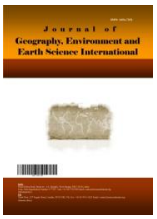

Journal of Geography, Environment and Earth Science International

23(3): 1-18, 2019; Article no.JGEESI.51038
ISSN: 2454-7352

GIS-based Network Analysis for Optimisation of Public Facilities Closure: A Study on Libraries in Leicestershire, United Kingdom

Efiong, Joel[1*]

[1]Department of Geography and Environmental Science, University of Calabar, P.M.B. 1115, Calabar, Nigeria.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/JGEESI/2019/v23i330168
Editor(s):
(1) Dr. Ahmet Sayar, Associate Professor, Department of Computer Engineering, Kocaeli University, Turkey.
Reviewers:
(1) Oribhabor Chinelo Blessing, University of Africa, Toru-Orua, Bayelsa State, Nigeria.
(2) Nick Namunga Waswa, Kenya.
Complete Peer review History: https://sdiarticle4.com/review-history/51038

Original Research Article

Received 19 June 2019
Accepted 27 August 2019
Published 02 October 2019

ABSTRACT

Many public facilities in the United Kingdom are being closed without consideration to their users, leading to social exclusion. Hence, this study investigated the use of geographical information systems (GIS) in identifying public facilities which can be closed while saving cost and minimizing distance, using the libraries in Leicestershire as case study. Data for the study were obtained from secondary sources through the internet. This study used the location-allocation tool model, within the geographical information environment, to identify a set of libraries that should be closed in Leicestershire to save 20% cost and optimised for the needs of unemployed people, children of school age and pensioners (people over 65 years). Based on these considerations, the study identified the following ten libraries for closure: Barwell, Blaby, Cosby, Desford, Enderby, Groby, Hathern, Kirby Muxloe, Mounstsorrel and Sapcote. If this is adopted, it therefore means that the distance that users will need to travel from their homes to libraries in the new order would have been minimised and access not denied. This study has therefore demonstrated the use of GIS in decision making. This method is an innovation in the use of the model and should be used to evaluate library accessibility and identify those that could be closed without much negative impacts at the national level and for other facilities elsewhere.

**Corresponding author: E-mail: joel_efiong@yahoo.com;*

Keywords: Optimisation; GIS; libraries closures; Leicestershire; location-allocation; network analysis.

1. INTRODUCTION

Libraries are public service centres in the UK as in elsewhere. The importance of libraries with its development from the traditional educational and cultural perspectives in the past, to where they have become modern information centres has been acknowledged [1]. Libraries are very useful and beneficial to the society, particularly the neighbourhood [2]. Also, many needs of the public, such as information, education, and recreation, are serviced by libraries [3,4].

Recent studies [5,6] have recognised public libraries as meeting places with the capacity to develop the community and it citizens. Further to this, a study [7] concluded that public libraries as a meeting place are helping to promote social inclusion, as they provide opportunities for citizens to be active across the different economic and social levels. The importance of public libraries in enhancing information access has been documented in literature [8,9,10]. Moreover, Hertel and Sprague [11] has demonstrated the integration of GIS and census data as a tool for library planning.

Despite these, many libraries in the UK are closing in recent years. A recent report reveals that as many as 200 public libraries in the UK were closed in 2012 [12]. In view of government structural reforms, local authorities and many other public agencies in the UK are being forced to reduce financial spending on the services they provide [13,14]. Many of these agencies are therefore faced with the difficulty of determining which facilities to close and at the same time minimising the negative effects of such closures. Comber and others [1] observed that libraries are usually included among facilities for planned closures whenever such discussions arise. Such closures, if not carefully optimised, could lead to processes of socio-spatial marginalization and exclusion [1]. Here the unemployed, children of school age and pensioners, could be the worst hit. While recent study [15] showed that distance weakly predicts library access dissatisfaction, such may change with the planned closures. Access to libraries could be more difficult for these vulnerable classes of people.

Literature [16] has revealed the impact of a public facility (Post Office) closures on users which could have been averted if such actions were optimised for certain factors. There is the need to optimise libraries closures so that these groups of people would not be further stretched. Making decision to close an existing facility (or locate a new one) can be supported by a GIS-based network analysis. This study therefore, used the geographical information systems (GIS) and particularly the location-allocation model to identify a subset of libraries in an English County to be closed based on the following considerations:

a. Saving a 20% cost, where cost associated with each library is the same regardless of its opening hours. This translates to 20% libraries closure;
b. Optimising for library users making up the demand (in this case, the unemployed people, children of school age and pensioners).

2. CONCEPTUAL FRAMEWORK

2.1 Access and Accessibility

Different definitions and practical applications of accessibility are available in literature [17,18,19,20]. Basically, accessibility has been described as the potential between origin and destination, when distance is taken into consideration [17,20]. Following this description, three main components of accessibility can be identified as follows: origin, destination and interaction (relationship) between the two. The main factor of interaction between origin and destination is the distance which either enhances or limits people from accessing the destination [21]. The concepts of access and accessibility is very important in this kind of study. While these concepts have been used in different ways by different authors, with its varied complexities [22,15], it is used in the present study to describe geographic distances from demand points (Output Areas) to supply centres (libraries).

Many studies have been conducted on facility accessibility. For example, [23] used a GIS-based network analysis to examine equity of access to greenspace in an urban environment for different religious and ethnic groups in the UK. Using a GIS-based network analysis and optimisation method to analyse the impact of proposed UK post office closures, Comber et al. (2009) found that these methods were appropriate for minimising the numbers of those experiencing reduction in access to post office

among the targeted class. Again, [15] explored the various relationships between accessibility and facility access.

Several studies conducted on library accessibility [e.g. 24,25,26,27,11] analysed accessibility only as straight-line distances between the user's residences and libraries. This method is flawed because many times, people do not make use of straight lines to get to their destinations. Distance measurements through such methods may therefore not be the accurate distance of travel by the user. As argued by Park [21] and Allen [28], distances measured with this method can be shorter than the actual travel distance as in a case where movement is along a curved road or limited by barriers like rivers. To overcome this, researchers have begun to use geographical information systems (GIS) to analyse accessibility of libraries in terms of geographical distance [21].

In an investigation on the reasons for public library closure and its effects on geographical market areas, it has been argued that if libraries must close to cut down cost during times of severe economic crisis, the issue of equity of access must be taken very seriously [29]. This will ensure that certain segments of the population are not affected disproportionately. Hence, the need to optimise for any such closures with population data.

2.2 Network Analysis: Location-Allocation Problems and Models

Location is one of the most important factors in the success of most organisations as it helps in providing high accessibility while lowering fixed and overhead costs [30]. Location-allocation analysis seeks to locate optimal sites for facilities (supply) over a set of demand points. The name therefore suggests a two-fold problem of locating facilities and allocating demands to the facilities. Location-allocation models therefore solve the demand and supply problems. In this study, library users served as the 'demand' while libraries locations served as 'supply'.

Location related problems have been classified into three main groups, namely: central, semi-desirable and obnoxious facilities [31,32]. Central facilities (which are the interest in this study) are desirable facilities to which people travel and interact with [32]. Such facilities include libraries, schools, greenspaces, health centres, and stores. One of the objectives of central location problems is therefore to find the best site for its location in such a manner that distance which may be expressed by different functions (such as geographic distance, time and service costs) is minimised. Hence, the closer the facilities to demand points, the better the access [32]. This supports Tobler's argument in the first law of geography that "everything is related to everything else, but near things are more related that distant things" [33].

There are several location-allocation problem types developed to answer specific kinds of questions. They include: minimise impedance, maximise coverage, maximise capacitated coverage, minimise facilities, maximise attendance, maximise market share and target market share. Details of their description and working procedures can be found on the ArcGIS website [34].

