $j = 1 \, to \, q$ (q = number of mosques)

Objective function:

Ai = Number of Churches in an Area

Bj = Number of Mosques in an Area

$G(x) = Z * Ai$ =Required number of Christians occupying an Area (4)

$G(y) = Z * Bj$ =Required number of Muslims occupying an Area (5)

$G(x)$: $G(y)$ = Ratio of Christians to Muslims occupying an Area (6)

$G(x) + G(y)$ = Estimations/predictions of an approximate population occupying a

Actual Area (7)

For optimality let w = a constant of 500 population which is the minimum required populations a community must have for a place of worship to be sited.

Let; $G(a) + G(b)/w = K$, which is the actual amount of worship centres that is supposed to be available if abiding by the 500 population per community (8)

For optimization, let M be the total number of worship centre in an area.

Thus, Optimality gives the ratio of M: K (9)

3.3 Service Area Map Derivation

Maps were drawn showing the existing facilities in their spatial positions viz a-viz the roads and wards. This map thus becomes a basis upon which the multi-criteria queries were based. To produce the service area map, buffers were created from the facilities based on the optimal and Tolerable distances of noise from the facilities derived from the mathematical model (Equation (1) and (2)). Thus, the buffer radius serves as the distance vector or service area covered by each facility. Each service area was then overlaid on the map of the Minna Base Map Wards and the Street layers.To facilitate multi-criteria query and analysis, the buffered regions were clipped to the wards and thereafter a spatial join was carried out to join the attributes within both layers. The resulting map, called Service-Area Map, is a single layer that combines all attributes of both the facilities, the wards and streets layers. Multi-criteria queries were performed to identify facilities that fall within optimal distance to various residents.Hence, the power of noise from the different worship centres as sound travels from the main source to the environment was achieved by calculating the powers of each speaker multiply by the number of the worship centres at each region/ward using Equation 3. The values of the power of these worship centres were divided by two to demarcate the region of high intensity and low intensity respectively.

4. Result and Discussion

Results were obtained and analysis carried out as follows:

4.1 Maxisum Location Problem Optimal and Tolerable Distances of noise from the speaker to Neighbourhood

Result obtained for optimal and Tolerable distances of the facilities to the building using Maxisum Location Model. The Maps of Worship Centres that do not agree by 500m buffer Criteria depicted by Figures 5 and 6 respectively (i.e. less than 500meters).

The location of Worship Centres that are Correctly Sited is depicted by Figures 7 and 8. These are the ones that are equally distributed for optimal use (i.e. fell within or above 500meters distance constraint factors imposed on the facilities to each residential area).

The range of intensity of noise from the speakers of the worship centres to the environment was depicted by Figures 9 and 10 respectively.

