ANALYSIS OF FIRE STATION LOCATION AND ROAD CONDITION ON SERVICE RESPONSE TIME: A STUDY OF Ogun West Senatorial District of Ogun State, Nigeria

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ABSTRACT

Fire services are important as they are to save lives and properties. However, there are few studies in developing countries on the effect of poor roads condition on fire service delivery. Thus this study, therefore examines the optimality in location and the effect of road conditions on the response time of fire service in the Ogun West Senatorial District, Nigeria. The concepts of the central place theory provided the theoretical background for this study and they are operationalized by models of the location-allocation (L-A) methods. The data for the L-A models in the study are the coordinates of the locations of the 509 settlements and the four fire stations, as well as the road network in the study area. The result of analysis from the study revealed that the fire service mean response time can be reduced by 61.62% from 18.97 minutes in the existing locational configuration of fire stations and on the existing condition of roads to 11.69 minutes if the locations are optimal and all roads are good. This study showed that fire service response time can be reduced in a given region if the locations of fire stations are carefully planned and the roads in the region are good.

Keywords: Fire emergency service, location analysis, response time, Nigeria, Road condition

1.0 Introduction

Fire outbreaks can cause great loss of lives and property. It was estimated that each year about 300,000 lives are lost to fire accidents globally (Zhang et.al. 2006). According to the International Association of Fire and Rescue Service’s (CTIF, 2020) records from 48 countries, in 2020 70,000 persons were injured in fires. In Nigeria about 136 lives and property worth about 4.3 million US Dollars (about two billion Nigerian Naira) were lost to different fire incidents across Nigeria in 2021 (Odeniyi, 2022). These losses could be reduced if the fire services were more efficient and the response time lowered.

The key objective in fire service provision is to minimize the response time to a fire incident. Response time is defined as the time from the receipt of a call of a fire incident to the arrival of the firefighting engine to the fire incident. Response time is a common performance measure and a critical factor in the measure of effectiveness of the fire-fighting services (Savsar, 2014; Wenyan, et. al. 2018). Loss of lives and properties will be reduced where the response time of fire service is at
the minimum. Emergency response is best if it arrives quickly to minimize the impact of the disaster (Yang et al. 2004). The proper response time is critical in firefighting, to beat flashovers. Flashover is the point at which a fire is fully developed so that people are not likely to survive and property is unsalvageable (Murray and Tong, 2009).

The expected response time of fire service varies from one country to another, it depends on operational and strategic factors. The operational factors include the speed of fire trucks, regulations guiding fire service operations, the discipline of fire service men, traffic situation in cities, etc. The strategic determinants of response time are the number and distribution of fire stations in a given area and the connectivity of the transport network. Apart from the connectivity of the transport network, the condition of the transport network can also affect fire service response time (Shoemaker, 2023). Previous studies have examined the effect of poor road design (Erdogan, 2023; Nguyen, et. al., 2021), flooding (Albano, et. al. 2014; Yu et. al., 2015; Daniel, et. al., 2017; Green, et. al., 2017), and traffic congestion (Popoola, et. al., 2013; Wenyan, et. al., 2018) on emergency service delivery. As noted by Shoemaker (2023) there is very little research on the effect of bad roads and barriers to swift police response and other emergencies. To the author’s knowledge, existing studies on the effect of bad roads (due to pot holes and rough road surfaces) on emergency service delivery are limited. Thus, there is need for more studies on how bad roads affect emergency services like the fire service. Following from this observation, the objective of this study is to examine the effects of location of fire stations and roads condition on the response time of the fire service in Ogun West Senatorial District, Nigeria. The literature discussed below is thus divided into two sections. The first section discusses the location of emergency services and its effect on response time, while the second section discusses how barriers and poor roads affect emergency service delivery.