Interest in the use of location-allocation methods to determine optimal location of facilities has been growing since the 1970s [35,36,37,38,31]. It has been argued that the *minimise impedance* (p-median) problems is the most attractive and often used model for location-allocation studies [39,40, 41,42,43,32]. The basic algorithm here is that, with a given number of candidate facilities X, and weighted demand points Y, it is possible to select a subset Z in such a way that the weighted distances between each demand point Y and the nearest facility X, is minimised. That means the demand points are allocated to the nearest facility.

The basic attractiveness of this model is based on the fact that the lesser the weighted travel distance (time), the more users will conveniently get to the nearest facility [32]. Hence, the concept of 'demand weighted distance' using the location-allocation tool seeks to ensure that most people are nearer to facilities. While it is argued that this model does not consider 'worst case' scenarios where the weighted travel distance may not be equal, which may force some users to travel to distant facilities [32], it was adopted here because the present study was rather seeking to optimise closures. Many studies using a location-allocation analysis seeks to determine optimal sites for locating facilities.

3. RESEARCH METHODOLOGY

3.1 Study Area

The primary concern here was to describe the methods of geographic data analysis for

selecting libraries in Leicestershire to be closed while at the same time considering the needs of some of its users. Consideration was given to the following categories of library users: the unemployed people, children of school age and pensioners (people over 65 years). However, to properly situate the description of the geographic data analysis, a summary of the study area is hereby presented.

The study was conducted in Leicestershire (one of the Counties in East Midlands in England) and Leicester City. Leicester City until recently was part of Leicestershire County as its administrative headquarters, but is now also a unitary authority. In the context of this study, Leicestershire was used to mean both Leicestershire County and Leicester City. It had a population of ~ 1 million people based on the 2011 census. Within this population, 187,419 were children of school age (5 – 19 years), 30,618 were unemployed and 157,306 were pensioners (above 65 years). There were a total of 3145 Census Output Areas, which are the finest census data units with an average population of 300 persons [44,23]. There were also a total of 52 public libraries located across Leicestershire. Fig. 1 is the map of Leicestershire while Fig. 2 shows the Output Areas with locations of 52 public libraries.

3.2 Research Design

The research design adopted for this study was experimental. This allowed the used of some controls on the group. This controls have been stated already in the introduction (saving a 20% cost, where cost associated with each library is the same regardless of its opening hours. This translated to 20% libraries closure and optimising for library users making up the demand (in this case, the unemployed people, children of school age and pensioners)).

3.3 Types and Sources of Data

Several types of data were collated this research (Table 1). There were a total of seven (7)

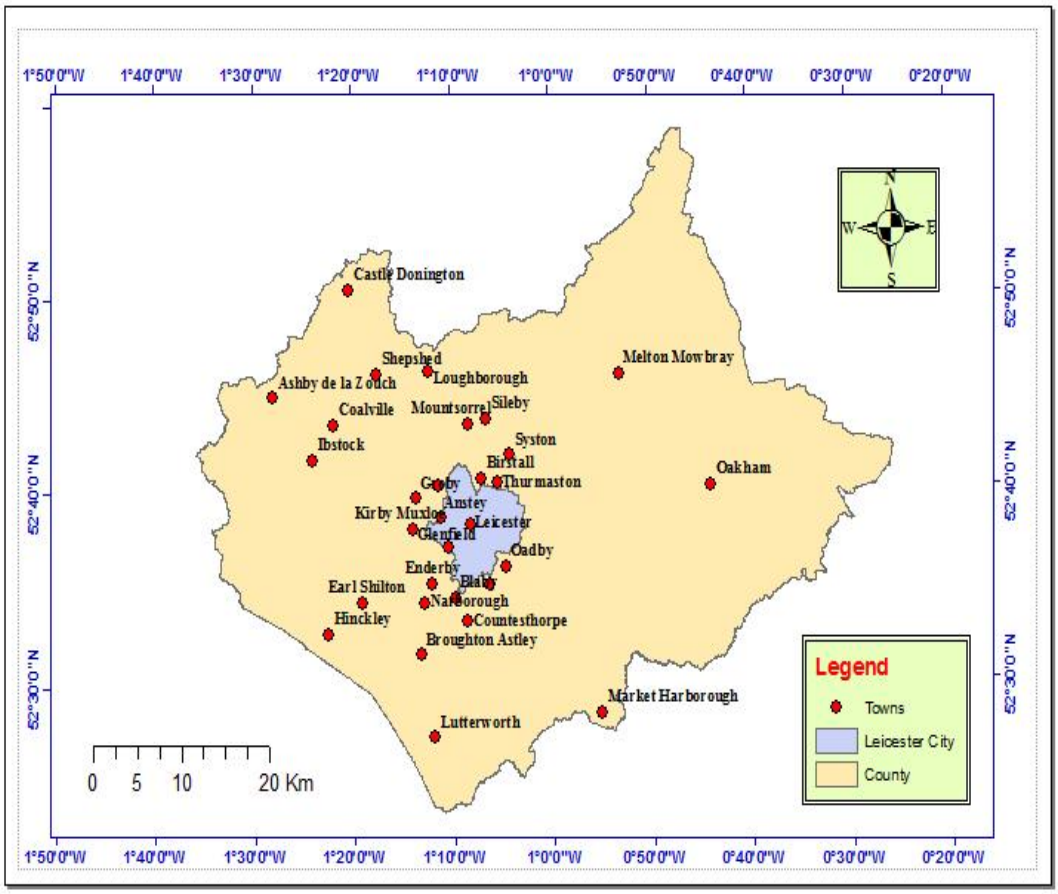

Fig. 1. Map of Leicestershire with Leicester City

Table 1. Data types and sources

S/N	Data/Layer	Type	Category	Remarks/Source
1	Leicestershire County Output Area (OA)	Polygon	Identity, Size	Edina; (Extracted from UK Data Service Census Support)
2	Leicestershire County Roads	Line	Length, type, Identity	DigiMap from Edina (Mastermap, ITN layer)
3	Leicestershire County Library	Point	Name, location, attribute	Project Folder
4	Leicestershire County OA Centroids	Point	Location/ Coordinates	Created from OAs Shapefile
5	Unemployed People	Polygon	Figures, locations	Extracted from 2011 population census data
6	Children of School Age	Polygon	Figures, locations	Extracted from 2011 population census data
7	Pensioners	Polygon	Figures, locations	Extracted from 2011 population census data

