International Journal of Computer Engineering Research Vol. 2(5), pp. 82-92, November 2011
Available online at http://www.academicjournals.org/IJCER
ISSN 2141- 6494 ©2011 Academic Journals
DOI: 10.5897/IJCER11.048

Full Length Research Paper

Managing distribution of national examinations using geospatial technologies: A case study of Pumwani and Central divisions

David Ndegwa Kuria[1]*, Moses Murimi Ngigi[2], Josephine Wanjiru Wanjiku[1] and Rachel Kavutha Kasumuni[2]

[1]Department of Geomatic Engineering and Geospatial Information Science, Kimathi University College of Technology, P. O. Box 657 – 10100, Nyeri, Kenya.
[2]Department of Geomatic Engineering and Geospatial Information Systems, Jomo Kenyatta University of Agriculture and Technology, P. O. Box 62000 – 00200, Nairobi, Kenya.

Accepted 18 October, 2011

Most of the spatially referenced data held by the Kenya national examination council (KNEC) are in analogue hard copy format. This necessitates large storage facilities for storing the paper maps, which have low retrieval speeds. Additionally, wear and tear are occasioned during retrieval and handling, and sometimes some of the data is lost. In this form data sharing is difficult and reproduction usually involves high costs per unit. The purpose of this paper is to implement a geographic information system (GIS) which will lower cost per unit, by allowing higher retrieval speeds, smaller storage facilities requirements, while facilitating data sharing. This GIS will perform all the tasks of the current manual system and in addition, provide functionality to aid in the efficient management of the Kenya national examination council data. To accomplish this, existing hardcopy data was digitized and cleaned. New data was collected, processed, analyzed and stored in the form of a geodatabase. This geodatabase stores both the spatially related data and the attribute data. This geodatabase can be used to answer many questions, but for this work, we emphasize the aspect of efficiency in exam distribution. To determine the most efficient routes to follow in the distribution of examinations during the examination period, a geometric network was prepared which was then used to determine the best routes. In this research, a prototype GIS has been developed. Visualization and comparison can be easily performed using the digital maps produced from the implemented system. The GIS database created can be used for purposes of querying and can be revised whenever new information is available. Shortest distances analysis and efficient distribution route determination were performed using spatial analysis and network analysis tools. From the distribution analysis, the service area analysis is demonstrated as giving a more realistic spatial extent of coverage compared to the buffering approach. From these analyses, the services area analysis and buffering approach showed areas of 980.96 and 223.15 Ha being beyond zone 5.

Key words: Geographic information systems, network analysis, route location.

INTRODUCTION

The Kenya national examinations council (KNEC) was established in 1980 under the KNEC Act of Parliament (CAP, 225A) of the Laws of Kenya (GoK, 1980). It was established to take over the functions previously undertaken by the defunct East African Examinations Council and the Ministry of Education to conduct school, post school and other examinations.

A narrow view of geographic information system (GIS) is that it is a computer system for the input, manipulation, storage and output of digital spatial data (Konecny, 2003). It is the integrated computer hardware and software that captures, stores, analyzes, and displays geographically referenced information (Tomlinson, 2007). It can also be defined as an organized collection of

*Corresponding author. E-mail: dn.kuria@gmail.com.

computer hardware and software, with supporting data and personnel, that captures, stores, manipulates, analyses, and displays all forms of geographically referenced information (Clarke and Langley, 1996; Birkin et al., 1996). There are as many views of GIS as uses and users with some viewing it as a way to automate the production of maps, while others see it as a complex system capable of solving geographic problems and supporting spatial decisions, with the power of GIS being an engine for analyzing data and revealing new insights. Still, others view it as a tool for maintaining complex inventories that adds spatial perspectives to existing information systems, allowing spatially distributed resources to be tracked and managed (Longley et al., 2005).

GIS has many uses in education such as being used as a teaching aid (Johansson, 2003; Zwartjes, 2010), to help with facilities management, vehicle routing, district boundary mapping, safety and preparedness, amongst a host of others (ESRI, 2010). There is a specific focus on education planning and the uses to which geographical information can be put in this context, with particular reference to the situation in Kenya. Some uses of GIS within the education sector are determination of spatial distribution of schools and the analysis of spatially referenced data (Mulaku and Nyadimo, 2011).

The traditional role of educational planners, that of planning school location, has been supplanted in recent years by additional tasks such as school improvement agenda (strategies to improve quality of school curricula) and examination target setting (Mulaku and Nyadimo, 2011). The latter target extends to KNEC, as the monitoring of performance is important, as it is not just schools which have to set targets for improved performance. There are many activities that must be carried out and monitored, largely through the use of data collected. Every time provisions are reviewed there are major changes in terms of financial cost and upheavals in schooling, which can affect the education of the youth (Langley, 1997). It is a complex situation which most of the time must be monitored, and changes implemented in as non-disruptive a manner as possible. In order to assist in this monitoring and analysis, role planners can utilize geographic information. All educational data have a spatial element and it is thus possible to visualize the enormous potential GIS holds for generating and analyzing huge datasets of geographic information, by schools, by local authorities and over time, nationally. The main uses of a GIS are, as in most other fields, the easy visualization of data and performance of sophisticated spatial analyses. KNEC has been using hardcopy maps for planning distribution and identification of various infrastructures necessary to successfully distribute and man the examinations. The hardcopy maps not needed are filed and stored and those required retrieved manually. These traditional methods of acquiring, storing and analyzing spatially referenced data have been proven to be costly and inflexible. There are several of reasons for adopting a GIS for the KNEC: Currently, the council does not have its data in digital form that can allow them to view the location of schools. At this time they only possess paper maps of the schools, which in some cases are already outdated. A geodatabase would allow the council to locate any school easily. Furthermore, visualization of the schools can be done in a more efficient fashion using data in digital form in comparison to using paper maps. Some of the issues that organizations dealing with spatially referenced data must contend with include:

1. Spatial information is poorly maintained or is often outdated: This takes the form of outdated maps. Attendant long delays in processing map revisions or inaccurate data records and summaries leads to user mistrust of the quality of the information.
2. Spatial data is not recorded or stored in a standardized way: The coordinate systems differ and map scales vary, making it difficult to use multiple data sets together.
3. The spatial data may not be defined in a consistent manner: In some cases, different organizations may require that similar data be organized using different classification systems to suit their peculiar needs.
4. Data is not shared: This arises from fear of misuse or because potential users may not know of the existence or whereabouts of the data. As a result different users keep their own copy of the original data leading to duplication of data. This results in the existence of different versions, which are not updated simultaneously.
5. Data retrieval and manipulation capabilities are inadequate: The retrieval of information such as routine reports may be too slow and the ability to perform complex or special purpose analyses of spatial information may be limited or non-existent.
6. New demands made by the organization: Such demands cannot be met using the prevailing information system in the organization. The organization’s mandate may be changed or a new legal requirement may take effect that cannot be satisfied without the capabilities of GIS, or at least computerization of existing records.