2.0 Literature review

Emergency facility location

Fire services are public facilities that are mostly provided by governments and funded through taxation. Their planning and provision are either by the rational planning approach or the incrementalist planning approach. The rational comprehensive approach to planning is based on the rational decision-making process, whereby all alternative plans to solve a problem are identified and evaluated. The best plan of the alternatives is implemented. The rational comprehensive planning approach is used in long-term comprehensive planning. One of the criticisms of the rational approach to planning is that it is not in line with political reality. Politicians prefer short-term plans, thus they often adopt the incrementalist approach to planning, which involves a limited departure from previous plans and gradual policy changes (Lindblom, 1959; Mantysalo, et. al., 2019). The incrementalist approach to planning allows for interference in the planning process by politicians and thus gives room for inefficiencies in the location of facilities. Such inefficiencies in the location of emergency services can be more devastating.

In rational and comprehensive planning of public facilities the concepts of the central place theory (CPT) are relevant. The CPT explains the size, numbers, and spacing of central places (in this case fire stations) supplying goods/services to the surrounding population (Briney, 2020). The range concept of the CPT specifies that there is a distance from the provider of
service beyond which the service will become irrelevant to the consumer. The range concept conforms with the maximal service distance in emergency service planning. There is always a distance or time that will render an emergency service irrelevant. To make this concept operational, the maximal covering location model of the location-allocation modelling approach can be used (Ayeni, 1992). The applications of the location-allocation approach are discussed below.

One of the key objectives of the management of fire services is to minimize the fire service response time. This will entail the strategic location of fire stations as close as possible to the areas they are expected to serve. Location-allocation (L-A) models can be used to configure the locations of fire service stations to minimize the distances to their service areas. Generally, the location-allocation (L-A) modelling approach deals with finding locations for facilities (e.g. fire stations) and at the same time allocating users to the facilities in a way to optimize certain goals such as minimizing distance travelled or maximizing population covered. Basic L-A models that are used in fire service location planning include the p-median and the covering location models.

The p-median is to minimise the average distance from the facilities to the demand points. The basic p-median model formed by Hakimi (1964) is widely applicable to the siting of public facilities. The p-median location model fixes the location, on a network, of public facilities and the allocation of consumers such that the total or mean distance or cost is at a minimum (Dantrakul, et al., 2014). The p-median model also called the central facility location model, is applicable in operationalising the concept of efficiency in public facility location planning. The p-median location model was first presented by Hakimi (1964) while finding the optimal location of switching centres for a telephone network. The mathematical description of the p-median model is given in the section on methods of data analysis.

Of relevance to planning the location of fire stations are the covering models. These models are based on the principle that fire service is to be delivered within a response time threshold value, to minimise injury and losses to fire. Two coverage models, of the L-A modelling approach, that are used to solve emergency facility location problems are the location set covering problem (LSCP) and the Maximal covering location problem (MCLP). The location set covering problem is to determine the minimum number and location of facilities that will ensure ‘total coverage’ of the population and properties within the maximal service distance from a facility. The maximal service distance is the distance of the farthest user of a service from a facility or service. The maximal covering location problem (MCLP) is to determine the location for a fixed number of facilities to maximize coverage of a population within a desired maximal service distance (Church and Revelle, 1974).

In addition to the objective of minimizing the distance between fire stations and the population, other fire station location objectives have been considered in the literature. Aleisa (2018) identified some of these objectives to include: maximizing service in high-risk areas, minimizing locating fire stations in areas where water resources are scarce, population density, speed of travel of fire-engine, the distance of a proposed new fire station from existing stations, the value of properties in the area covered, hazardous materials location, type of roads, etc.
Effect of barriers and poor roads on emergency services

There are studies that have been carried out to examine how poorly designed roads affect emergency service delivery. For example, Erdogan (2023) examined how speed bumps on roads cause ambulances to waste time during emergencies. It was discovered that the lost time, due to speed humps, for the van ambulance with a speed of 70 km/h was 8.41 seconds. Also Nguyen, et. al (2021) simulated and analyzed the effect of road bumping and speed of multi-purpose forest fire fighting vehicles. Recently, the Smart Growth Movement encourages narrower streets in residential areas, however, Civicwell (2013) had expressed fears that the narrow streets would slow down responding emergency vehicles in an emergency situation.

