Application of Spatial Decision Support System to Blood Bank Information Systems

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Abstract
The availability of blood is one of the important requirements in treating medical emergencies; the blood banks do not maintain buffer stocks as required during that time. Thus the buffer stock is obtained from the local donors in the city. In this paper we propose a Geographic Information System (GIS) integrated with blood bank information system to help the blood bank staff to increase or maintain the buffer stock by studying spatial distribution of donors, classification of donors and defining blood bank service areas. Each one of these issues is covered using several GIS functions including buffer analysis, network analysis and overlay analysis. The former is used to produce drive-time to reach blood bank by a required donor and the overlay analysis is applied at the selected blood bank to calculate the size of its donors around the city. The created application is regarded as a spatial decision support system for blood bank information system.

1. Introduction

India's blood banking system has serious shortcomings. The gap between demand and supply of blood is continuously widening. India has an annual requirement of approximately, 5.0 million units of blood. The actual collection is only approximately 3.50 million units. A study, conducted by the National AIDS Control Organization (NACO), regarding blood banking services in India, has revealed many shortcomings, including the decentralized nature of blood services, shortage of human, technological and financial resources and deficit in the availability of blood, especially from voluntary donors. Paradoxically, very few blood banks are operating to their full capacity. Inappropriate use of blood and wastage is not an uncommon occurrence. Even during an emergency, the onus is on the patient's relatives to arrange for replacement of blood. Blood bank information system is the portal which bridges the gap between the demand and supply of blood. This portal aims to bring blood donors and recipients under a common on-line platform. Donors can register themselves on the site after going through the basic requirements for donating blood. This portal also has useful information regarding blood donation such as scientific information, tips and facts. The proposed system is an efficient blood bank management system with an aim of ensuring that every patient has access to an adequate quantity of safe blood in a centralized manner.

The management system should solve the issue of demand and wastage and lead to self-sufficiency in blood requirement (Kros and Pang, 2004). This should encourage new donors and retain old donors to donate blood. In fact, from donor recruitment to blood dissemination, blood bank staff is involved in various decision-making procedures. However, from the perspective of blood bank staff, they often seek more support from the blood bank information systems other than inputting and retrieving historical data only. At least, such a system should be able to assemble the heterogeneous data into legible reports for appropriate decision-making support. It is known that any reasonable decision should comply with the objective data, subject to the supervision of knowledge (Brittenham et al., 2001). In this paper we study a competent blood bank information system integrated with a geographical analysis to study the spatial distribution of blood donors, classification of donors and defining blood bank service area using GIS analysis tools and analytical functions.

2. Methods

2.1 Need for Study

India has many blood banks, all-functioning in a decentralized fashion. In the current system, individual hospitals have their own blood banks and there is no interaction between blood banks. Some of the blood banks are attached to hospitals and

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there are some stand-alone private blood banks. As each hospital and private blood bank has its own systems and limitations, co-ordination between the blood banks is practically impossible. The numbers of donors are less when compared to the blood banks and so the efficiency and quality of blood banks is low, resulting in wastage of blood and blood components. An efficient blood bank management system should be developed, with an aim of ensuring every patient access to an adequate quantity of safe blood in a centralized manner. Customer satisfaction is a critical indicator in contemporary enterprise evaluation (Roh et al., 2005). With no exception, a blood bank should dedicate to the enhancement of blood donors' satisfaction and loyalty as well. Such task seems more terrific with regard to the double role of a blood bank: on one side, the blood bank should provide considerate service so as to attract more voluntary blood donors; on the other side, it should guarantee timely, impartial blood supply to blood transfusion facilities. The implementation of GIS based geo statistical analysis for blood bank information systems enables accurate recording and quick response to various user needs, which definitely contributes to the enhancement of customer satisfaction. Nevertheless, by its massive records and superior computation, a blood bank information system can do more to enhance customer satisfaction. The non-profit blood donation and transfusion service, by measuring the number of donors in a particular area using GIS, is a central theme to recruit and retain enough voluntary blood donors. Moreover, a few accessory strategies have been recommended for blood donation promotion, such as encouraging propaganda, interesting souvenirs, and warm donation reminding, etc. However, there is no common strategy for all regions due to social, economic and cultural diversities. Thus, it has been a long tradition of interest in blood donation and transfusion service to analyze the behavior patterns of local blood donors (Sime, 2005), including their distributions and variations.