The vision of KNEC is to be an efficient testing and evaluation center for quality education, while its mission is to objectively test and evaluate the curriculum to enhance and safeguard globally accepted certification standards (KNEC, 2008). The core functions of KNEC are as follows: (a) Development of school and post-school examinations, (b) registration of candidates for various examinations, (c) administration and processing of examinations, (d) certification of candidates’ results, (e) researching into examinations and school curricula and, (f) evaluation, assessment and equation of certificates from other examining bodies.

The examinations developed and administered by KNEC are as follows: (i) Kenya certificate of primary

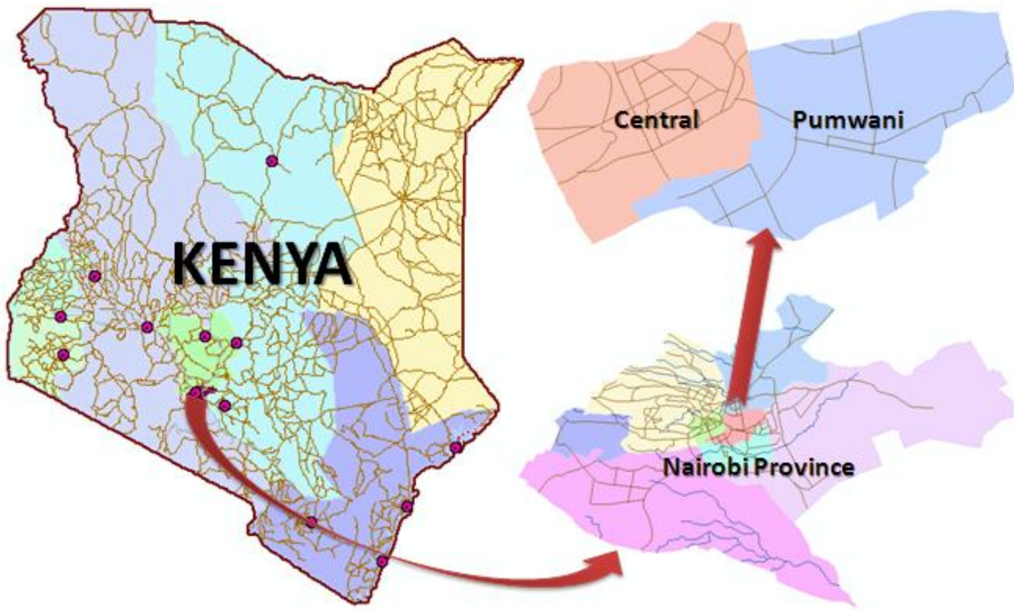

Figure 1. The study area adopted in the pilot phase.

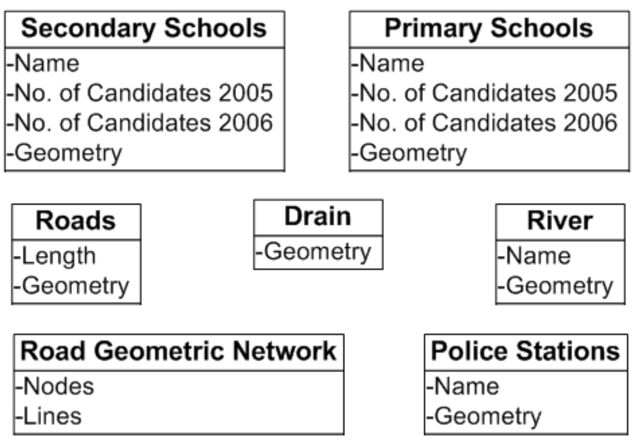

Figure 2. Feature classes and associated key attributes.

education (KCPE), (ii) Kenya certificate of secondary education (KCSE), (iii) Primary teachers examination (PTE) for both pre-service and in-service trainees, (iv) Teacher certificate in adult education (TCAE), (v) Post school examinations in business and technical subjects and, (vi) English proficiency examinations for law graduates seeking to join Kenya School of Law.

A GIS implementation will help improve maintenance of the maps as they are in digital form compared to the traditional analogue format. The objective of this research is to develop a GIS to assist the KNEC in managing examination related issues. Some of the features of this GIS will be improved efficiency in distribution of examinations, ability to evaluate schools well served by the existing distribution centers and determining routes to follow when distributing from a center to far flung schools. These features are in addition to the visualization capabilities of a GIS which can be used to generate maps showing the spatial distribution of schools.

MATERIALS AND METHODS

Study area

The study area is located in Nairobi province and lies between 36°48′39.532″ E to 36°53′1.021″ E and 1°14′59.266″ S to 1°17′51.45″ S with an approximate area of 24.535 km². It covers the two division of Central division and Pumwani division. It has about 30 primary schools and 17 secondary schools. Figure 1 shows the geographic location of the study area. In this area, there are two police stations that are usually used as the central distribution points for examination purposes. These are the Central Police Station and Kamukunji Police Station. The spatial data used in this research was provided by the Geomatic Engineering and Geospatial Information Systems (analog topographic maps). Attribute information on registration and enrollment in schools was provided by the KNEC.

To achieve the objectives of this research, the activities were divided into two main components: Data capture and network analysis. Data capture entailed conversion of existing analog data into digital form. The data collected was collated with attribute data from.

KNEC to come with data representation portrayed in Figure 2. Six main feature classes were identified of which the key were Primary Schools, Secondary Schools, Police Stations and Roads. These data were stored in a geodatabase, after which a geometric network was constructed. This network comprises of links and nodes with the links representing possible path segments that can be followed, and the nodes representing possible turning points. Common network operations include computational processes to find the shortest, least-cost, or most-efficient path (path finding), to analyze network connectivity (tracing), and to assign portions of a