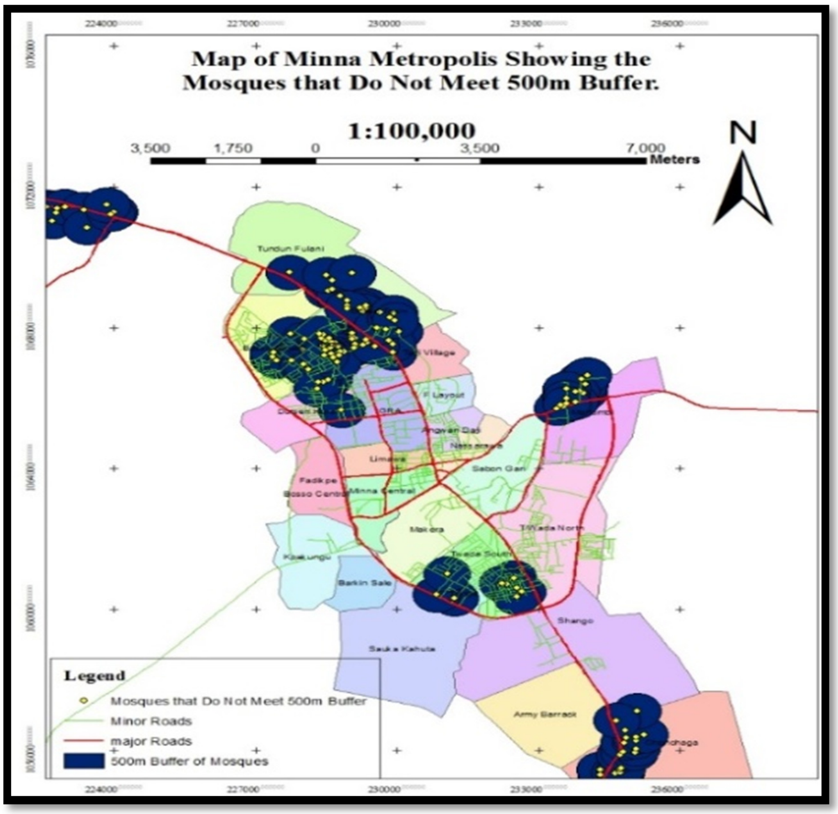

Fig. 5. Mosques that are affected by less than 500m

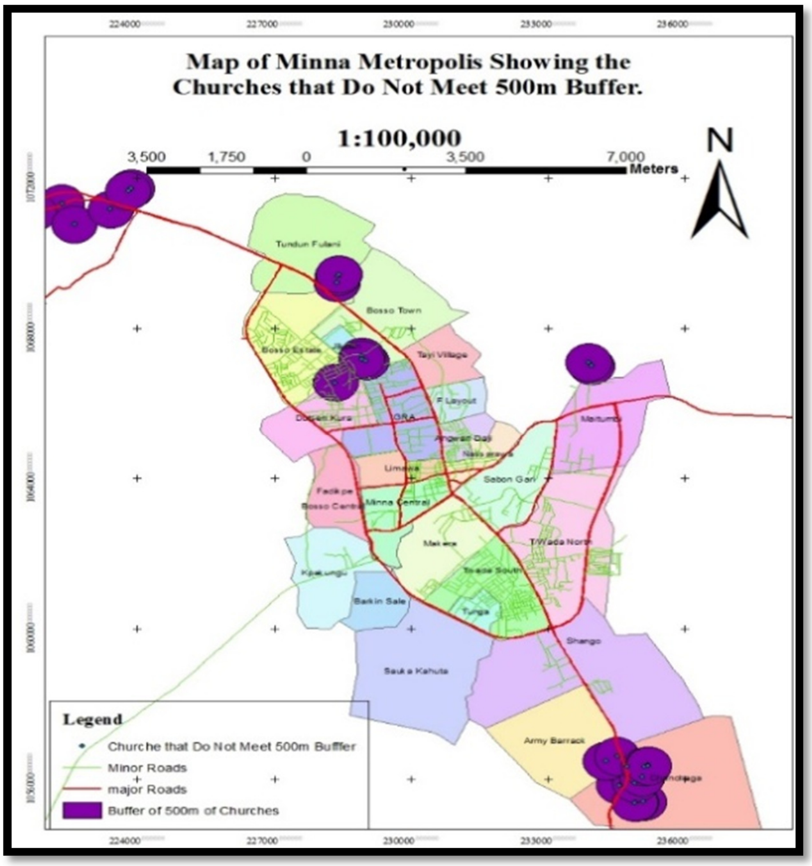

Fig. 6. Churches that are affected by less than 500m

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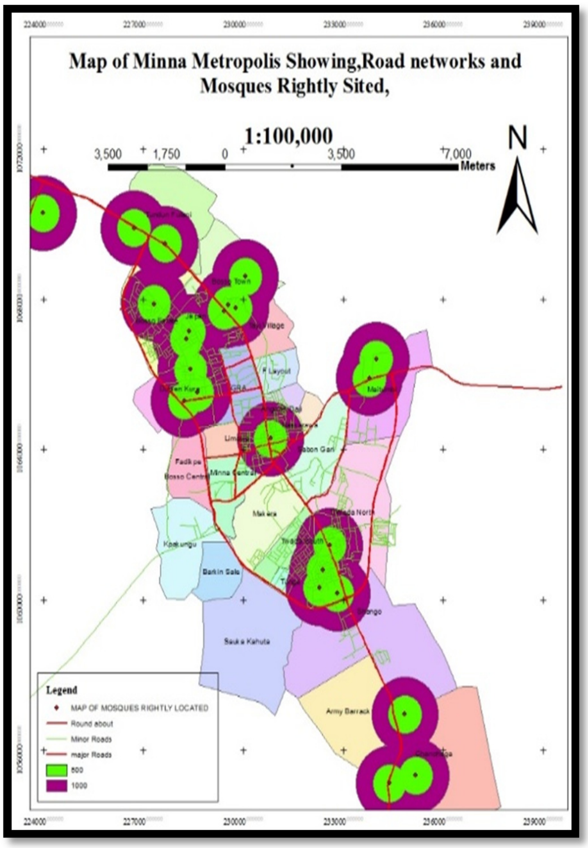