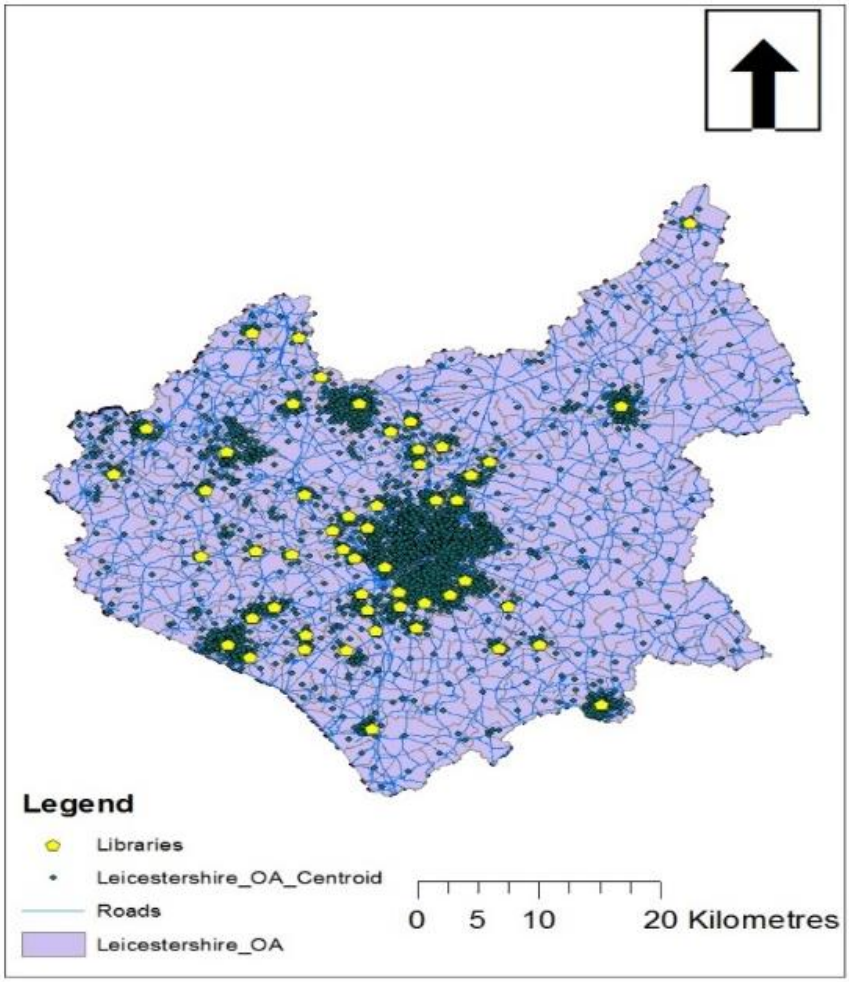

Fig. 2. Leicestershire output areas showing locations of 52 public libraries

sets of data. Their collation was considered to be necessary for the identification of Libraries in Leicestershire which should close in order to save 20% cost. They included data on Leicestershire County Output Area (OA), Leicestershire County Roads, Leicestershire County Library, Leicestershire County OA Centroids, Unemployed People, Children of School Age, and Pensioners.

3.4 Sampling Technique

It is common practice in spatial data analysis to treat the entire population as sample [45]. Hence, the entire population of 52 libraries in Leicestershire was treated as sample since the objective of the study was to use GIS to determine the facilities that should be closed based on the already stated controls.

3.5 Data Analysis Procedure

In the initial data analysis, choropleth maps showing the spatial distributions of library users were produced for each category and the total demand. Thi0s was followed by overlaying the Leicestershire County library data layer on each of the choropleth maps. This was considered necessary for visual observation and display of libraries over the different demands within the study area.

Network analysis technique was adopted in the subsequent data analysis. While there are alternative methods (e.g., buffering) to answering questions that relates to linear networks including facilities like libraries, the use of network analysis offers the optimal technique in this regard [46]. It should be noted that network analysis assesses the demand and supply of goods and services [23]. The ArcGIS software ® Desktop 10.1 for Windows ® was used for this analysis. This software was licenced to the University of Leicester, UK where the researcher had access to it while studying there. Several options are available in the Network Analyst extension in ArcGIS (including the route solver, closest facility solver, service area solver, OD cost matrix solver, vehicle routing problem solver and location-allocation solver) for the solving of common network problems. The study used the location-allocation model as it helped in selecting which facilities, in this case libraries, from a set of libraries to close or to remain with regards to their relationship with demand centres. It also allowed for the optimisation of socio-economic variables (e.g., population). In adopting this model, the researcher sought to minimise the overall distance between libraries and demand points (Output Areas, here summarised as Output Area Centroids). Libraries were considered as 'supply' while Output Areas were considered as 'demand'.

The centroid data was included within the dataset to provide the central points of the output area polygons for network analysis. This may not be the most accurate method for assessing distance due to the possibility of over or under estimation. With this method, it has been argued that many of the Output Areas Centroids are not directly on road network [23]. However, it is assumed in this study that these estimations even themselves out throughout the output area.

Since this study was basically that of supply and demand, an attempt was made, first and foremost, to examine the spatial distribution of demand over the study area. It should be remembered that library users making up the 'demand' in this study were unemployed people, children of school age and pensioners (people over 65 years). This was done for the individual groups and then for the total demand population.

The ArcCatalog was used to build the network dataset that was added to the project database. The steps that are usually followed in a location-allocation analysis can be found at [34]. They are here by summarised as follows:

- Preparing of display: which involved starting the ArcMap 10.1, enabling ArcGIS Network Analyst extension and customising the Network Analyst toolbar.
- The following layers were then added to the map: Leicestershire County Output Area (OA), Leicestershire County Roads, Leicestershire County Library, Leicestershire County OA Centroids, Unemployed People, Children of School Age and Pensioners and the road network dataset that was built in the ArcCatalog.
- Creating the location-allocation analysis layer.
- Adding candidate facilities (in this case the libraries).
- Adding the demand points (Here, the attribute tables of data layers of library users making up the 'demand' in this study are unemployed people, children of school age and pensioners were first join to the attribute table of Leicestershire County OA. Centroids. This was to allow for the

weighting of each group of library users and also their total population which were used for optimisation of closures. Here, Leicestershire County OA Centroids was selected from the Load from drop-down list with 'label' being mapped to the Location Analysis Properties section. The 'Weight' property in the 'Field' column was set to any of the categories of library users at each run of the analysis. This allowed each demand point to be weighted by the population of the library users within each Output Area.

- Setting up the properties of the location-allocation analysis: In the Analysis Setting tab of the Layer Properties dialog box of the Network Analyst window, Impedance was set to Length (Metres). Travel From was left in the default option of Facility to Demand since it is considered as a good choice for minimise impedance problem type. On the Advance Setting tab, minimise impedance was selected as the problem type, facilities to choose was increased to 42(since we are interested in closing 20% of the libraries which is approximates 10 out of 52) with no Impedance Cut off. Impedance Transformation was set at 'Power' with impedance parameter of 2.0. It is argued that the application of transformation is capable of equalising the overall distances between the demand points and the nearest facility. Moreover, libraries, like health facilities, are interested in equity of service and are usually located in this manner. This allows a minority of distant users not to travel long distances before getting to the facility. Hence, using the Network Analyst function in ArcGIS, travel distances from demand points to libraries were measured based on road networks.

4. RESULTS

The results in this section described the current spatial distribution of libraries over the Leicestershire with respect to demand points (library users). It also examined how accessible this facilities were and then optimised demand for 20% closure of the facilities.

4.1 Spatial Distribution of Libraries over Demand (Users)

Initial analysis was done to examine the spatial distribution of facilities to close (libraries) over the study area. Figs. 3 – 6 show the spatial

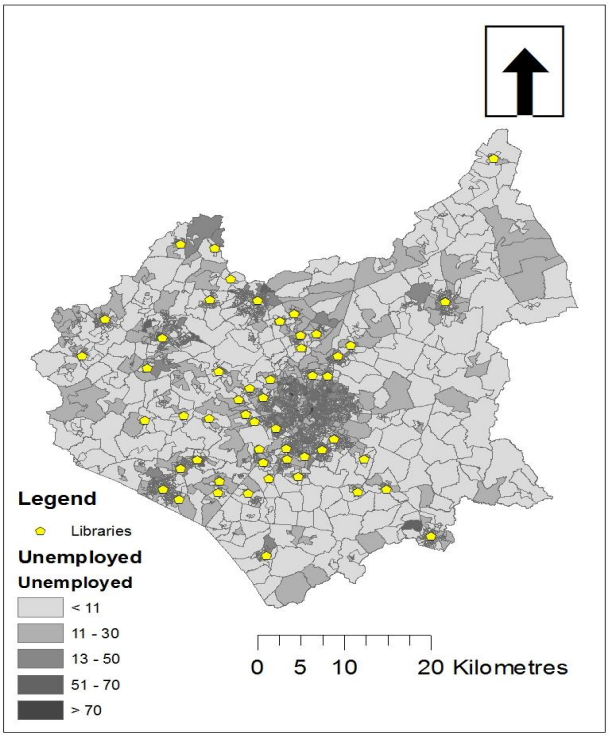

Fig. 3. Spatial distribution of libraries over demand points weighted by the population of unemployed