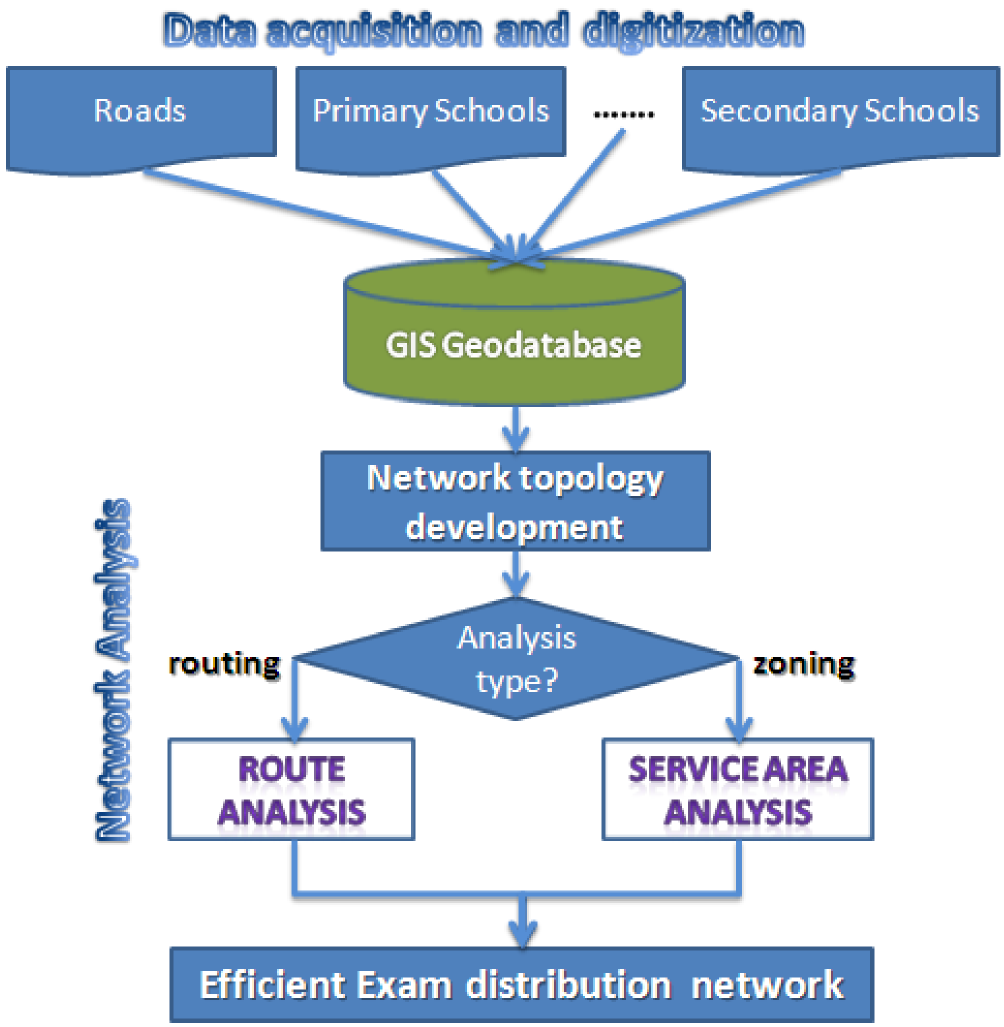

Figure 3. Methodology workflow adopted in this research.

network to a location based on some given criteria (allocation) (Jiang and Claramunt, 2004). The geometric network generated was used in "Service area analysis" and "Route analysis".

A network service area is a region that encompasses all accessible streets (that is, streets that are within specified impedance). For instance, a one-hour service area for a point on a network includes all the streets that can be reached within one hour or minutes from that point. Service areas also help evaluate accessibility. Concentric service areas show how accessibility varies with impedance (ESRI, 2010a). The notion of impedance is borrowed from electronics and refers to the resistance to traffic flow encountered when traversing the network.

Using route analysis, one can find the best way to get from one location to another or to visit several locations. The locations can be specified interactively by placing points on the screen, entering an address, or using points in an existing feature class or feature layer. In this way, in the event of needing to visit more than two points, the best route can be determined for the order of locations as specified by the user.

Depending on the type of analysis desired, a route can be selected (shortest in terms of length) between the distribution center and examination centers, or a service area can be produced showing how well the existing distribution centers are able to serve the examination centers. This scheme's workflow is represented by Figure 3.

RESULTS AND DISCUSSION

The geodatabase and geometric network developed in the research were used to answer a variety of queries spanning simple to complex queries. This geodatabase is then useful for many purposes, such as preparing charts and reports, visualization of special purpose maps, posing queries to the system and generating the efficient distribution map. For example, the geodatabase can be used to assess the trend in registration of candidates across years for both primary and secondary school students. Figure 4 shows the variation of students' registration between 2005 and 2006 for the Kenya Certificate of Primary Education. Figure 5 shows the registration of students for the Kenya Certificate of Secondary Education for the same two years. These two