Roads in poor condition, with potholes and uneven/rough surface can affect emergency service delivery, particularly in rural areas. However, as noted by Shoemaker (2023) most of the studies on poor roads have not looked at its effect on emergency service delivery. For instance Popoola et. al. (2013) simply identified the effect of poor roads, on commuters, in Nigeria as causing delay in movements, stress, accident and increased fuel consumption. Also Enwerem and Ali (2016) observed in their study that that annual losses from vehicle maintenance, due to bad roads is valued at over 133.8 billion Naira in Nigeria. They also identified that bad roads in Nigeria are as a result of the use of poor construction methods and materials, effect of weather elements on the road surface and non-availability or poor drainage. However, Muhammad and Siyan (2016) identified that poor roads in Nigeria are due to inadequate routine maintenance and improper use of roads. In Australia, a study by Song, et. al. (2021) ranked temperature, deep water drainage, percentage of heavy vehicles, traffic volume, and soil moisture levels as factors causing road deterioration.

Another barrier that can hamper emergency service delivery is flooded roads. In a study carried out by Albano, et. al. (2014) they identified flood hotspots on the road network in Ginosa, Italy for risk reduction measures in emergencies. Daniel, et. al. (2017) integrated mapping of real events with network analysis to evaluate the impacts of flooding on emergency service to vulnerable populations in York, UK. Other studies on flood impacts on emergency response include Yu, et. al. (2015) and Green, et. al. (2017).

Apart from physical barriers on the roads discussed above, traffic congestion, particularly in urban areas has been identified as a barrier that can seriously affect the response time of emergency services. In a study of large Chinese cities Wenyan, et. al. (2018) observed that traffic congestion significantly affect response time of medical emergency service. They use a transportation simulation model to estimate the travel time under free-flow and congested road conditions in their study. On the causes of traffic congestion in Nigeria Popoola et. al. (2013) identified that inadequate road capacity and poor road design, poor road pavement, poor traffic management, poor drainage system, poor driving and parking habits, lack of pedestrian facilities, etc. are the major causes of traffic congestion.

3.0 Material and methods

Study Area

Ogun West Senatorial District in Ogun State is the study area for this work. The region is located at the border fringe of Ogun state in the southwestern part of Nigeria (see Figure 1). The study area lies between Latitudes 6° 26’ and 7° 56’ North
of the Equator; and Longitudes 2° 41’ and 3° 27’ East of the Greenwich Meridian. The total land area of the Region is 5,801.68 sq. kilometres. The population of the Ogun West Senatorial District based on the 1991 population census is 733,524 and according to the 2006 census it was 1,112,761. The 2022 projected population of the Ogun West Senatorial District is 1,390,193 (Ogun State Government, 2010).

If we use the national definition of urban centres as places with more than 20,000 persons, then there are eight urban centres in the Ogun West Senatorial District. Thus the region is mainly rural. The eight urban centres in the Ogun West Senatorial District are Sango-Ota, Ado-Odo, Ibesa, Imeko, Aiyetoro, Igbogila, Owode and Ilaro. The major mode of transport in the Ogun West Senatorial District is road. The motorable roads are classified according to ownership as Federal roads, State roads and Local Government roads. There are four fire stations in the Ogun West Senatorial District. They are located at Sango-Ota, Ipokia, Aiyetoro and Ilaro. The fire stations are managed by the Ogun State Fire Service Department.

Data used in the study

The data for this study consist of the coordinates of the location of all settlements and fire stations in the Ogun West Senatorial District and the road networks. The list of the 509 settlements in the Ogun West Senatorial District was obtained from National Population Commission’s directory and their locations were identified on the digitized maps. Paper maps (1:75,000 and 1: 250,000) of the study area produced by the Survey Division of the Ministry of Works and Housing, Abeokuta, Ogun State were used for the study. The paper maps were scanned on an A0 size scanner and the digital copy was georeferenced and used for analysis in this study. The coordinates of the settlements were generated from the georeferenced scanned map of the study area. The names and addresses of the four fire stations at Sango-Ota, Ipokia, Aiyetoro and Ilaro were obtained from the Ogun State Fire Service office.
Data on the road network were obtained from the topographic maps and updated with Google Maps. The three categories of roads in the Ogun West Senatorial District are the primary roads, the secondary roads and the minor roads. The primary roads are owned and maintained by the Federal government, while the secondary roads are owned and maintained by the State government. The minor roads are owned and maintained by the local government. The primary and secondary roads get a fair level of maintenance attention from the Federal and State governments, while the minor roads receive little attention, particularly the rural roads. In this study, it is difficult to assess accurately the physical condition of individual roads in the study area. Thus a general appraisal was applied by rating all the primary and secondary roads as good and the minor roads were rated as poor.