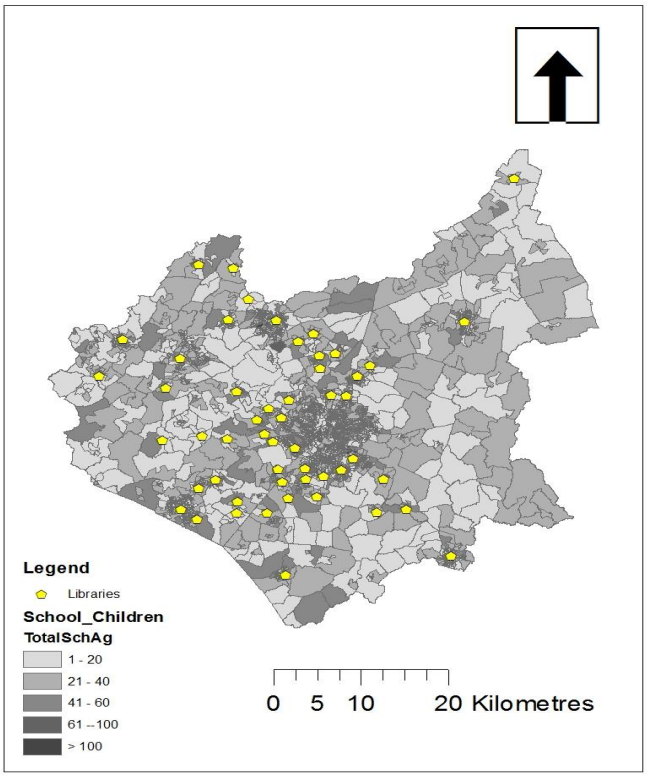

Fig. 4. Spatial distribution of libraries over demand points weighted by the population of school children

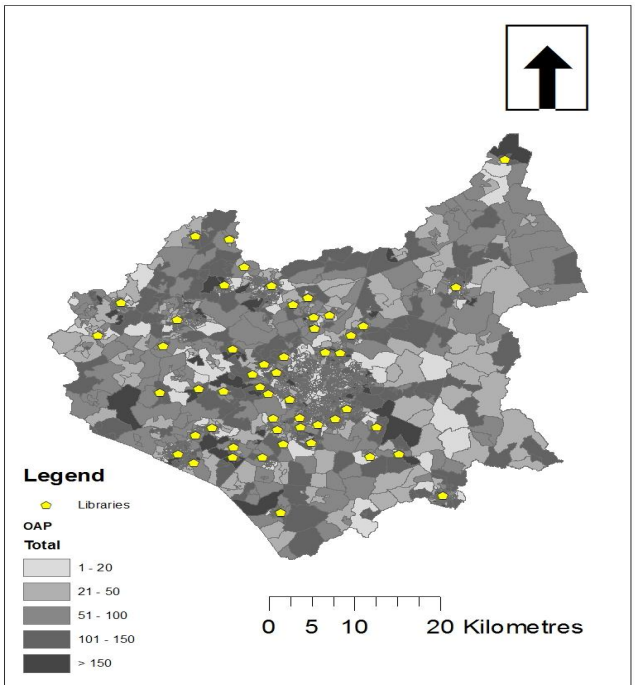

Fig. 5. Spatial distribution of libraries over demand points weighted by the population of pensioners

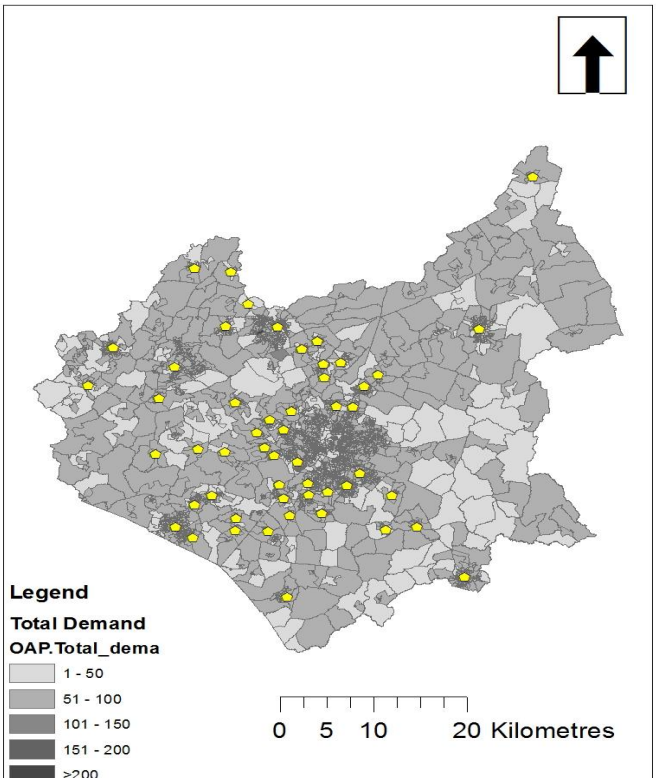

Fig. 6. Spatial distribution of libraries over demand points weighted by total population

distribution of libraries over demand points weighted by the population of users in terms of unemployed people, children of school age, pensioners and total demand respectively. Most of the libraries are clustered within the central and eastern portions of Leicestershire.

4.2 Current Access to Libraries

Current access to libraries in Leicestershire can be visualise in Fig. 7. The statistics of Total Length and Total Weighted Length are summarised in Table 2.

Table 2 revealed the total count, minimum, maximum, sum, mean and standard deviation for these distance characteristics. Total weighted length shows the weighted cost of travelling between the library users and libraries. Because of the large number of facilities and demand points that are involved in this study, the full attribute table of the line property of the location-allocation layer cannot be displayed here. However, the mean value is 2651.132112 m (Table 2). Moreover, these are not straight-line distances. Similarly, the Total Length which indicates the cost of traveling between library users and libraries is 317652.836255.

Table 2. Summary of some line class properties for current access to libraries in Leicestershire

Statistic	Total weighted length	Total length
Total count	3144	3144
Minimum	0	0
Maximum	3360471.448983	19884.446444
Sum	998700517.18454	8335159.361424
Mean	317652.836255	2651.132112
Standard Deviation	290531.275449	2097.617638