Fig. 7. Churches that are correctly sited

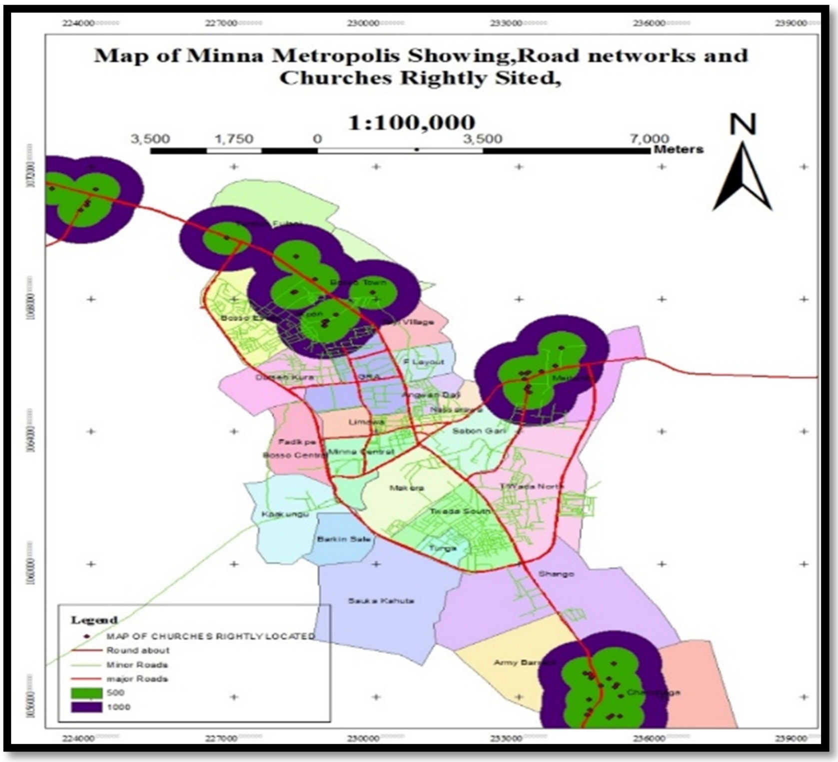

Fig. 8. Mosques that are correctly sited

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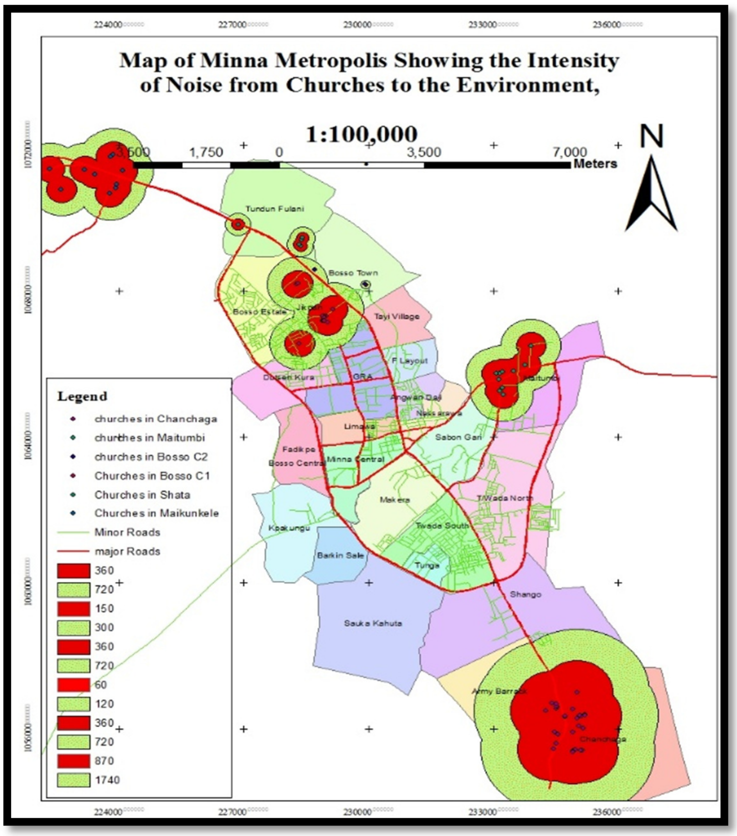