In location-allocation modelling the interaction between the settlements and the fire stations measured the friction of movements over the roads according to their condition. Thus the impedance parameter for the primary and secondary roads is one. This means that a vehicle will travel smoothly without hindrance on the roads. The impedance parameter for minor roads is three. This means that a vehicle will take three times the normal time it will use on a good road. The three categories of roads in the Ogun West Senatorial District are shown in Figure 2.

Methods of data analysis

Location-allocation models

The location-allocation (L-A) models (ArcGIS 10) were used to analyse the objectives in fire service location and planning in this study. Location-allocation modelling has been noted to be a highly relevant technique for planning different location strategies (Dantrakul, et. al, 2014). Generally, the location-allocation (L-A) problem is preoccupied with the placement of one or more facilities (the location problem) and the assignment of users to these facilities in a manner that optimizes specific goals (known as the objective function) such as minimizing transportation costs/ distance travelled and maximizing population covered. The most frequently used L-A models in public facility location planning are those based on minimizing distance and those based on maximizing coverage”. These models are the central facilities location (p-median) and the covering models. The two models are used in this study. The p-median location model fixes the location, on a network, of public facilities and the allocation of consumers such that the total or mean distance or cost is at a minimum (Dantrakul, et al, 2014). The covering models seek to provide coverage to demand points by ensuring that services are within a specified distance (Daskin, 2013). The specification of a maximal distance in the covering models makes them to be suitable for examining objectives in planning the location of emergency facilities. The mathematical formulations of the p-median and the covering models are given below.
The p-median

The location-allocation model (p-median) was run using the L-A program in ArcGIS v 10.15.

Mathematical description of the p-median model

\[
\text{Minimize } \quad F_1 = \sum_{i \in I} \sum_{j \in J} d_{ij} y_{ij} \quad \text{(the objective function)}
\]

Subject to:

\[
\sum_{j \in J} x_j = p \quad \text{(2)}
\]

\[
\sum_{j \in J} y_{ij} = 1 \quad \forall i \in I \quad \text{(3)}
\]

\[
y_{ij} - x_j \leq 0 \quad \forall i \in I, \quad j \in J \quad \text{(4)}
\]

\[
x_j \in \{0, 1\} \quad \forall j \in J \quad \text{(5)}
\]

\[
y_{ij} \in \{0, 1\} \quad \forall i \in I, \quad j \in J \quad \text{(6)}
\]

The objective function minimizes the demand-weighted cost.

where:

\[ I = \text{the set of demand nodes (settlements) indexed by } i \]
J = the set of facility locations (fire stations), indexed by \( j \)

d_\text{ij} distance between demand node i and facility site j

\( p \) = the number of facilities (fire stations) to locate

\( x_{\text{j}} = \begin{cases} 1 \text{ if we locate at site } j \\ 0 \text{ if not } \end{cases} \)

\( y_{\text{ij}} = \begin{cases} 1 \text{ if demand node } i \text{ is assigned to a facility at node } j \\ 0 \text{ if not} \end{cases} \)

The objective function (1) minimizes the total cost of travel. Constraint (2) specifies that \( p \) facilities are to be located. Constraint set (3) entails that each demand node be allocated precisely to one facility. Constraint set (4) limits demand node allocation to open facilities. Constraint set (5) ascertains the siting decision variable as binary. Constraint set (6) requires the demand at a node to be allocated to one facility only. For more information on the p-median problem see Daskin (2013).