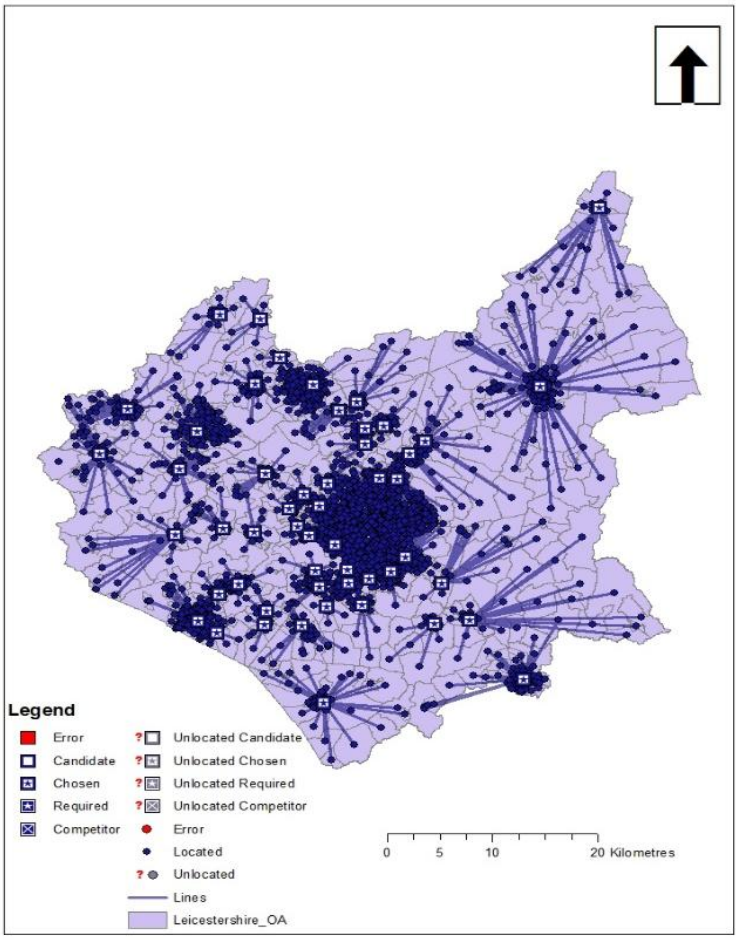

Fig. 7. Current access to libraries

4.3 Library Selection

Table 3 and Figs. 8 – 11 show the selection of libraries to close with different optimisation routines.

4.4 Access to Libraries with Optimisation

The statistics of Total Length and Total Weighted Length are summarised in Table 4.

Table 3. Libraries closures for the various optimisation considerations

No optimisation	Optimising for unemployed people	Optimising for children of school age	Optimising for pensioners	Optimising for total demand
Barwell	Barwell	Barwell	Barwell	Barwell
Blabby	Cosby	Blaby	Blaby	Blabby
Cosby	Countesthorpe	Cosby	Cosby	Cosby
Desford	Desford	Desford	Enderby	Desford
Enderby	Enderby	Enderby	Hathern	Enderby
Groby	Groby	Groby	Kriby Muxloe	Groby
Hathern	Hathern	Hathern	Muntsorrel	Hathern
Kirby Muxloe	Kirby Muxloe	Kirby Muxloe	Ratby	Kirby Muxloe
Mountsorrel	Rothley	Rothley	South Wigston	Mountsorrel
Sapcote	Sapcote	Sapcote	Stoney Stanton	Sapcote

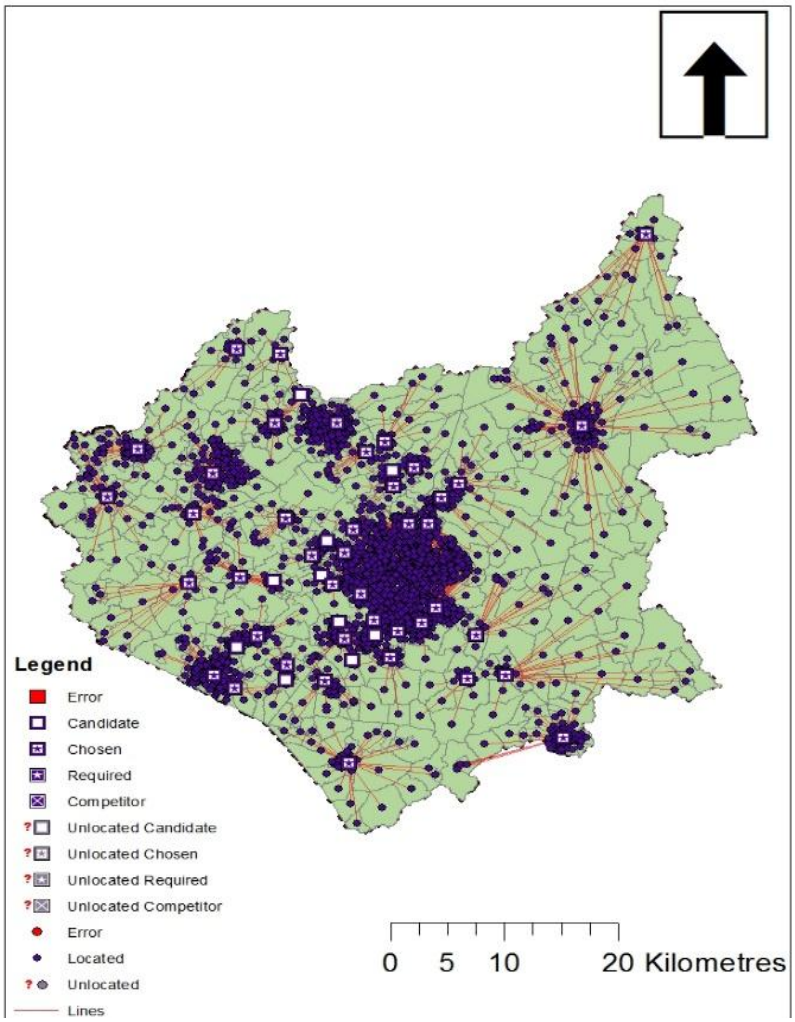

Fig. 8. Library selection to minimise distance and optimise for total demand (unemployed people + children of school age + pensioners users in terms of pensioners users in terms of unemployed people

Table 4. Summary of some line class properties for access to libraries in Leicestershire with optimisation for total demand

Statistic	Total weighted length	Total length
Total count	3144	3144
Minimum	0	0
Maximum	3360471.448983	19884.446444
Sum	1029922807.556105	8598470.000279
Mean	327583.59019	2734.882316
Standard Deviation	287993.848856	2067.285778

When the results in Tables 2 and 4 are compared, it is discovered that the maximum, sum and mean for each measure has increase with optimisation. However, the standard deviation is lower indicating closeness to the mean. Hence, the optimisation procedures actually minimised distance.

5. DISCUSSION OF FINDINGS

This study was aimed at using geographical information systems (GIS) and particularly the location-allocation model to identify a subset of libraries in an English County to be closed, giving considerations to saving a 20% cost and

optimising for library users including the unemployed people, children of school age and pensioners. Five runs of network analysis were made to select libraries to close. From the first network analysis for libraries to close, 'candidate' facilities are those to be closed while 'chosen' are to remain. Ten sets of libraries are chosen in each case. Details of the selected libraries are contained in the attribute tables of the map project. Each of the optimisation plans involved identifying 10 out of 52 libraries that should close while minimising distances to be travelled by users to the remaining 42 libraries. The discussions that follow in this section are based on the results that are presented preceding section.

The results from the first network analysis (Fig. 7) reveal that one demand point was not allocated to any facility on both the Facility ID and Allocated Weight columns of the attribute tables of the demand points. Since no impedance cut-off was set for the analysis, this demand point therefore appears to be a restricted element of the network [47].

Figs. 8 - 11 show the ten libraries that are not assigned any demand point. These libraries were identified using the identify icon on the Arc Map 10.1 main menu and through selection by attributes, they were readily assembled together in the attribute table for the facilities layer and summarised in Table 3. A visualisation of these figures reveals that these identified libraries are generally within close distances with other libraries. On comparing Figs. 8 and 9, it could be observed that most of the demand points that were assigned to these selected libraries in Fig. 8 are now being assigned to nearby libraries in Fig. 11.