Fig. 9. Noise Intensity to the Environment from the church

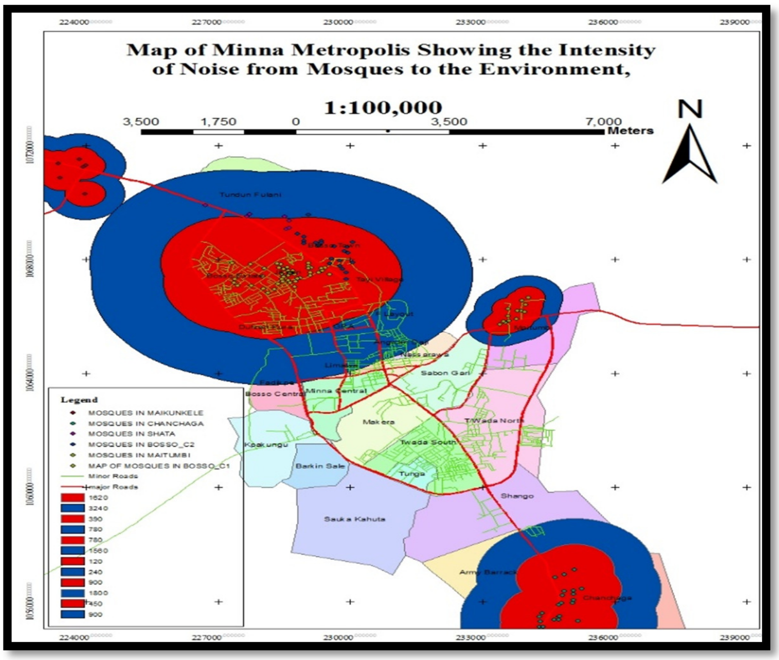

Fig. 10. Noise Intensity to the Environment by Mosque

The variation of the intensity of both facilities in the research area (See figure 11). The power of sound in watt from the facility to the Environment, (i.e. A-Churches and B-Mosques) in the research area (see figure 12).

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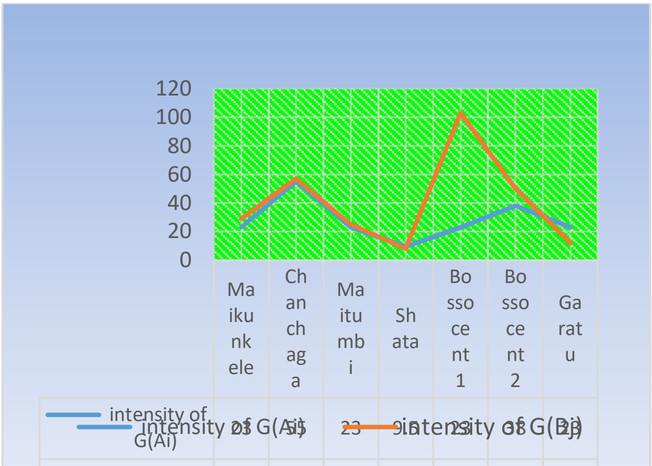

Fig. 11. The intensity of both Facilities (i.e. A- Churches and B- Mosques) in the research area

