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GEOSTATISTICAL ASSESSMENT OF THE EFFECTIVENESS OF HAND WASHING FACILITIES (HWF) LOCATION FOR COVID-19 RESPONSE IN UNIVERSITY OF ILORIN

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ABSTRACT

The spatial distribution pattern of the Hand Washing facilities (HWF) in the University of Ilorin, Kwara State, Nigeria, is relatively unknown. This study utilized the geostatistical and network analyst tools to assess the spatial pattern of the HWF. It analysed the area serviced by the HWF and present an approach to optimized the HWF to better service the university community, and mitigate the transmission of the COVID-19 virus. This was achieved by integrating the location of the HWF, building footprints and road network data using GIS-based techniques. Kernel Density Estimation (KDE) technique was applied on the locations of the HWF to get the pattern, topology and the Service Area analysis of Network analyst tools were used to analysed the service areas. Finally, the Location Allocation analysis method of the Network analyst tools was executed to identify new locations, and to improve spatial distribution as well as optimize the service area. The outcome of the pattern analysis showed the standard scores, z-scores, to be -0.154926, and p-value to be 0.8768. This implied that the HWF were randomly distributed. The service area results indicated that 33.43% of the area of study was serviced and as such insufficient. Forty-nine (49) additional locations are identified as needed for better coverage of the study area and in turn increase the service area of the study area to 85.64%.

KEYWORDS: Handwashing; GIS; Geostatistical Analysis; Kernel Density Estimation; Service Area; Location Allocation; Spatial Autocorrelation; COVID-19.

1.0 INTRODUCTION

The coronavirus disease-2019 (COVID-19) outbreak whose causative agent has been identified as severe acute respiratory syndrome corona virus 2 (SARS-CoV-2), spreads when an infected person breathes out droplets and very small particles that contain the virus (Shao et al., 2021; UNICEF and SIWI, 2020). Although still early to be certain, the SARS- CoV-2 has been classified as a zoonotic disease and transmission to humans was believed to be either from seafoods, animals like bats, or through an unknown medium (Haider et al., 2020).

On the 14th February, 2020, the first case in Africa was recorded, (O. S. Ilesanmi et al., 2020). Nigeria recorded its index case of COVID-19 on 27th February, 2020, and first death on 23rd March, 2020 (Ibrahim & Oladipo, 2020). The COVID-19 outbreak became a pandemic on the 11th March 2020, with more than 244,321,481 cases, and 4,962,546 deaths reported globally, as of October 24, 2021. Out of the total reported cases and deaths globally, Africa reported 8,540,540 cases, and 217,484 deaths, with 210,460 cases and 2,882 deaths from Nigeria within the same period (Africa CDC, 2019; Worldometer, 2021).

The African Union (AU) recognized the socioeconomic impact faced by member states, as it implemented the public health safety measures (PHSM) to mitigate the impact of the pandemic. The PHSM included physical and social distancing measures, sanitizer with alcohol-based, handwashing with soap and water regularly, face masks usage, schools and border closure, ban on social events, and lockdown (Eze et al., 2021; F. F. Ilesanmi et al., 2021; Shao et al., 2021; United Nations, 2020).

The Federal Government of Nigeria (FGN), through the Presidential Task Force on 29th March, 2020 announced a lockdown on FCT, Lagos, and Ogun state effective from 30th March, 2020 (Ibrahim & Oladipo, 2020). The Minister of Education had also announced all schools' closure on the 19th March, 2020, to take effect on the 23th March, 2020 (Oluka et al., 2020). Although, schools' closure and other measures were intended to control the spread of the virus within schools and other sectors of the country, those measures were also intended to prevent transmission to other vulnerable people, and not collapsed the health sector. These closures and the subsequent lockdown measures have had adverse effects on the system of education and other socioeconomic activities.(Nicola et al., 2020; Oluka et al., 2020; Wren-Lewis, 2020).

Consequently, the University of Ilorin implemented some measures to mitigate the spread of the virus by promoting hand hygiene, and provided alcohol-based sanitizers and installation of handwashing facilities (HWF). Hand washing with soap and water is always preferably more efficient in removing and reducing the number of microbes on the hands (Islam et al., 2020). There are other instances that hinder the individual's ability to perform hand washing with soap and water. The use of alcohol hand-based disinfectants containing 60% alcohol is used in such cases (Hadaway, 2020).