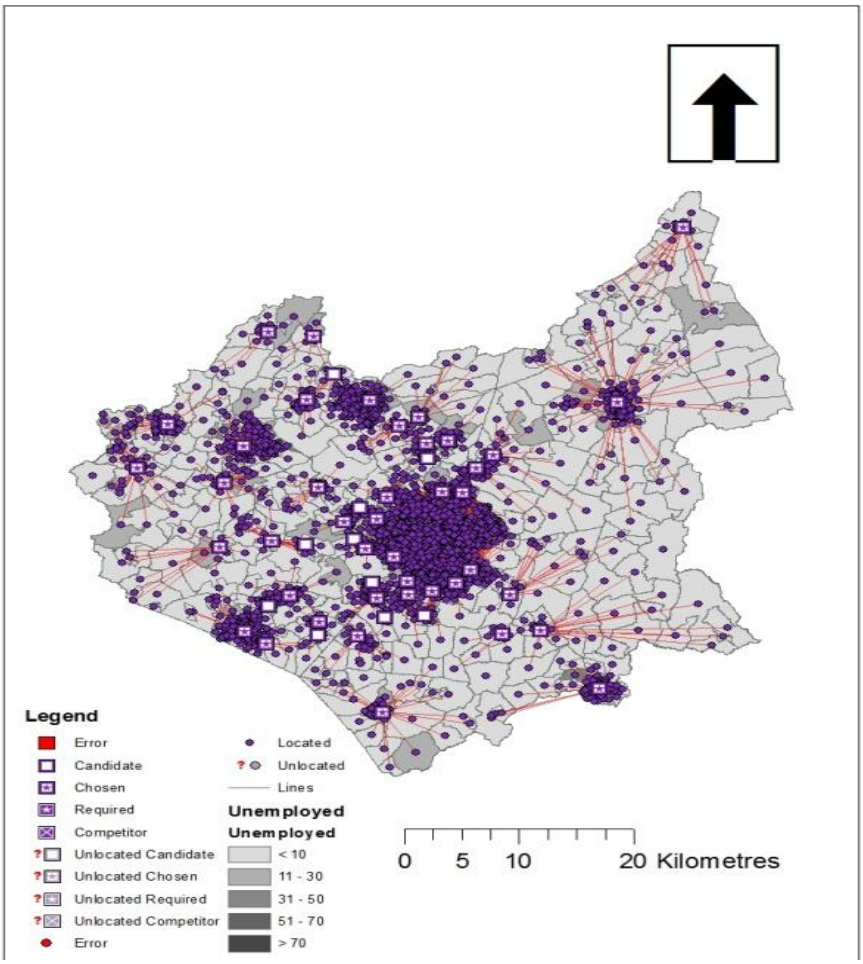

Fig. 9. Library closures with optimisation for the unemployed people users in terms of pensioners users in terms of unemployed people

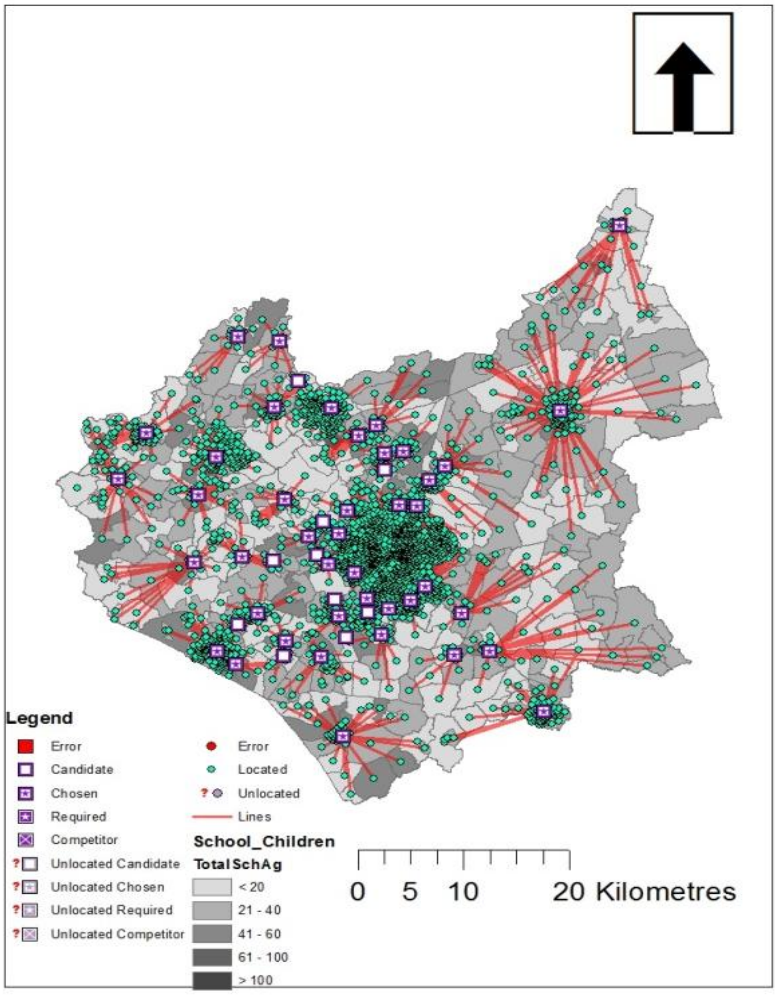

Fig. 10. Library closures with optimisation for children of school age people + children of school age + pensioners users in terms of pensioners users in terms of unemployed people

The results in the previous section indicate that if consideration is given to the unemployed people, then the following libraries were selected for closure: Barwell, Cosby, Countesthorpe, Desford, Enderby, Groby, Hathern, Kirby Muxloe, Rothley and Sapcote. If children of school age are considered, then Barwell, Blaby, Cosby, Desford, Enderby, Groby, Hathern, Kirby Muxloe, Rothley and Sapcote, were selected. Also, if consideration is given to pensioners (people over 65 years of age), the outcome of the analysis shows that the following libraries should close: Barwell, Blaby, Cosby, Enderby, Hathern, Kirby Muxloe, Mounstsorrel, Ratby, South Wigston and Stony Stanton. However, when the total demand was considered, Barwell, Blaby, Cosby, Desford, Enderby, Groby, Hathern, Kirby Muxloe, Mounstsorrel and Sapcote were identified for closures. This output presents the same results as that obtained when no consideration was not made for any category of the population. Some libraries like Barwell, Enderby, Hathern and Kirby Muxloe were repeatedly selected during each procedure. The impact of closing such libraries will certainly be very limited. Hence, the issue of socio-spatial marginalization and exclusion argued by Comber et al. [1] in their study would be minimised.

The selection of the 10 libraries that should be closed in this study was not based on any specified distance criteria, unlike the case of post offices as studied by Comber et al. [16] since the present researcher is not aware of any distance criterion for locating libraries in the UK. However, studies have shown that library users are usually

those that reside within 10 miles of library location [48]. This is approximately 16 km. From the results, only four demand points exceeded this measure (Fig. 12). Fortunately, the library that services these demand points has not been selected to close. Every other demand points are still found to be within this generalised library users' distance.

The clustering of majority of libraries in the central and western part of Leicestershire over the northern and eastern portion already places the later at a disadvantage if any closures take place there. Library users, particularly the unemployed, children of school age and pensioners, may need to travel further distances to get the services of one. This may result to social exclusion and many persons within these categories are either not entitled to have personal vehicles or not likely to have one.

It seems from this study that most of the libraries that have been selected to close in each case of the optimisation fall within the urban areas and particularly within the central portion of the study area. This is also where we have the highest concentration of public libraries within Leicestershire with much closed proximities. Fig. 13 illustrates the proximities of libraries to one another in Leicestershire. Most of the libraries within the central portion of the Leicestershire are within 1 to 2 km apart. With this, and the optimisation procedures, it would be expected that the selection of libraries for closures will have minimal impact on users travel distance to the next available library.