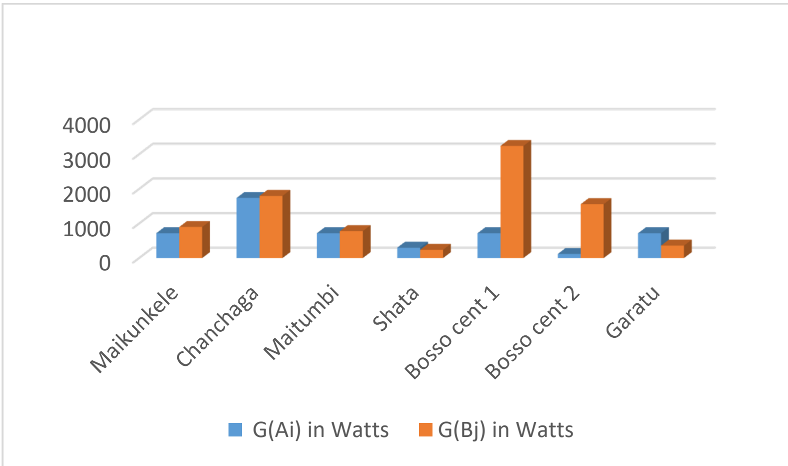

Fig. 12. The power of sound in watt from the facility to the Environment, (i.e. A-Churches and B-Mosques) in the research area

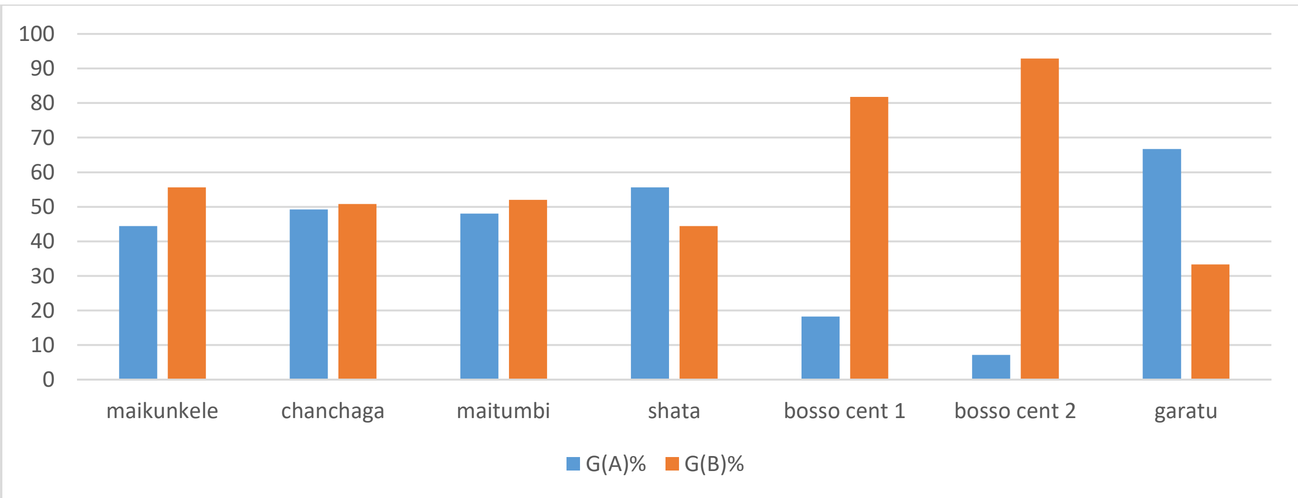

Fig. 13. Proportion ratio of Christian to Muslim population of some districts in the study area, (i.e. A-Churches and B-Mosques)

4.2 Statistical Analysis on Worship Centres in the Study Area

Table 2 is the results of the statistical analysis carried out on worship centres within the study area and figure 9 is the percentage variation of Churches to Mosques in some part of the study area.

Table 2
The statistical results analysis

DISTRICTS	A	B	G(Ai)	G(YBj)	G(Ai):G(Bj)	G(a,b)	Ai%	Ai^{O}	Bj%	Bj^{O}	K	M:K	D
Maikunkele	12	15	3000	3750	3000:3750	6750	44.4	160	55.6	200	13	27:13	14
Chanchaga	29	30	7250	7500	7250:7500	14750	49.2	177	50.8	183	30	59:30	29
Maitumbi	12	13	3000	3250	3000:3250	6250	48	172.8	52	187.2	13	25:13	12
Shata	5	4	1250	1000	1250:1000	2250	55.6	200	44.4	160	5	9:5	4
Bosso central 1	2	54	3000	13500	3000:13500	4500	18.2	65.5	81.8	294.5	33	66:33	33
Bosso central 2	12	26	500	6500	500:6500	7000	7.1	25.7	92.9	334.3	14	28:14	14
Garatu	12	6	3000	1500	3000:1500	16500	66.7	240	33.3	120	9	18:9	9

4.3 Statistical Analysis on Noise for Each District

Churches and Mosques within Minna City make use of horn speaker during their programme which producing a perpetual sound force level (i.e. the physical intensity of sound, acoustic power intensity, intensity level, strength- the amount of energy transmitted (i.e. by acoustic or electromagnetic radiation) of 60w/132db/1m short range and its frequency response of 160-7000hz. Thus, this investigation was based on personal research carried out by the authors to determine the effect of worship centres within the study area. Table 3 gives the analysis of computed Intensity values of each wards/regions in the study area.