The most cost-effective public health intervention is handwashing with soap. It protects people from life-threatening illnesses such as cholera, other diarrhea diseases, pneumonia and intestinal worms (Islam et al., 2020). Researches have related handwashing to reducing cases of acute respiratory infection by 16-23%, pneumonia by 50%, close to 48% reduction in diarrhea has been linked to: 16–23% reduction in incidence of acute respiratory infection, 50% reduction in pneumonia and considerable reduction in neonatal infections (Aiello et al., 2008; Curtis & Cairncross, 2003).

Nevertheless, the access to handwashing facilities in low and middle-income countries is poor (Islam et al., 2020). Generally, 40% of households do not have handwashing facilities with soap and water, and only 19% of people wash their hands with soap after excreting. 43% of healthcare facilities are without handwashing facilities, and 47% of schools in developing countries do not have handwashing facilities. As a result, suitable hand hygiene is difficult for millions of people, and adds to the transmission of infections. Thus, makes dealing with this pandemic very difficult (Islam et al., 2020; John Knight et al., 2020). Considering these low handwashing rates, interventions promoting good handwashing behavior are of utmost importance.

2.0 MATERIALS AND METHODS

2.1 Study Area

The University of Ilorin (Unilorin), Ilorin, Nigeria, is a Federal Government-owned University of higher learning, established in 1976. The landmass is about 15,000hectares, and cut across several rural communities in Kwara State, Nigeria. The University community has over 4,500 staff and 56,600 students on the main campus, College of Health Sciences, and School of Preliminary Studies (Alade et al., 2020; Durotoye et al., 2020). The part covered by this study is the main campus, located approximately between longitude 4° 39' 36" E to 4° 41' 19" E and latitude 8° 27' 54" N to 8° 28' 09" N.

Figure 1: Study Area

2.2 Data Source and Study Period

Data used for this study are geographic coordinates (longitude and latitude coordinates) of handwashing facility, building footprints and road networks generated from imagery downloaded on SAS planet. The locations of HWF were picked on 20th September, 2021.

2.3 Data Processing and Analysis

This study aimed to investigate the spatial distribution of handwashing facilities (HWF) in UNILORIN, and determined the optimal placement of additional facilities to improve access. In this section, the interpretation of different analytical methods will be discussed.

2.3.1 Spatial Autocorrelation

The spatial autocorrelation (Global Moran's I) refers to the correlation of neighbouring observations of similar variable that are separated at interval either spatially or temporally. It is used to determine the spatial heterogeneity, using attribute values as well as locations of features (Gao, 2021). For this analysis, summary polygon data of the HWF were created. This was done by creating a fishnet of rectangular cells, called grid polygon, and a spatial join was used to count the number of HWF that fall within each grid cell. The grid size was set to 100m, as it is essential to select grid size that will contain at least one point in each polygon across the dataset. After creating the grid and spatial join used to link the grid cells and HWF together, the spatial autocorrelation tool was used for the analysis. Moran's I index value ranges from −1 to +1. A value near +1 denotes a clustered spatial autocorrelation, whereas a value near −1 represents a dispersed spatial autocorrelation, and zero denotes random distribution of HWF (Gao, 2021). A statistically significant Moran's I value ($p < 0.05$) can lead to rejection of the null hypothesis, this is after taken into consideration the interactions between neighbouring observations through weights (Gao, 2021). The formula below is used for calculation:

$$\text{Moran's } I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(z_i-\bar{z}\right)\left(z_j-\bar{z}\right)}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\sum_{i=1}^{n}\left(z_i-\bar{z}\right)^2} \qquad (1)$$

where n refers to the total number of spatial entities indexed by i and j, z_i represents the value of the ith observation unit, $\bar{z}$ denotes the mean of all the observation units, w_{ij} stands for the matrix of binary spatial weights or the strength of interactions between observations i and j, and $w_{ij} = 1$ if they share a common border, or 0 otherwise, and it is the sum of all the observations. (Gao, 2021).