The findings of this study imply that loss of accessibility can be reduced for the unemployed people, children of school age and pensioners if optimisation plans are adopted for

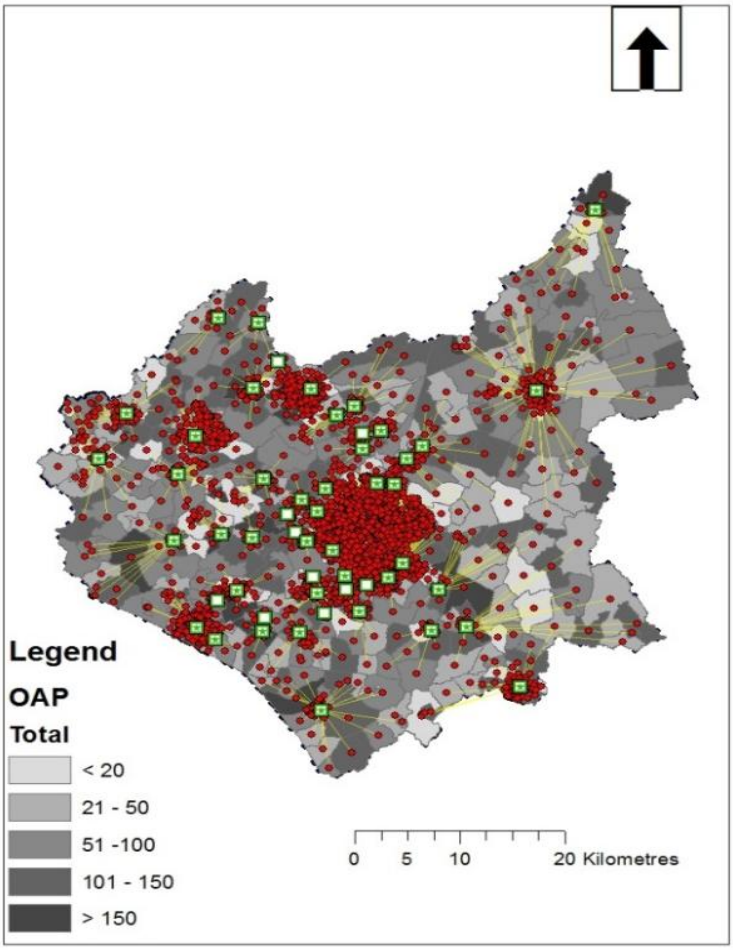

Fig. 11. Library closures with optimisation for pensioners

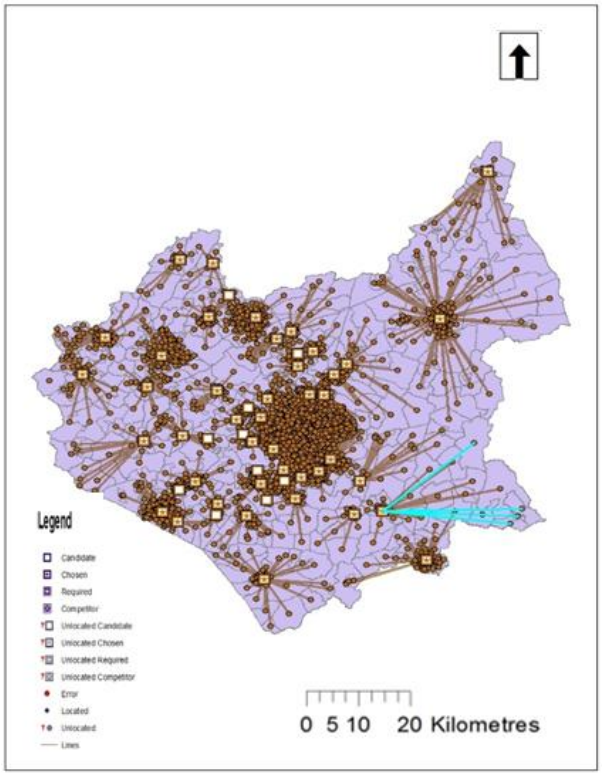

Fig. 12. Locating four demand points further than 16 km to their nearest libraries (The light-blue lines shows the selection)

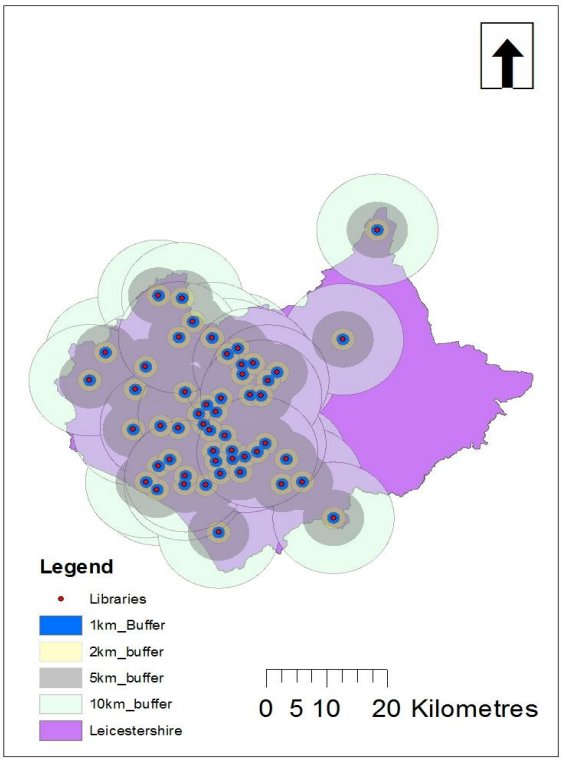

Fig. 13. Proximities of libraries to one another within 1, 2, 5 and 10 km buffers in Leicestershire

library closures. This agrees with the findings of Comber et al. [16] who argued that alternative closure plans, in the case of post offices in Leicestershire, could have reduced the loss of accessibility to this public facility after most of them had closed without any optimisation considerations nor access criteria that was set by the agency in-charge. Such could be avoided in the case of libraries.

In any case, considering the importance of libraries to the community, this study does not in any way argue for their closures. However, it proffers suggestions for optimisation in the circumstance that these closures are inevitable. This study has shown how a location-allocation tool in ArcGIS can be used to select a set of libraries in Leicestershire that should close while at the same time optimising for certain categories of users. It should be noted that most previous study using location-allocation model were on sitting of facilities rather than closing [42,43,32], hence an innovation in the use of the model.

6. CONCLUSION

Libraries are important public facilities that have gone beyond its traditional sphere of operation to becoming centres that promote social inclusion. They are part of the social and economic life of the people. However, many public agencies, including libraries in the UK have been forced to reduce their spending leading to some closures. Choosing the libraries that should close was the focus of the study.

This study used location-allocation model of network analysis to identify ten library sites to close in Leicestershire while optimising for certain classes of library users: the unemployed people, children of school age and pensioners (people over 65 years of age). Data for the study were assembled during the group stage of the project. The study identified set of libraries to close for the optimisation of the demands of the various users and saving 20% cost. Based on these considerations, this study has shown that the following ten libraries: Barwell, Blaby, Cosby, Desford, Enderby, Groby, Hathern, Kirby Muxloe, Mounstsorrel and Sapcote, should close. If this is adopted, it therefore means that the distance that users will need to travel from their homes to libraries in the new order would have been minimised, access not denied and hence social inclusion not jeopardised.