**Maximal covering model:**

The maximal covering location model was used to find the maximum population which can be covered within a specified distance or time for a limited number of facilities (Church and ReVelle, 1974). There are various formulations of the maximal covering model. It could be defined either in terms of coverage achieved or in terms of some maximal distance constraint.

For instance, it may be defined in terms of coverage, \( u_j \) as (Ayeni, 1992):

\[
\text{Maximize } F_3 = \sum_i a_i u_i \quad \text{(7)}
\]

subject to

\[
\sum_{j \in N_i} u_j \leq \sum_{j \in \mathcal{N}_i} v_j 
\]

\[
\sum_{j} v_j = p 
\]

and

\[
N_i = \{ j \mid d_{ij} \leq S \} 
\]

where:

\( I \) represent the set of demand points (the distribution of settlements),

\( j \) the set of facility sites (fire stations)

\( p \) = the number of facilities (fire stations) to locate

\( d_{ij} \) is the shortest distance from node i to site j

\( S_i \) the maximal service distance for demand node i

The details of how to run these models are contained in the user manual of ArcGIS 10 (ESRI, 2010).

**4.0 Results and discussions**

The results of findings in this paper are presented according to the outcome of the existing and optimal distribution of fire stations and the effect of the condition of the roads on fire service delivery capability. Fire trucks can travel at emergency speed on good roads while their speed will be reduced on poor roads. All the Federal and State roads in the study area are categorized to be good, while the Local Government roads are categorized to be poor. The categorization is based on the maintenance attention given to the roads by the respective government agencies that are charged to construct and maintain the roads. The categories of roads in the study area are shown in Figure 2.
Evaluating the existing fire service delivery on different road conditions

The p-median variant of the location-allocation methods was used to evaluate the existing distribution of fire stations in the Ogun West Senatorial District, where four fire stations are to service 509 settlements (see Figure 2). The p-median model allocated each settlement to the nearest fire station. The result of the allocations showed that it will take 73.32 minutes to get to the farthest settlement in Ogun West Senatorial District if the fire truck travels at 100 kilometres per hour along the good portion of the roads and at 33.33 kilometres per hour along the poor sections of the roads. It is assumed that the impedance or friction of movement along the poor roads is three times that of the good roads. The mean time to get to all settlements from the existing four fire stations is 18.97 minutes. This result showed that the mean time in the study area is above the standard of 5 minutes and 20 seconds response time recommended by the National Fire Protection Association (NFPA, 2023).

The implication of the high mean response time or delayed response time in the study area is that the fire service is not likely to beat the flashover (flashover is the point at which a fire is fully developed) in the event of a fire outbreak. Thus more properties will be lost to fire in the study area. Hence there is need to improve the existing distribution of fire stations and the roads to reduce the response time.

Table 1: Statistics of fire service delivery from the actual location of fire stations on existing roads condition

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Distance (in km)</th>
<th>Time (in minutes, assuming the fire truck travels at 100 km/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum distance</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum distance</td>
<td>122.22</td>
<td>73.32</td>
</tr>
<tr>
<td>Mean distance</td>
<td>31.62</td>
<td>18.97</td>
</tr>
<tr>
<td>The standard deviation of the distance</td>
<td>17.0</td>
<td>10.20</td>
</tr>
</tbody>
</table>

Source: p-median model output

Evaluating the optimal fire service delivery on different road conditions

Studies of emergency service delivery often involve assessing the existing locations and comparing them with optimal locations. The p-median model can be used to find optimal locations for emergency services to improve their performance. The p-median model was used to find the optimal locations for the four fire stations in Ogun West Senatorial District. To find the optimal locations all eight urban centres are considered as potential sites for a fire station and the p-median model was used to find the four best locations. See Figure 3 for the existing and optimal location of fire stations in the study area. The potential sites were restricted to urban centres as the government currently does not locate fire stations in rural settlements because of the low population and lack of water in many rural settlements. The statistics of the expected service delivery from the four optimal sites of fire stations are presented in Table 2. It will take the fire truck 73.32
minutes to get to the farthest settlement from the nearest fire station in the optimal distribution of fire stations. This is the same time it will take to the farthest settlement in the existing distribution of fire stations. The mean time to all settlements has reduced in the optimal distribution of fire stations to 14.78 minutes from 18.97 minutes in the existing distribution, giving a reduction of 22.09% in the average response time of fire service in the Region. The implication of a reduced response time from optimally locating the fire stations is that the fire service will be able reduce damage to properties in the event of a fire by getting to the scene of fire incident quicker.