The Average Nearest Neighbor is used to identify the pattern, and shows statistically the significant level of clustering or dispersion in a set of features. If the average nearest neighbor is less than the null hypothesis, it is considered clustered, and if greater than the null hypothesis, then it is dispersed. Else, we accept the null hypothesis (Lakshmi et al., 2019) that the HWF are randomly distributed. The Manhattan distance method which incorporates network space was used and not the Euclidean distance that uses straight line between points (Lakshmi et al., 2019; Okabe & Sugihara, 2012). For this pattern analysis, the null hypothesis states that there is no pattern. If z-score is between -1.96 and +1.96, one cannot reject the null hypothesis, and the resultant pattern could probably be the result of a random distribution. On the other hand, if the analysis results in a very high or very low z-score, it will mean that it is very unlikely that the spatial pattern observed is as a result of random distribution, as the pattern detected is very likely to be too unusual to be random.

2.3.2 Kernel Density Estimation

The kernel density estimation was carried out on the location of HWF, so as to detect spatial pattern of the HWF in Unilorin, and create a density surface model of the locations. In kernel density estimation, the point pattern is analysed by counting the number of events per unit area within a moving quadrat or "window". This process can generate smooth estimates of univariate probability densities from a sample of points $\hat{f}(x,y)$ (Gao, 2021). It is calculated as:

$$\hat{f}(x,y) = \frac{1}{nh_xh_y}\sum_{1}^{n} k\left[\frac{x-x_i}{h_x}, \frac{x-x_i}{h_y}\right] \qquad (2)$$

Where $k\left[\frac{x-x_i}{h_x}, \frac{x-x_i}{h_y}\right]$ represents the kernel weighting function, in which,

$$h_x = \sigma_x \left(\frac{2}{3n}\right)^{\frac{1}{6}} \qquad (3)$$

where n stands for the number of points enclosed in bands h_x and h_y, the kernel bandwidth in the x and y directions, respectively; σ_x denotes the standard deviation of all the enclosed observations within the bandwidth. (Gao, 2021).

The density surface only tries to convey the geographic trends and not specific values at a location (Thakali et al., 2015). In this study, the search neighborhood was set to 50m, as the average human walking speed is 1.39m/s, or 5km/h or 83.4m/min (Conversion-website.com, 2021; Cronkleton, 2019).

2.3.3 Service Areas

The evaluation of the HWF service areas is done using the Thiessen polygon analysis and Service Area Analysis. These analyses were used to unveil the effectiveness of both methods in service area analysis. Thiessen Polygon Method performs a zone-based analysis, thereby, ignoring the road networks and other impedance effects and only makes use of the HWF location to create polygon areas. The Service Area Analysis on the other hand, performs a network-based analysis and covers road networks and other impedance (Olawoyin & Acheampong, 2017; ÖZKAN, 2019). The service area analysis impedance was set to Length, and the default breaks to 50m. Thus, the accessibility radius or walking distance is set to 50m.

2.3.4 Location Allocation

The location allocation analysis was implemented in other to show the insufficiency of the HWF, and to help propose how to correct the inadequacy. The location-allocation model was used after performing topology on the road network. The Location Allocation analysis was used to recommend additional locations to increase the service area of HWF (Eshetu et al., 2019). In this analysis the Maximize Coverage was chosen as the problem type option, this will give the minimum number of facilities needed to cover all or the greatest amount of demand within the specified impedance cutoff (Johnston et al., 2001). Impedance which can be distance, time or travel effort is the cost between two points (El Karim & Awawdeh, 2020). The impedance cutoff is set to 50m, this served as the walking distance, 67 candidate locations were proposed outside the existing service area in order to increase the coverage area.

$$Maximize \left\{ F = \sum_{i \in I} \alpha_i x_i \right\} \tag{4}$$

where I represent the group of demand points or the time duration or the population as a weight, and x_i is the location-allocation parameter with a value of either 0 or 1. After setting the parameters of the analysis layer and selecting the “minimize impedance” location-allocation type, the spatial locations of HWF and the demand points were provided for Unilorin facilities, represented by point layers in the Network Analysis window. The network was then solved to get the results and recommendations for new locations of HWF in the study area.

3.0 RESULTS AND DISCUSSION

In this section, the interpretation of results obtained from different analytical methods and assessment of their implications for the improvement of HWF access will be discussed.
Spatial Distribution.
In this part of the study, the spatial distribution of HWF is plotted with the building footprints, road network. A total of 58 HWF were identified on campus to aid in prevention of infectious diseases.