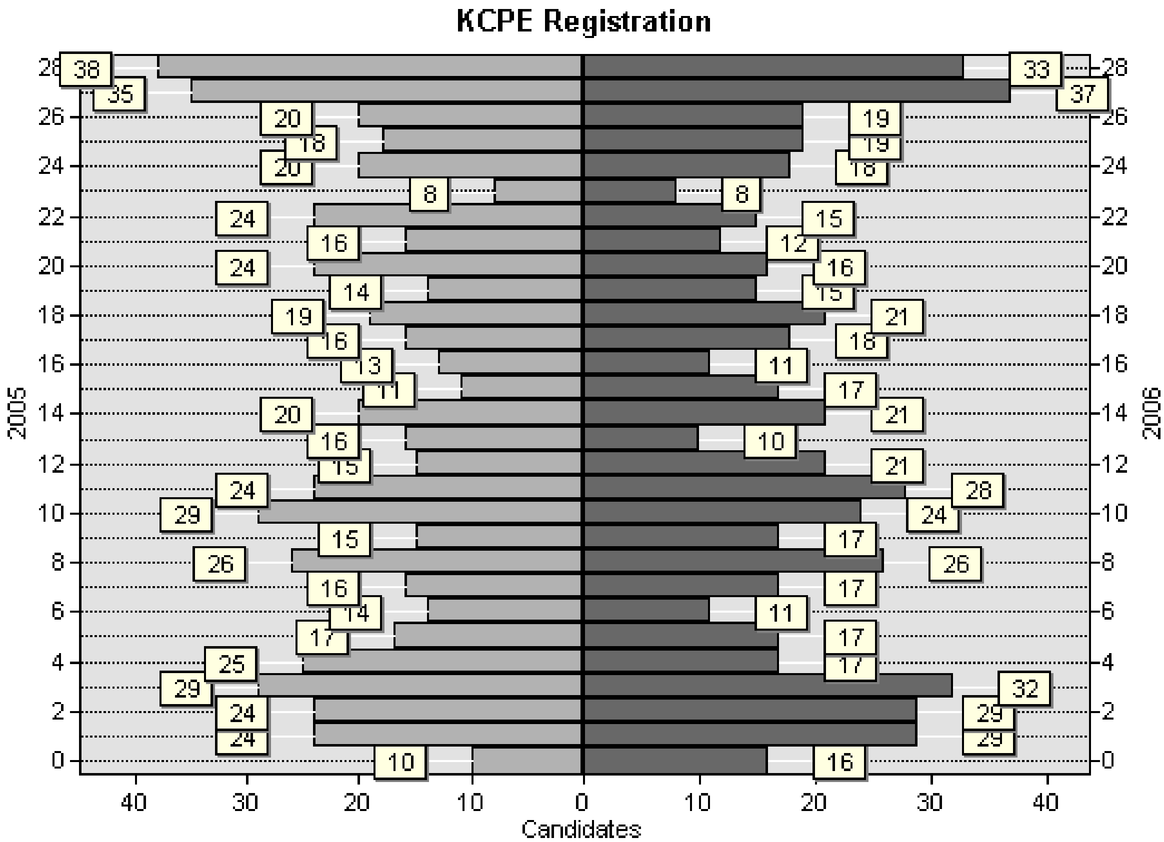

Figure 4. Graphing capabilities - KCPE registration for 2005 and 2006 compared.

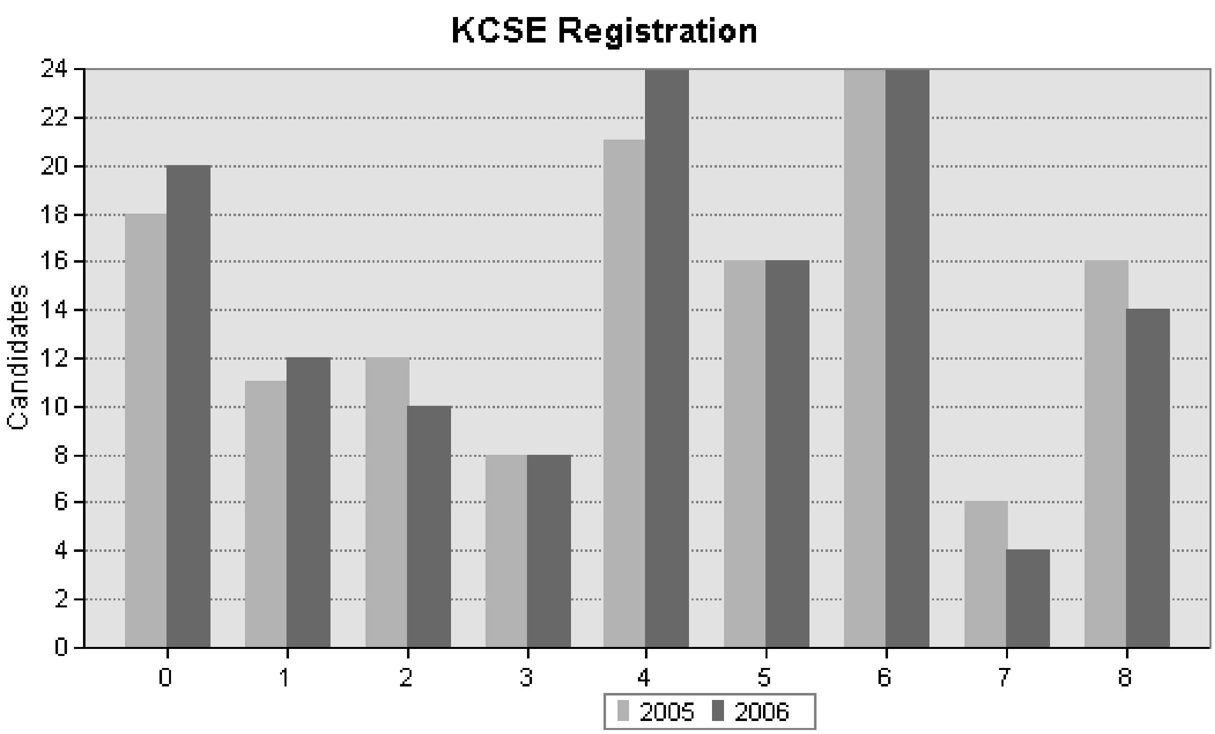

Figure 5. Graphing capabilities - KCSE registration.