Figure 3: Actual and Optimal Location of Fire Stations with Fire Truck Travelling on Different Road Conditions
Evaluating existing fire service assuming uniform good roads condition

Most studies of emergency service delivery often assumed that all roads in the study area are in good condition and that emergency vehicles will travel at allowable maximum speed. As indicated earlier not all the roads in the study area are in good condition. See Figure 4 for pictures of good and poor roads in the study area. The implication of fixing all the roads, on fire service delivery, is thus examined in this section. The p-median model was used to allocate all the settlements in Ogun West Senatorial District to the existing four fire stations, assuming all the roads in the Region are good. The model-generated statistics of fire service delivery in the Ogun West Senatorial District are presented in Table 3. If all the roads in Ogun West Senatorial District are fixed the fire truck will get to the farthest settlement from the nearest fire station in 43.0 minutes. Thus a reduction of 41.45% in time to the farthest settlement can be achieved by fixing the roads.

![A typical good road in the study area](image1)

![A typical poor road in the study area](image2)

Figure 4: Good and poor roads in Ogun West Senatorial District

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Distance (in km)</th>
<th>Time (in minutes, assuming the fire truck travels at 100km/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum distance</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum distance</td>
<td>122.22</td>
<td>73.32</td>
</tr>
<tr>
<td>Mean distance</td>
<td>24.64</td>
<td>14.78</td>
</tr>
<tr>
<td>Standard deviation of the</td>
<td>15.92</td>
<td>9.55</td>
</tr>
<tr>
<td>distance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: p-median model output
Table 3: Statistics of fire service delivery from the existing fire stations to all settlements on good roads

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Distance (in km)</th>
<th>Time (in minutes, assuming the fire truck travels at 100km/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum distance</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum distance</td>
<td>71.68</td>
<td>43.0</td>
</tr>
<tr>
<td>Mean distance</td>
<td>25.66</td>
<td>15.39</td>
</tr>
<tr>
<td>The standard deviation of the distance</td>
<td>12.70</td>
<td>7.62</td>
</tr>
</tbody>
</table>

Source: p-median model output

Optimal location of Fire Service assuming uniform good roads condition

Fire service delivery can be improved in the study area by locating the fire stations optimally (allowing the model to choose the best locations) and assuming all the roads are in good condition. The p-median model was used to find four optimal locations from the locations of eight urban centres in the Ogun West Senatorial District. All the roads are modelled to be good. The result of the fire service delivery under these conditions is presented in Table 4. By rearranging the locations of the four fire stations optimally and assuming all the roads are good, the fire truck will get to the farthest settlement from the nearest fire station in 43.0 minutes. The mean response time is reduced to 11.69 minutes compared to 15.39 minutes in the existing configuration of the location of fire stations on good roads. A reduction of 24.09 per cent is achieved, in mean response time, by relocating the existing fire stations to optimal locations and assuming all roads are good. In summary, the fire service mean response time can be reduced by 61.62 percent from 18.97 minutes in the existing locational configuration and condition of roads to 11.69 minutes if the locations are optimal and all roads are good.