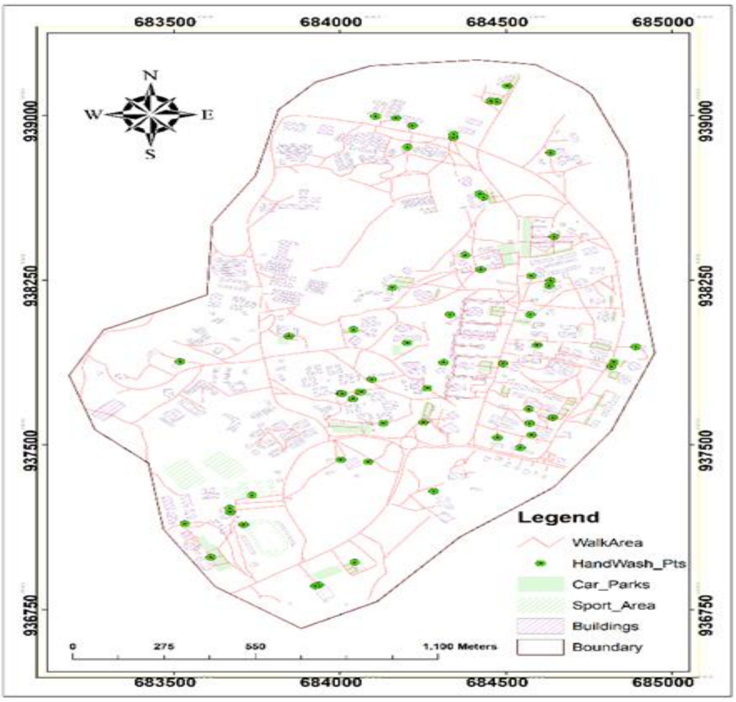
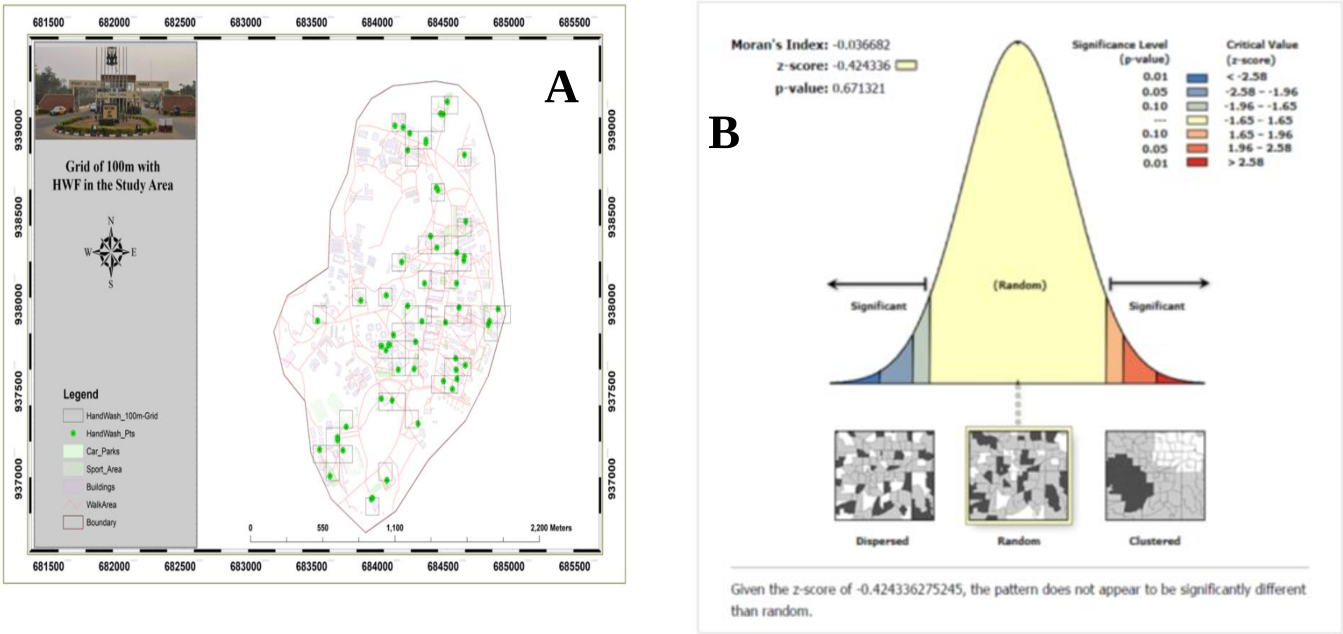


Figure 2: Spatial Distribution

3.1 Spatial Autocorrelation of HWF



Moran's Index: -0.036682
z-score: -0.424336
p-value: 0.671321

Given the z-score of -0.424336275245, the pattern does not appear to be significantly different than random.