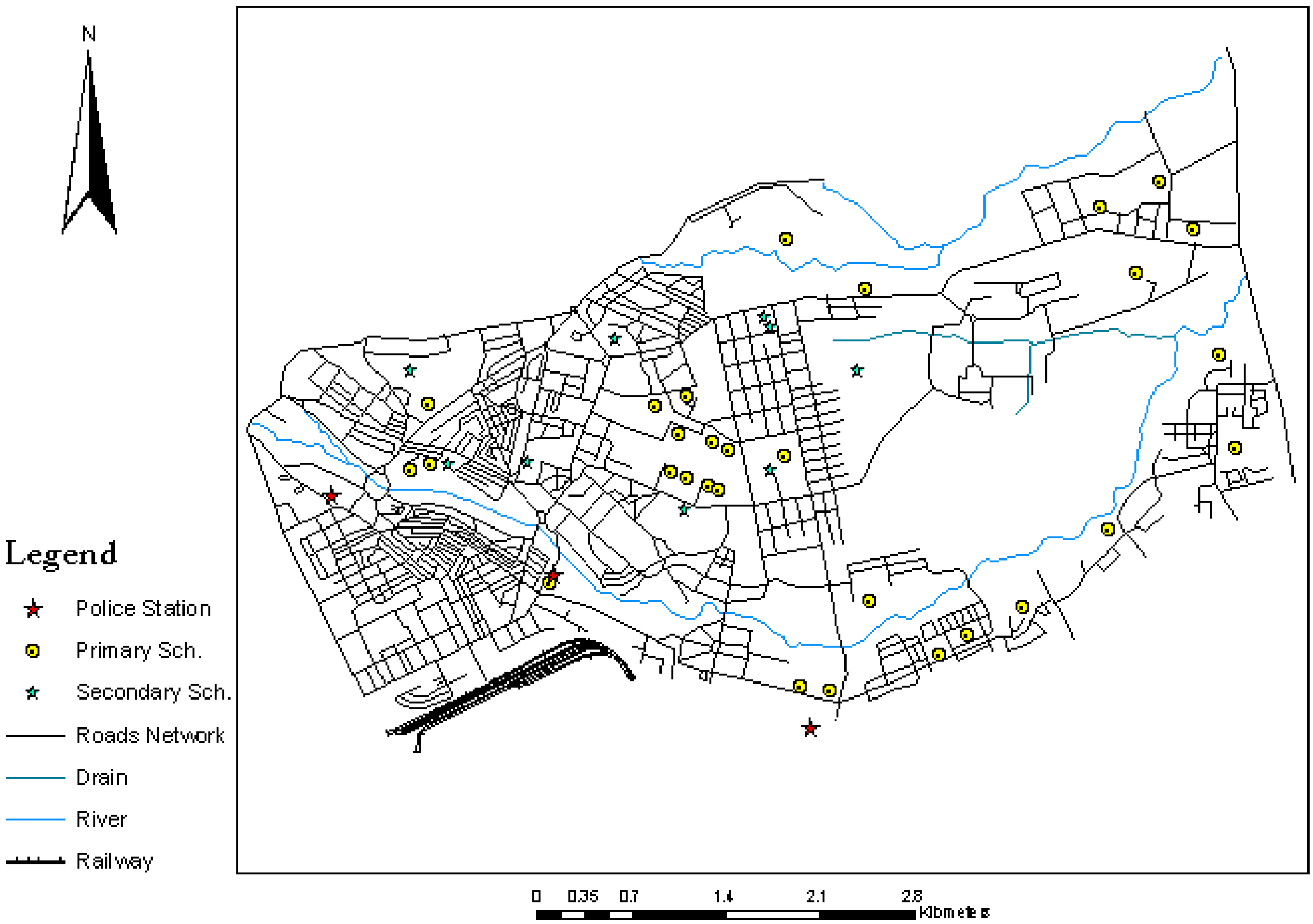

Figure 6. KNEC special purpose map.

figures show that as would be expected that despite slight variations in the numbers, there is an almost 1:1 correspondence between the years. This can be related to the facilities available in each school and the corresponding catchment population.

One of the main strengths of the GIS is the quality visualization of spatial data as special maps. Such a special purpose map suitable for KNEC is depicted in Figure 6. Maps of this nature contain information on the location of Police stations, schools (both primary and secondary), roads (geometric network) and some basemap layers such as rivers, drains and rail tracks. The national examinations are normally dispersed to the divisional police stations on the eve of the examinationsso that the following day they get distributed to the targeted schools. Security detail is also provided from these police stations to ensure maintenance of law and order and to ensure there are no exam irregularities.

Some of the simple queries that this GIS can answer include selection queries such as:

1. Select schools with 'No. of candidates 2005' > 100

2. Select 'Primary School' with 'Name' = 'Guru Nanak Primary School'

Some of the queries supporting planning purposes include:

a. Select schools with distance from roads > 1 km: Such a query can be used to identify schools which are not well served. However, such a query while useful for proximity analysis may not be appropriate in distribution analysis along transport networks (Jiang and Claramunt, 2004; ESRI, 2010a). This is because it uses the idea behind 'buffer analysis' which utilizes equidistant generation of a buffer zone around the selected feature without due regard to accessibility considerations (impedances).

b. These limitations are addressed by the road geometric network that has been developed, through which network based analyses were conducted. A geometric network topology comprises of a set of nodes (stops), link(routes) and barriers (hindrances). An impedance value can be calculated for each of the links to describe the resistance to flow along that particular link. It is possible to incorporate many factors in the calculation of impedances

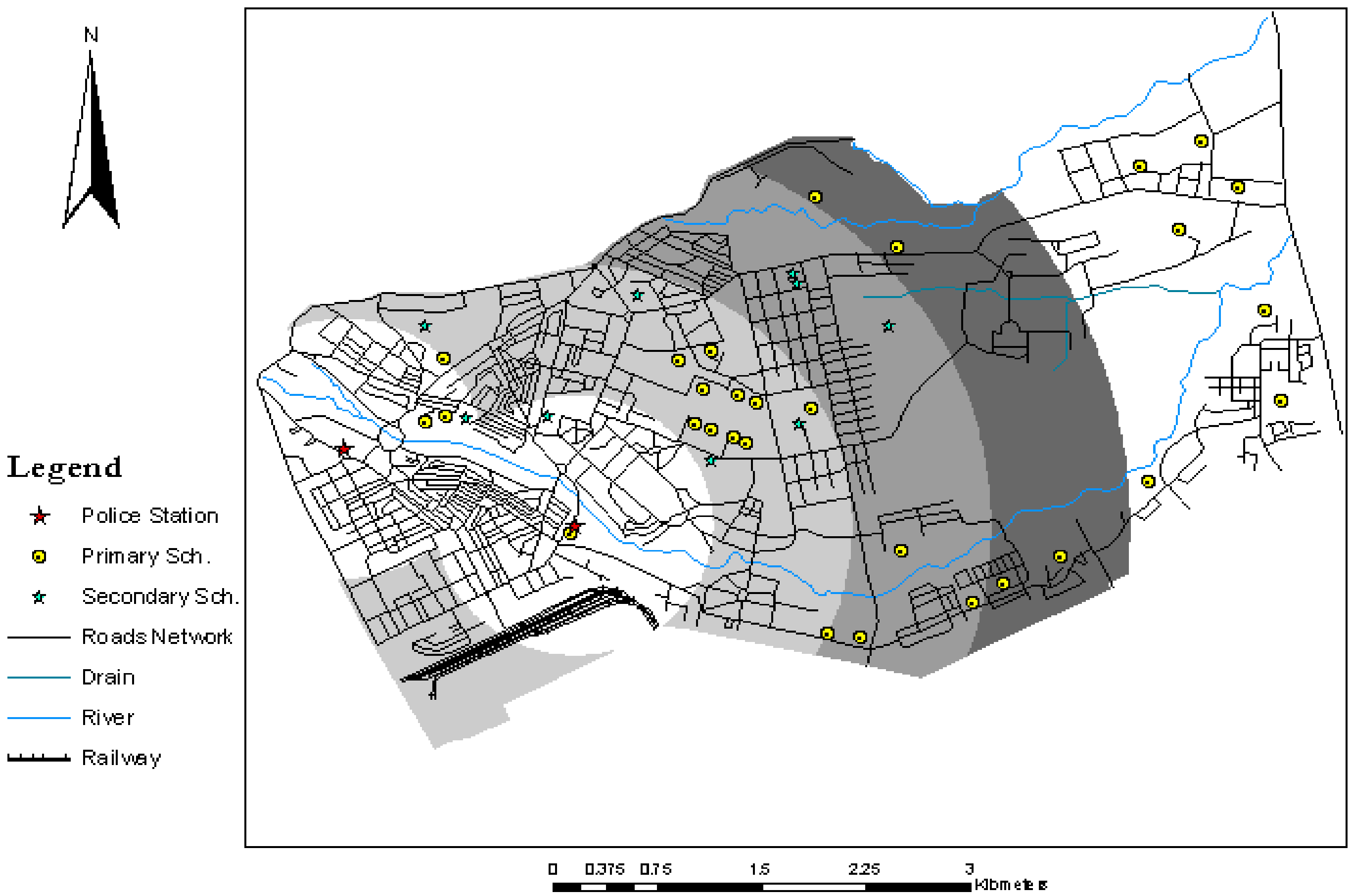

Figure 7. Buffer zoning to show how well the distribution centers serve the exam centers.

to motions such as wind speed and direction, slope of the link, road class hierarchy (can lower class road join a road of a higher class directly?), road surface condition (describing friction) etc. In this research to begin with, it is assumed that all the links have the same impedance and uses simple link length to perform the network analysis. Using this assumption, the network developed can answer the query.