Table 4: Statistics of fire service delivery from optimally located fire stations to all settlements in Ogun West Senatorial District

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Distance (in km)</th>
<th>Time (in minutes, assuming the fire truck travels at 100km/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum distance</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum distance</td>
<td>71.68</td>
<td>43.0</td>
</tr>
<tr>
<td>Mean distance</td>
<td>19.49</td>
<td>11.69</td>
</tr>
<tr>
<td>The standard deviation of the distance</td>
<td>11.07</td>
<td>6.64</td>
</tr>
</tbody>
</table>

Source: p-median model output
Coverage of Settlements by the fire service in the Ogun West Senatorial District

In studies of emergency service delivery, the interest is often about how to use available resources to maximize the proportion of people and properties that can be covered within a stipulated critical time limit. Most times, available resources are not sufficient to cover the total population within the desired time limit. This problem is the maximal coverage location problem (MCLP) and the maximal coverage location model of the location-allocation methods can be used to solve it. One of the usefulness of the location-allocation methods is that they can aid decision-making by providing different scenarios in a "what-if-analysis". Table 5 presents the result generated by applying the maximal coverage location model to find the proportion of settlements that are covered within 5, 10 and 15 minutes by the fire service in the Ogun West Senatorial District. The recommended fire service response time by the National Fire Protection Association (NFPA, 2023) is 5 minutes and 20 seconds. Within 5 minutes 6.68 percent of settlements are covered in Ogun West Senatorial District and within 15 minutes the proportion of settlements covered will be increased to 33.99 percent. The expected emergency response time varies from one country to another. A decision maker can construct a similar table to find the coverage of the population that can be achieved within a desired service time.

Table 5: Proportion of Settlements that can be covered within 5, 10 and 15 Minutes

<table>
<thead>
<tr>
<th>Maximum Time (in Minutes)</th>
<th>Number of Settlements</th>
<th>The proportion of Total Settlements Covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>34</td>
<td>6.68%</td>
</tr>
<tr>
<td>10</td>
<td>100</td>
<td>19.65%</td>
</tr>
<tr>
<td>15</td>
<td>173</td>
<td>33.99%</td>
</tr>
</tbody>
</table>

Source: Author’s computation using the Location-Allocation Module in ArcGIS

Another dimension in the study of emergency service delivery is to determine the minimum number of facilities that are needed to cover the entire population within a desired service response time. This problem is the set covering location problem and it is solved by the set covering location model. A table that is similar to Table 6 can be constructed by applying the set covering location model for decision-making on minimum facilities required to achieve a desired emergency service response level. It is shown in Table 6 that if the NFPA standard of 5 minutes and 20 seconds is to be met in Ogun West Senatorial District 124 fire stations will be required in addition to the existing four fire stations. If the desired fire response time is 30 minutes, 10 fire stations will be required in addition to the existing four fire stations. Figure 5 shows the locations of the existing four fire stations and the proposed 10 fire stations for the 30-minute scenario.
Table 6: Number of Fire Stations Required to Cover All Settlements

<table>
<thead>
<tr>
<th>Maximum Time</th>
<th>Number of Additional Fire Stations Required</th>
<th>Total Number of Fire Stations Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Minutes</td>
<td>124</td>
<td>128</td>
</tr>
<tr>
<td>10 Minutes</td>
<td>56</td>
<td>60</td>
</tr>
<tr>
<td>15 Minutes</td>
<td>33</td>
<td>37</td>
</tr>
<tr>
<td>20 Minutes</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>25 Minutes</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>30 Minutes</td>
<td>10</td>
<td>14</td>
</tr>
</tbody>
</table>

Source: Author’s computation using the Location-Allocation Module in ArcGIS

5.0 Conclusion and recommendations

The key objective in fire service provision is to minimize the response time to a fire incident. Reduced response time can save lives and properties in an emergency. It was demonstrated in this study that fire service response time can be reduced by careful planning of the location of fire stations, providing necessary number of fire stations and by fixing bad roads. Generally poor roads can have damaging effect on fire service by delaying response times. It will also increase fire trucks maintenance costs and limit accessibility. Fire service authorities can adopt the planning techniques demonstrated in this study to optimize the location of fire stations and thereby reduce the fire service response time. Also governments can make fixing roads a priority to reduce the response time of fire service, reduce maintenance costs of emergency vehicles and even make life more comfortable for the citizens. In addition to fixing bad roads, careful planning of the locations and adequate can also drastically reduce the response time of fire service in an area.

Figure 5: Locations of Existing and Required Fire Stations to Cover All Settlements Within 30 Minutes
REFERENCES