Figure 3: Spatial join of Grid Cells and HWF (A), and Spatial Autocorrelation (B).

After spatially joining the grid cells and HWF (Fig 3A), the spatial autocorrelation (Fig 3B) was calculated (Moran's Index: -0.036682, z-score: -0.424336 and p-value: 0.671321 with 90% confidence interval). The results of Moran's I index suggest that the distribution of HWF in the study area is close to random, with no significant clustered or dispersed spatial autocorrelation. This indicates that the location of HWF is not influenced by neighbouring areas, and the availability of HWF is not related to the spatial arrangement of demand locations.

This result is consistent with the p-value of 0.671321, which suggests that there is no significant spatial autocorrelation in the distribution of HWF. These findings imply that the provision of HWF in the study area is not biased towards certain locations, and that it is evenly distributed across the study area.

The analysis also indicated that the distribution of HWF was close to the normal distribution, as indicated by the z-score of -0.424336. The negative value indicates that the mean is slightly lower than the median. This finding suggests that the distribution of HWF is relatively stable and predictable, which has important implications for planning and resource allocation.

However, the negative Moran's Index value (-0.036682) suggests a weak negative spatial autocorrelation in the distribution of HWF. This implies that areas with low access to HWF are surrounded by areas with high access and vice versa. This result could be used to inform targeted interventions to improve access to HWF in areas with low access. For instance, the University authority could focus on installing additional HWF in areas with low access to improve the overall distribution of HWF in the study area.