C. Which is the shortest and fastest route from a point A to a point B?

In this research, the shortest route will also be flagged out as the fastest route too. However, by considering the factors outlined in the foregoing, it is clear that the shortest route to some point may not necessarily be the fastest route (most economical route).

Two types of network analyses were undertaken in this research: route analysis and service area analysis. Route analysis chooses the most appropriate route based on the criteria given (impedances) in the links and nodes, bearing in mind any barrier (physical or otherwise) that may have been placed at some sections of the network (e.g. if there are road works on some sections of a road in the network, such a road will not be available and alternate routes will be determined). Service area analysis determines how well facilities in a network are served or are serving the area (ESRI, 2010a). Buffering may accomplish more or less the same objective, but it has the shortcoming that it does not consider accessibility aspects. To clarify this fact, the two approaches are compared in Figures 7 and 8. In both cases, the zoning interval is 1 km. it can be seen that at 5 km there are still some schools that are not well served. These are in the far flung parts of the Pumwani division. These two approaches show that the current distribution of the police stations is not optimal for distribution of exams. Several approaches can be used to address this: (i) Create a police station in the Pumwani division appropriately located in the better networked portion of region to the extreme right of the division or (ii) other police stations in the neighboring divisions could be used to ameliorate this deficiency if they are used in the network analysis.

In the buffering approach the geometric network is not considered as having a significant impact on the zones, it is totally ignored. To offset this limitation, service area analysis incorporates the geometric network in the zoning. Zones are designated along possible routes originating from the distribution centers. Figure 8 shows

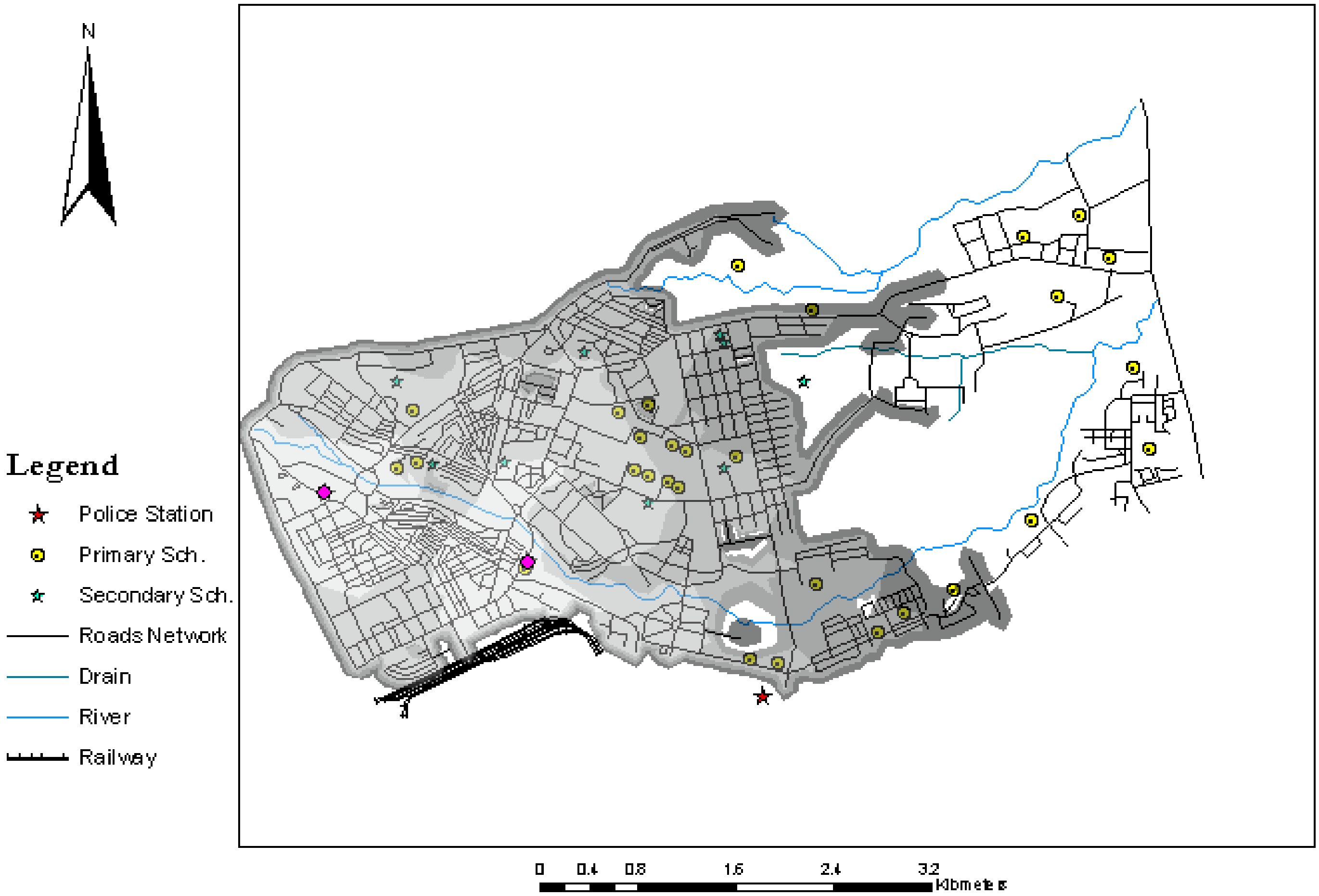

Figure 8. Service area analysis showing the effectiveness of the existing distribution network.

Table 1. Area comparison for service area viz. buffering approaches.

Zone (Km)	Service area (Ha)	Buffering (Ha)	Difference (Ha)
1	254.52	535.74	281.21
2	460.31	552.89	92.58
3	328.96	436.66	107.70
4	287.19	385.81	98.62
5	141.58	319.28	177.70
Total	1,472.56	2,230.37	757.81

the service area zoning. It is clear that there are areas that are not well served in the intermediate zones, especially where there is an inadequate road network but would have been flagged as adequately served from the buffer analysis only.