Table 3
Computed Intensity values of the considered wards/regions

Districts	G(Ai)	G(Bj)	G(Ai)watts	G(Bj)watts	G(Ai) intensity	G(Bj) intensity
Maikunkele	12	15	720	900	0.00023	0.00029
Chanchaga	29	30	1740	1800	0.00055	0.00057
Maitumbi	12	13	720	780	0.00023	0.00025
Shata	5	4	300	240	0.000095	0.00008
Bosso central 1	12	54	720	3240	0.00023	0.00012
Bosso central 2	2	26	120	1560	0.000038	0.00050
Garatu	12	6	720	360	0.00023	0.00103

4.4 Discussion and Result

From the results, the following inferences were drawn on the facilities: Since there are no restricted rules governing siting of worship centres it may not be located everywhere optimally, therefore, from Figures 3 to 4 more residential areas were affected with the noise generated from the sound-speaker used by these worship centers (i.e. churches and mosques) when a distance less than 500meters criteria was used based on their location to the residential areas while Figure 5 to 6 shows the residential areas that are farther from the noise generated from the sound-speaker used by these worship centers based on their location when an optimal distance of 500meters and above was used.

Figure 7 to 9 depicts the intensity of the sound coming from the both worship centres (i.e. churches and mosques) and also shows the Region/Ward with the highest sound intensity. The orange colour represents the noise from Mosques while the blue represents the noise generated by the Churches. In a similar way, Figure 10 shows the power of the speakers in watt, which also shows the Region/Ward with the loudest power of noise when the worship centres are operating at the same time, the Orange colour bar represents the power of noise coming from the Mosques while the Blue colour bar represents the power of noise coming from Churches. Figure 11 shows the Proportion ratio of Christian to Muslim population of some districts in the study area.

4.5 Way of Controlling Urban Noise

Pubic needs to be sensitized on the evil of noise and the need to curtail it. The three tiers of government need to cooperate in educating the masses in this area. All noise level need to be identified in order to determine acceptable level of noise from it. And government should promulgate law forbidden either public or religion bodies or individual from installing external speakers on any building or automobile. Government should set up monitoring and enforcement agencies from its different tiers designated to monitor and enforce sanctions. Residents should mindful of their obligations to their neighbour for peaceful coexistence in the community. Urban designers should adhere strictly to master plan; they should monitor and control development to follow the already approved land use for any sector of the urban land.

5. Conclusion and Suggestion

5.1 Conclusion

A pollutant is a substance that impinges on the quality of other substances rendering the latter less suitable for man's use. Noise fouls air and atmospheric quality making it less suitable for use. It thus constitutes pollution to air and atmospheric, a composite medium through which noise travels. Efforts of governments and their agencies towards a pollution free environment have been directed mainly at ridding the government of solid, water and other tangible wastes and pollutants. Urban noise and its environmental hazards can effectively curtail through the above suggested approaches. However, the Maxisum location-allocation model was able to map out the optimal and Tolerable service areas of noise generated through the sound- speaker to the residential area both the churches and mosques within the study area with a primary goal of minimizing the maximum effect of noise from the facility to each demand node. This method of location-allocation when integrated with GIS will provide an optimal location of facilities. Based on capacity and demand information and queries generated in this work, it is evident that there is need for relocation of some churches and mosques within the study area.

5.2 Suggestion

This work has proved that both the Local Government Area and Niger State Government must quickly put a lay down rules to checkmate the indiscriminate siting of a place of worship centres within the study area in order to curb the upsurge in worship centres inadequacy in part of Minna metropolis through this it prevent the environmental factor such as noise generated from the sound speaker used by these worship centres. Therefore, we urge the government, to widen its dragnet of surveillance across the length and breadth of the state in such a manner that noise pollution in whatever form or by which institution, in contained, it only from the health of the people.

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