3.2 Kernel Density Estimation

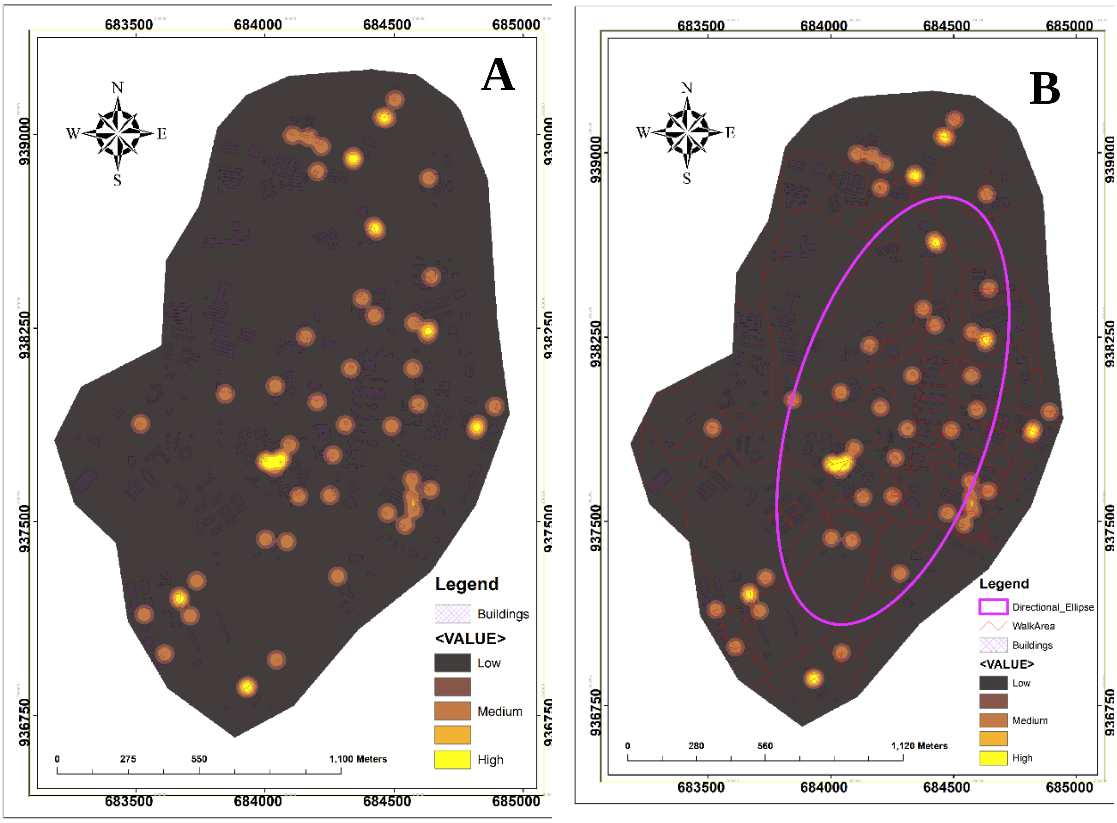


Figure 4: Kernel Density Estimation (A), and Directional Distribution (B)

The kernel density estimation of the location of HWF (Fig 4A), reveals that the highest density of the facilities is located close to the central region of the study area. The density surface model created through this analysis helps to visualize the spatial distribution of the facilities and provides a basis for identifying areas with high and low concentrations of HWF.

The directional distribution analysis shows that the trend of HWF in Unilorin is oriented in a north-south direction, following the road network. This implies that the road network plays a significant role in the spatial distribution of HWF, and there is a higher concentration of facilities along major roads in the study area.

3.3 Service Areas

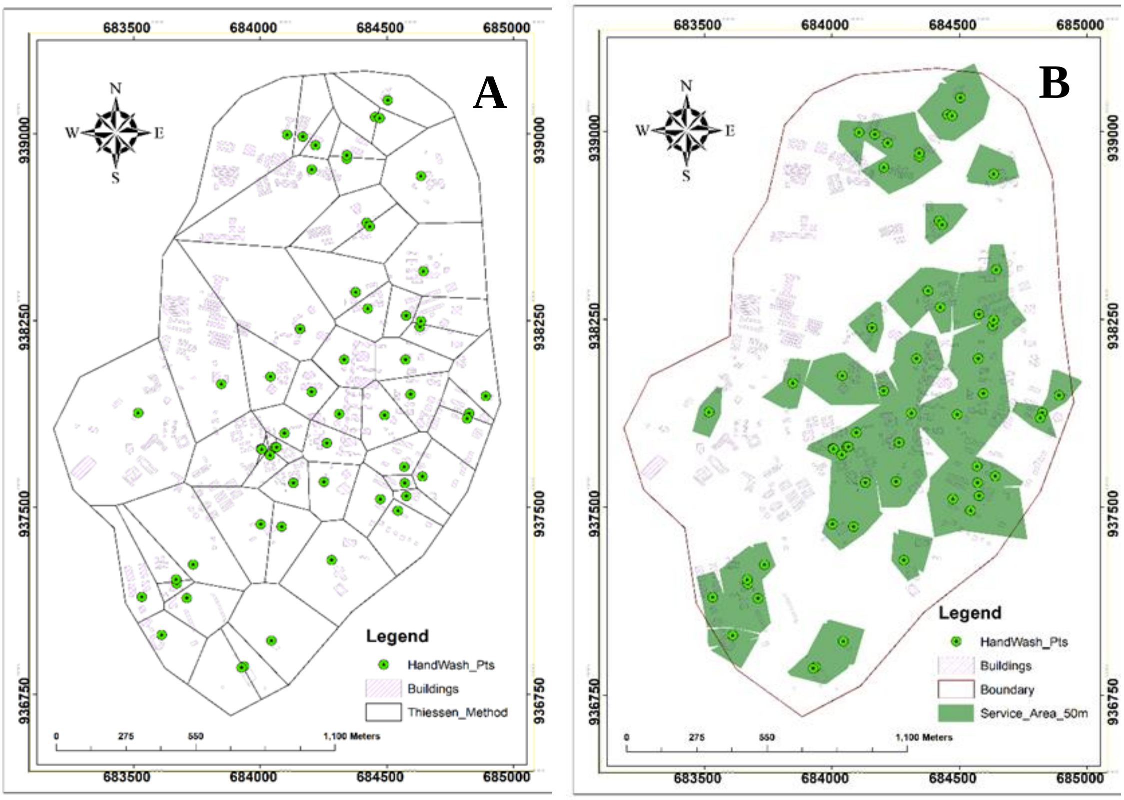


Figure 5: Thiessen Polygon Analysis (A), and Service Area Analysis by Road Network (B)

Thiessen polygon analysis (Fig 5A), provides a method to define service areas based on proximity. The larger the Thiessen polygon, the fewer demand locations have access to HWF. However, this method ignores the road network and other factors that may affect access.