Comparing Figures 7 and 8, it can be seen that it is important to consider the distribution network's impact. There are some schools that are found within the buffer zones but are missing out in the service area zones since they can not be accessed using the existing road network.

Table 1 shows the quantitative comparison of the two approaches. Overall, it is clear that the service area analysis all round returns smaller area as it gives regard to the nature of the road network. The combined area of the divisions considered was evaluated as 2,453.52 Ha meaning that the service area analysis flags 980.96 Ha as completely beyond zone 5 while 223.15 Ha is what is beyond zone 5 from the buffering approach.

Another form of analysis possible with a geometric network which was executed in this research is route analysis. Route analysis allows one to determine alternative routes depending on the conditions that the user specifies. Creating a route can mean finding the

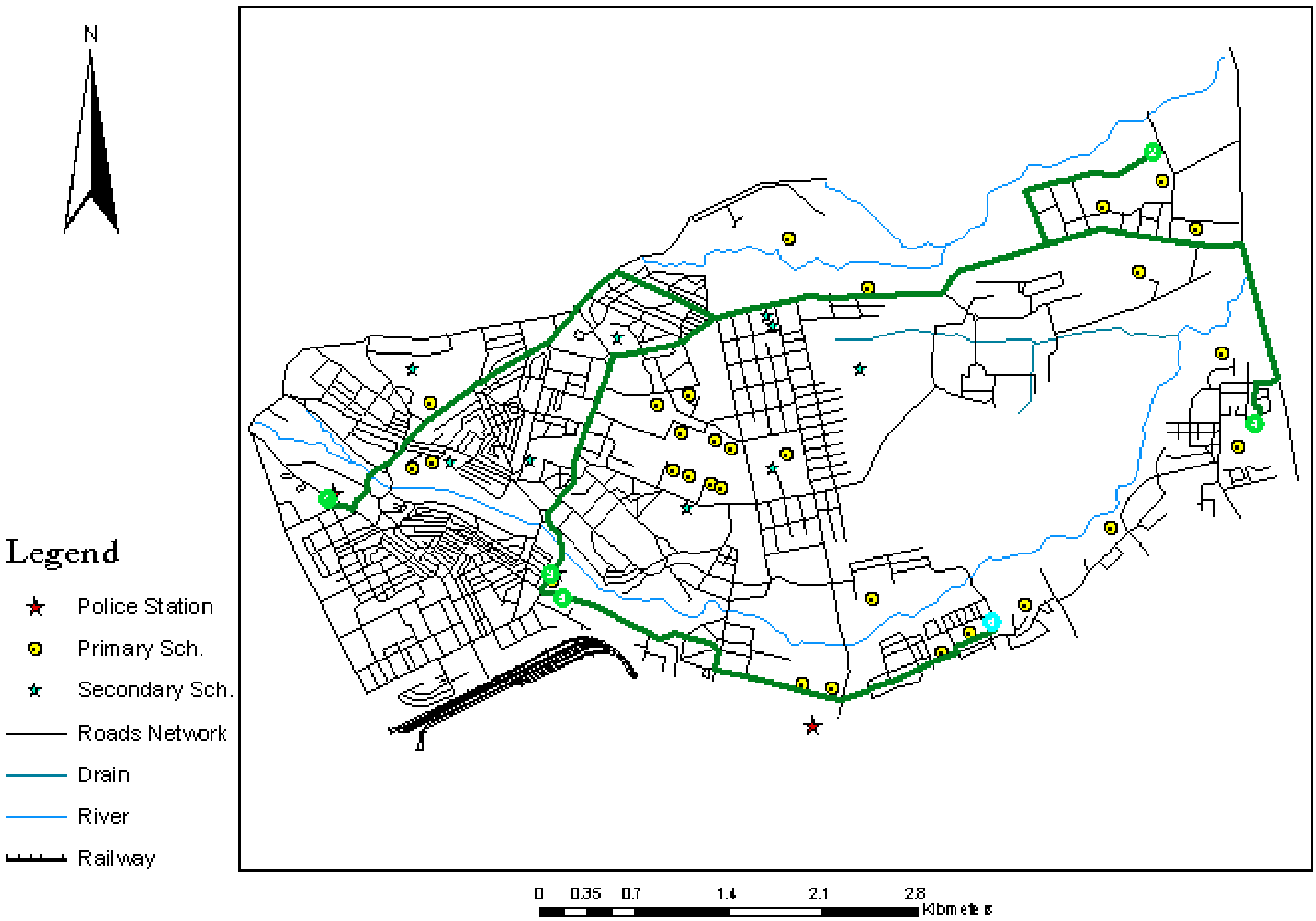

Figure 9. Route analysis without barriers.

quickest, shortest, or most scenic route, depending on the impedances chosen. If the impedance is time, then the best route is the quickest route. Hence, the best route can be defined as the route that has the lowest impedance, or least cost, where the impedance is chosen by the user. Any cost attribute can be used as the impedance when determining the best route (ESRI, 2008).

In this research, two scenarios are considered: (i) Network without any barriers in which case the shortest distance is computed (this research assumes uniform impedance in which case the shortest route is also the best route) throughout the network (Figure 9) and (ii) network in which barriers (e.g. roads underconstructions/ renovation and accident occurrences) are placed on some of the paths (Figure 10) to simulate situations where some routes maybe temporarily unusable.

In both scenarios the two distribution centers are the origins and four prospective destinations. Figure 9 shows the routes to the destinations following the shortest paths corresponding to scenario 1. In the second scenario, three barriers are introduced along the shortest paths picked in scenario 1. Figure 10 show the new alternative shortest paths through the same points.

Conclusion

A prototype GIS has been developed, capable of answering simple attribute and spatial queries and visualization of spatial data. This GIS has at its core a geodatabase that will be useful in efficient and effective planning for better management and decision making by KNEC. It addresses the challenge of fast data access, retrieval, manipulation and storage that the agency has grappled with in managing the schools information. A geometric network using roads data has been developed that can be used to perform efficient routing between distribution centers and various examination centers. This network has been demonstrated as being capable of showing examination centers that are not well served by the existing distribution network. It has also been shown