The method adopted in this study can be used to evaluate library accessibility at a larger level, e.g. National level, with optimisation for different targeted populations. While the method adopted in this study supports transparency, the calculation of distance based on proximity to nodes of actual demand points could leave some demand points out of the analysis as was experienced in the present analysis. The use of centroid data which are not directly on road network is another weakness of the study. Further research could however, be conducted on this for any improvement. In any case, this is an innovation in the use of the model.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Comber A, Brunsdon C, Phillips M. The varying impact of geographic distance as a predictor of dissatisfaction over facility access. Applied Spatial Analysis and Policy. 2012;5(4):333-352.
2. Song BD, Morrison JR, Ko YD. Efficient location and allocation strategies for undesirable facilities considering their fundamental properties. Computers & Industrial Facilities. 2013;65:475-484.
3. Sin SJ, Kim K. Use and non-use of public libraries in the information age: A logistic regression analysis of household characteristics and library services variables. Library & Information Science Research. 2008;30:207–215.
4. D'Elia G. The roles of the public library in society: The results of a national survey. Final report. Urban Libraries Council, Evanston, IL; 1993.
5. Audunson RA. The public library as a meeting-place in a multicultural and digital context: The necessity of low-intensive meeting-places. Journal of Documentation. 2005;61:429−441.
6. Goulding A. A community forum: UK public libraries as meeting places. In Langeland, M. (ed.), Librarianship in the information age: Proceedings from the 13th BOBCATSSS-symposium. 2005;349−358.
7. Aabø S, Audunson R, Vårheim A. How do public libraries function as meeting places? Library & Information Science Research. 2010;32:16–26.
8. Bertot JC, McClure CR, Jaeger PT, Ryan J. Public libraries and the internet 2006: study results and findings; 2006.

Available:http://www.ii.fsu.edu/projectFiles/plinternet/2006/2006_plinternet.pdf 2006
9. Bishop AP, Tidline TJ, Shoemaker S, Salela P. Public libraries and networked information services in low-income communities. Library & Information Science Research. 1999;1: 361−390.
10. McCook KP, Geist P. Toward a just and productive society: An analysis of the recommendations of the white house conference on library and information services. Washington, D.C.: National Commission on Library and Information Science; 1994.
11. Hertel K, Sprague N. GIS and census data: Tools for library planning. Library Hi Tech. 2007;25: 246–259.
12. Flood A. UK lost more than 200 libraries in. The Guardian' 2012.
Available:http://www.theguardian.com/books/2012/dec/10/uk-lost-200-libraries-2012. 2012
13. Cabinet Office. The coalition: Our programme for government. London: Cabinet Office; 2010a.
14. Cabinet Office. Draft structural reform plan; 2010b.
Available:https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/60804/srp-cabinet-office_3.pdf
15. Comber AJ, Brunsdon C, Radburn R. A spatial analysis of variations in health access: Linking geography, socio-economic status and access perceptions. International Journal of Health Geographies. 2011;10(44):1-11.
16. Comber A, Brunsdon C, Hardy J, Radburn R. Using a GIS-based network analysis and optimisation routines to evaluate service provision: A case study of the UK Post Office. Applied Spatial Analysis and Policy. 2009;2(1):47-64.
17. Hansen WG. How accessibility shapes land use. Journal of the American Planning Association. 1959;25(2):73–76.
18. Ingram DR. The concept of accessibility: A search for an operational form. Regional Studies. 1970;2:101–107.
19. Penchansky R, Thomas JW. The concept of access: Definition and relationship to consumer satisfaction. Medical Care. 1981;19(2):127–140.
20. Envail P. Accessibility planning: A chimera? Doctoral dissertation. University of Leeds, England; 2007.
21. Park SJ. Measuring public library accessibility: A case study using GIS. Library & Information Science Research. 2012;34:13-21.
22. Maroko AR, Maantay JA, Sohler NL, Grady KL, Arno PS. The complexities of measuring access to parks and physical activity sites in New York City: A quantitative and qualitative approach. International Journal of Health Geography. 2009;8:34.
23. Comber A, Brunsdon C, Green E. Using a GIS-based network analysis to determine urban greenspace accessibility for different ethics and religious groups. Landscape and Urban Planning. 2008;86: 103-114.
24. Hayes R, Palmer ES. The effects of distance upon use of libraries: Case studies based on a survey of users of the Los Angeles Public Library central library and branches. Library Research. 1983; 5:67–100.
25. Cole KJ, Gatrell AC. Public libraries in Salford: A geographical analysis of provision and access. Environment and Planning. 1986;18:253–268.
26. Hawkins AM. Geographical Information Systems (GIS): Their use as decision support tools in public libraries and the integration of GIS with other computer technology. New Library World. 1994; 95(7):4–13.
27. Koontz CM. Library facility siting and location handbook. Greenwood, Westport, CT; 1997.
28. Allen DW. GISTUTORIAL 2: spatial analysis workbook. Esri Press, New York; 2013.
29. Koontz CM, Jue DK, Bishop BW. Public library facility closure: An investigation of reasons for closure and effects on geographic market areas. Library & Information Science Research. 2009;31: 84–91.
30. Ghosh A, Craig CS. A location allocation model for facility planning in a competitive environment. Geographical Analysis. 1984; 16(1):40-51.
31. Hodgart RI. Optimising access to public services: A review of problems models and methods of locating central facilities. Progress in Human Geography. 1978;2:17-48.
32. Rahman S, Smith DK. Use of location-allocation models in health service development planning in developing nations. European Journal of Operational Research. 2000:123:437-452.

33. Tobler WR. A computer movie simulating urban growth in the Detroit region. Economic Geography. 1970;46:234–240.
34. Available:http://resources.arcgis.com/en/help/main/10.1/index.htm#/00470000006700 0000.htm
35. Scott AJ. Combinational programming, spatial analysis and planning. Methuen, London; 1971.
36. Sheppard ES. A conceptual framework for dynamic location-allocation analysis. Environment and Planning. 1974;6:547-64.
37. Lea AC. A model taxonomy and a view of research frontiers in normative locational modeling. Paper presented at the International Symposium on Locational Decisions, Banff, Alberta; 1978.
38. Leonardi G. A unifying framework for public facility location problems-part 1: A critical overview and some unsolved problems. Environment and Planning. 1981;13:1001-1028.
39. Teitz MB, Bart P. Heuristic methods for estimating the generalized vertex median of weighted graph. Operations Research. 1968;16:955-961.
40. Toregas C, Revelle CS. Optimal location under time or distance constraints. Papers in Regional Science. 1996;28:133-143.
41. Revelle C, Church R. A spatial model for the locational construct of Teitz. Papers in Regional Science. 1977;39:129-35.
42. Zeller Achabel Brown. Market penetration and locational conflict in franchise systems. Decision Science. 1980;11:58-80.
43. Erkut E, Neman S. Analytical models for locating undesirable facilities. European Journal of Operational Research. 1989;40:275-291.
44. Martin D. Census output areas: From concept to prototype. Population Trends. 1998;94:19-24.
45. O'Sullivan D, Unwin DJ. Geographic information analysis. 2nd Edition. John Wiley & Sons, New Jersey; 2010.
46. Handley J, Pauleit S, Slim P, Ling C, Lindley S. Providing accessible natural greenspace in towns and cities: A practical guide to accessing the resource and implementing local standards for provision in Wales. Centre for Urban and Regional Ecology, School of Planning and Landscape, University of Manchester, Manchester; 2003.
Available:http://publications.naturalengland.org.uk
47. Available:http://help.arcgis.com/en/arcgisdesktop/10.1/help/index.htm#//0047000000 50000000
48. Palmer ES. The effect of distance on public library use: A literature survey. Library Research. 1981;3(3):315-334.

Peer-review history:
The peer review history for this paper can be accessed here:
https://sdiarticle4.com/review-history/51038