The service area by road network analysis (Fig 5B), using the average walking speed of 1.4m/s, however, reveals that only 33.82% of the total area in the study area is covered within a 50m the walking distance, and 56.91% of 369 demand locations have access to HWF. This implies that a large proportion (66.18%) of the study area, and also 43.09% of demand locations lack adequate access to HW. This result highlights the need for targeted interventions to improve access to HWF in the study area.

3.4 Location Allocation

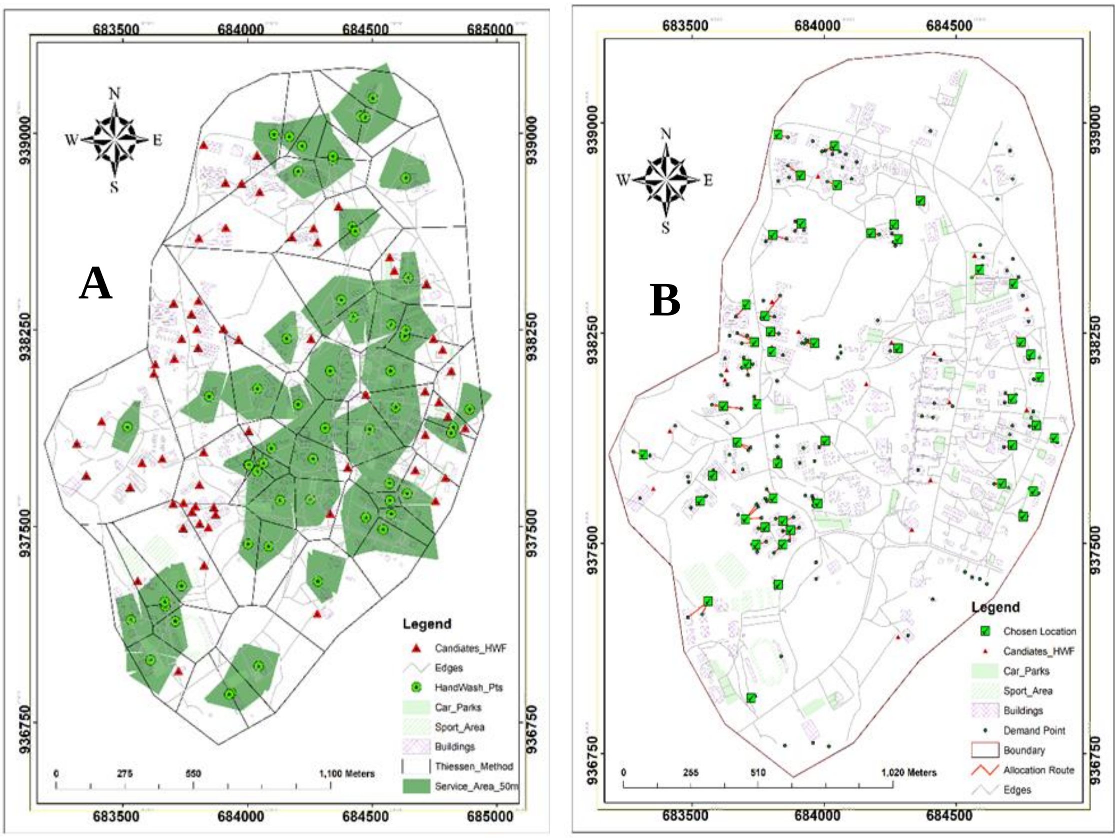


Figure 6: Candidates HWF for Location Allocation (A), and Chosen Locations for Optimization (B)

Of the 369 demand locations identified in the study area, 56.91% have access to facilities within a 50m walking distance. This result indicates that there is still a substantial portion of the demand locations that do not have adequate access to HWF. Therefore, the optimal service area analysis was conducted to identify candidate locations for installing additional HWF. Sixty-seven (67) candidate locations were selected outside the existing service area for optimal service, and after performing location allocation analysis, forty-nine (49) locations were chosen within a 50m walking distance.