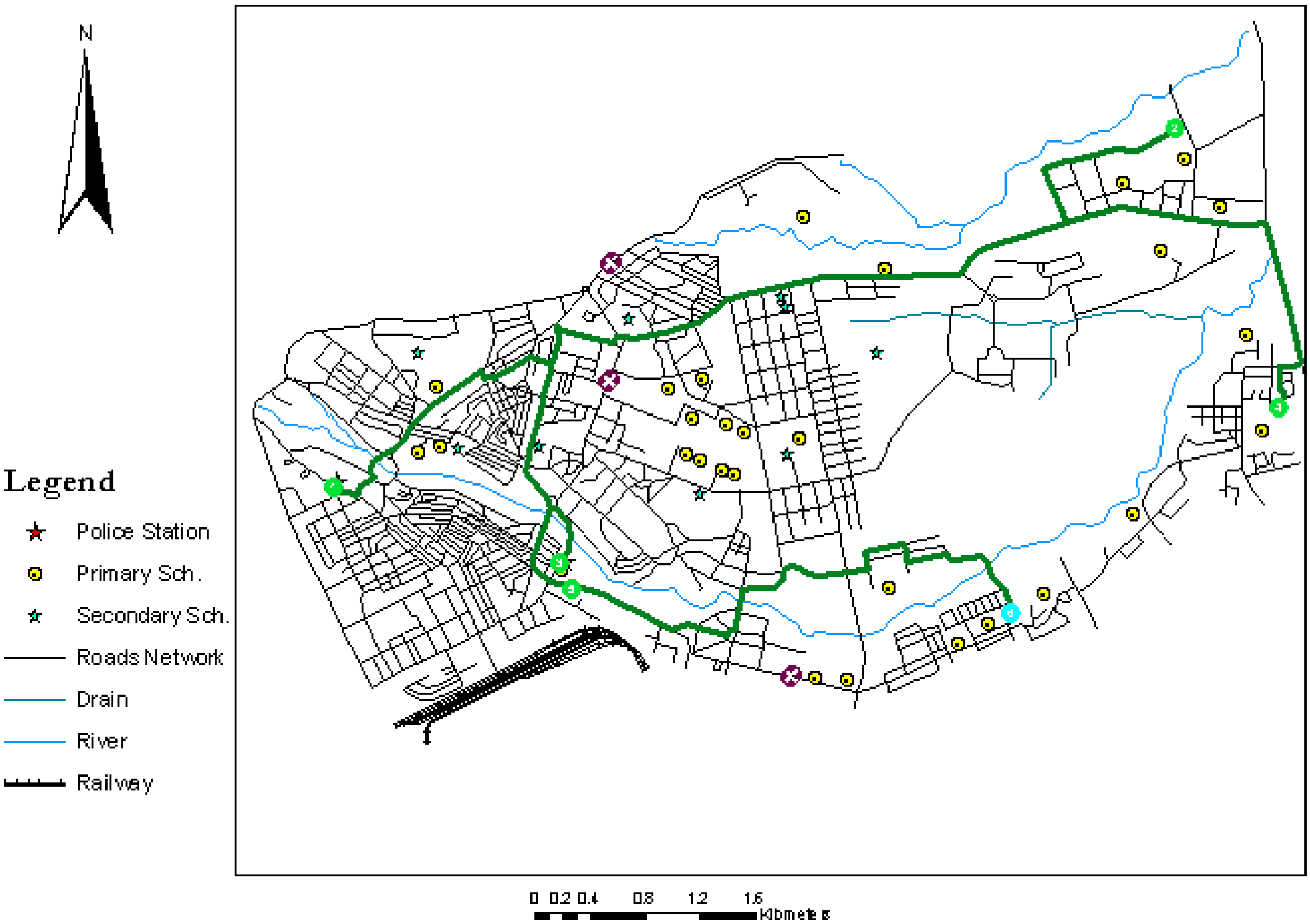

Figure 10. Route analysis circumventing three (3) barriers.

that with respect to determining a distribution network, it is better to use service area analysis rather than buffer analysis.

Several improvements are recommended, but which can follow after the prototype has been implemented. First, it is recommended that the geodatabase developed in this research can be connected to other KNEC and education sector related databases (e.g. teacher-student ratios, teaching resource facilities etc). This will improve the utility of the overall system as such information can be linked to the spatial data to unravel unique relationships hidden in the data.

Secondly, it is recommended that information about impedance factors (contributors) be collected and incorporated to improve the value of the results obtained from the system. From the findings of the research, it is proposed that a new distribution center should be designated or established in Pumwani division to ease the distribution strain. This center will serve the far flung schools in the division. It is further recommended that the prototype should be extended to cover the whole of Nairobi province and ultimately nationally.

ACKNOWLEDGEMENTS

The authors wish to appreciate facilitation during data acquisition and execution of the research quest by the Jomo Kenyatta University of Agriculture and Technology. The three anonymous reviewers who reviewed the manuscript gave critical insights and their remarks have greatly helped improve the manuscript and their contribution is appreciated.

REFERENCES

Birkin M, Clarke GP, Clarke M and Wilson AG (1996). Intelligent GIS, Geoinformation. Cambridge.

Clarke GP, Langley R (1996). The potential of GIS and spatial modelling for planning in the new education market. Environment and Planning C, Government and Policy, 14: 301-323.

ESRI (2008). Network Analysis. ArcGIS desktop help. ESRI Press, California.

ESRI (2010). *GIS for Schools.* Retrieved october 12, 2011, from GIS for Education: http://www.esri.com/industries/k-12/index.html.

ESRI (2010a). Types of network analysis layers. ESRI Press, California.

Government of Kenya (1980). Kenya National Examination Council Act, CAP 255A. Laws of Kenya. Government Printers, Nairobi.

Jiang B and Claramunt C (2004). Topological analysis of urban street networks. Environment and Planning B: Planning and Design, 31: 151-162.

Johansson T (2003). GIS in Teacher Education – Facilitating GIS. Retrieved October 13, 2011, from Scan GIS: http://www.scangis.org/scangis2003/papers/20.pdf.

Kenya National Examination Council (2008). Mission and vision. Retrieved September 14 2010, from KNEC: http://www.examscouncil.or.ke/mission.php.

Konecny G (2003). Geoinformation: Remote sensing, photogrammetry and Geographic Information Systems. Taylor and Francis, London.

Langley R (1997). The use and development of GIS and spatial interaction models for planning in education. PhD thesis. University of Leeds, Leeds.

Longley PA, Goodchilde MF, Maguire D J and Rhind DW (2005). Geographic Information Systems and Science. John Wiley and Sons Ltd, Chichester.

Mulaku GC and Nyadimo E (2011). GIS in Education Planning: The Kenyan School Mapping Project. Surv. Rev., 43(323): 567-578.

Tomlinson R (2007). Thinking about GIS: Geographic Information System Planning for Managers (Third ed.). ESRI Presss, California.

Zwartjes L (2010). iGuess: Introducing GIS Use in Education in Several Subjects. Retrieved Oct. 12, 2011, from iGuess Project: http://www.iguess.eu/uploads/docs/geotech03.pdf.