Finally, the optimal area analysis reveals that after optimizing the location of HWF, 85.64% of the demand locations have access to HWF within a 50m walking distance, and 57.54% of the total area of the study area is covered. The total number of HWF increased from the previous count to one hundred and seven (107). This result indicates that targeted interventions can substantially improve access to HWF in the study area. These findings are important because improved access to HWF can help prevent the spread of infectious diseases and promote public health.

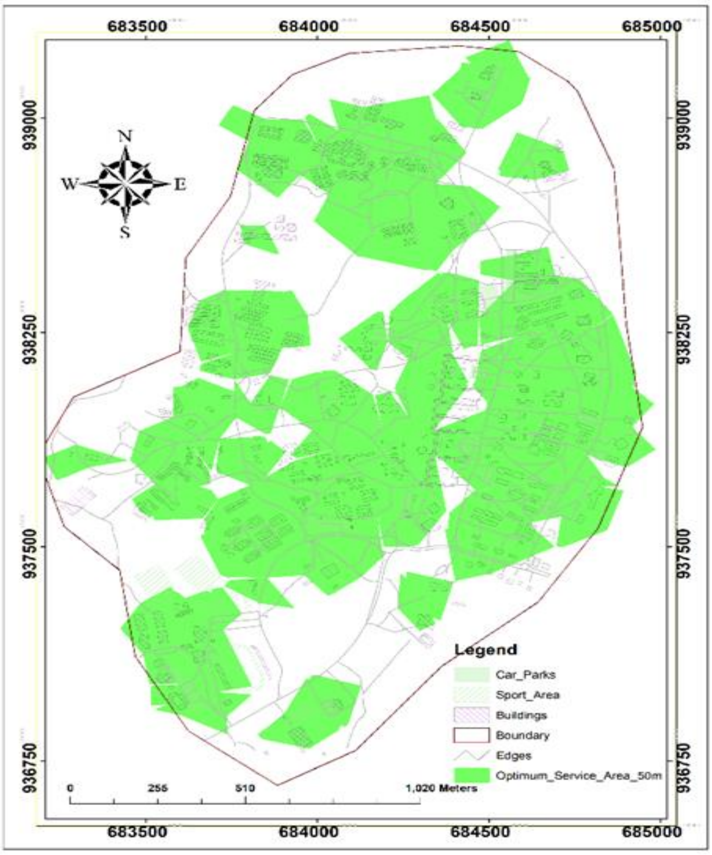


Figure 7: Optimized Service Area

4.0 CONCLUSION

This study has provided valuable insights into the spatial distribution of handwashing facilities (HWF), and the effectiveness of these facilities. The analysis revealed that the distribution of HWF is not significantly influenced by neighbouring areas, as shown by the p-value of 0.671321, indicating a lack of spatial autocorrelation. However, a weak negative spatial autocorrelation was observed, indicating that areas with low access tend to be surrounded by areas with high access and vice versa.

Furthermore, the study revealed that a majority of the demand points in the study area (66.57%) lacks adequate access to HWF, as shown by the service area analysis by road network. The Thiessen polygon analysis highlighted those larger polygons indicate fewer locations with access to HWF. However, the optimal service area analysis showed promise in expanding access to HWF by identifying 49 new locations within a 50m walking distance. This resulted in an increase in the total number of HWF to 107, thereby improving access for 85.64% of the demand locations.

The results of this study have significant implications for public health policies aimed at improving access to handwashing facilities. The findings suggest that interventions should focus on expanding the service area of existing facilities and identifying new locations for optimal service to improve access. Furthermore, efforts should be made to address the observed weak negative spatial autocorrelation in HWF access to ensure that areas with low access are not left behind.

In conclusion, this study highlights the importance of understanding the spatial distribution of handwashing facilities and the factors affecting access to these facilities. The findings underscore the need for evidence-based policies and interventions to improve access to handwashing facilities, which are critical in preventing the spread of infectious diseases. By implementing the recommendations of this study, policymakers and health practitioners can take concrete steps towards improving public health outcomes and promoting a healthier society.

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