2.2 Research Issues and Analysis Techniques

GIS has several techniques and functions that can be used for blood donation and transfusion service planning. Each one of these functions can be applied on different blood donation and transfusion related issues. For example, the issue of donor accessibility can be modeled in GIS using simple functions such as buffer function or using spatial analytical functions such as spatial interaction technique (Huff, 1963). Spatial interaction or gravity models estimate the flow of donors between locations in geo-space. Factors can include origin propulsive objects such as the number of donors in residential areas, destination attractiveness variables such as the facilities at blood bank, and proximity relationships between the locations measured in terms such as driving distance or travel time. In addition, the topological, or connective, relationships between areas must be identified, particularly considering the often conflicting relationship between distance and topology. This study has selected three major planning issues and uses GIS for analyzing these issues. The first issue is related to spatial distribution of blood donors. GIS has different tools that can be used for defining any location on the map. One of these tools is called on-screen digitizing which is used by the present study to capture and define spatial distribution of blood donors. MapInfo software is used by the present study, to define all blood donors' location. These data are collected from the city and GIS coverage is digitized on the MapInfo application, using polygon and point-drawing tools that are located on the editor menu. After creating the required city ward polygons, the next step was to enter the collected attributes of blood donors such as name, age–sex and blood group, profession of donor, donation history and type of donor to study the spatial distribution. All of these data are linked to the demand coverage and used for the second issue of this application that is related to the classification of donors with the type of blood, by profession and the number of history of donation. The third main issue of the present application is related to defining the blood bank service area by using spatial interaction model. This issue is covered using three main GIS techniques that are buffer, network and overlay analysis. Buffer analysis is one of the GIS modules facilitates the modeling of spatial futures with a specified zone. This module is used in present study for determining and calculating 15 minute drive time of the donor to reach a blood bank. If there were more blood donors visiting a blood bank in a specific period from an area, it is obviously justified to allocate a mobile blood bank service area to promote blood donation instead of troubling the donors. In general, a network analysis is also used in the system of interconnected linear features, through which resources are transported or communication is achieved. The network data model is an abstract representation of the components and characteristics of real world network systems. The key to produce successful network analysis models is in understanding the relationship between the characteristics of physical network systems and the representation of those characteristics by the elements of the network model.

Network coverage is formed with several elements such as links, nodes, stops and turns. These elements are used together to perform the required GIS functions. One of the important elements that need to be covered before calculating network travel time is called the link impedance. It refers to the cost associated with traversing an entire network link. The present study has calculated travel time for each arc based on the average driving speed along each arc length. The resulted cost is saved as an arc attribute and used during the process of creating drive-time service area of the selected blood bank. The third main GIS analytical technique that is used within the blood bank service area issue is called overlay analysis. This technique is used in different studies and for many purposes (Birkin et al., 1996 and Burns, 1995). Overlay analysis manipulates the spatial data organized in different layers to create combined spatial features according to logical conditions specified in Boolean algebra (Chou, 1997). The logical conditions are specified with operands (data elements) and operators (relationships among data elements). The most well used overall functions are called union, intersect and identity. This study has used the intersect function to analyze distribution of donors which fall inside the created drive-time blood bank service area. This overlay function creates a new output coverage that has only city wards that falls inside blood bank service area. There are several potential uses for overlay analysis functions. One of these uses is related to defining distribution of donors in a selected service area and which is covered by the present study.

3. Results and Discussion

3.1 Using GIS in Blood Bank Information System

This part of the paper presents a GIS application that is created for one private blood bank at Tumkur city. Tumkur is a district place of Karnataka in India. The city has a population of about half a million, 4 allopathic hospitals and 69 private hospitals and there are only six blood banks. One blood bank is attached to the government hospital and the other five are private and community blood banks. As the demand for blood is very high and there is deficit of 40-50 percent of blood as voluntary contribution is only 25 percent. Thus there is a need for widespread of importance of voluntary blood donation with the aim of recruiting, retaining voluntary and recognition of non-remunerated blood donors. We often hear of patients succumbing to their injuries for want of blood. The hospitals blood banks may not be having the required blood and even if it could arrange transfusion, the blood group may not match with that of the patient.

If the blood group happens to be of a very rare type, it is needless to imagine the plight of the person in need of blood. So this can be handled with GIS technique to quickly locate the blood donor of the required blood group nearer to a given blood bank. A prototype system is developed for a blood bank named Sanjeeveni Blood Bank information system (SBIS), which is one of the private premier blood banks in Tumkur, where the system can be specially optimized for blood donation services equipped with many advanced technologies. For example, a computerized decision making support system is designed and two kinds of paradigms are adopted in SBIS: data driven decision support system and quantitative statistical analyses using spatial decision support system. Further, both kinds of decision-making support modules are distributed in SBIS so as to support the decentralized affairs in that blood center. Finally, the decision-making support modules in SBIS provide analytical results and operational suggestions only. Any decision should be validated and approved by the relevant blood bank staff. The created application covers three main demand related issues, which are spatial distribution of donors, classification of donors and defining blood bank service areas.

3.2 Spatial Distribution of Donors

Almost every blood bank has a database about its existing donors and saves such data in different Management Information Systems (MIS). These systems are used for finding needed information about donors' number or recording file and for reviewing the donation history of every donor. The MIS designed for blood bank information system is as shown in Figure 1. One of the main limitations of MIS is related to the lack of their spatial presentation of these data. Blood bank administrators are used to working with MIS but are still not very well aware about the importance of using Spatial Information Systems (SIS) with their donor's data. Many Blood bank managers who were interviewed during the stage of data collection did not realize the benefits of using GIS or SIS in their organizations. Accordingly, the presented study has created a GIS application that can be used as a guide for identifying some of the benefits from using GIS in their blood bank organizations. One of the main issues related to health demand is regarding defining its location within the city. There are several methods that can be used in GIS for identifying location of any feature. For example, a GIS function called geocoding can be used to create points features on a map from a table having x, y coordinates of any addresses.

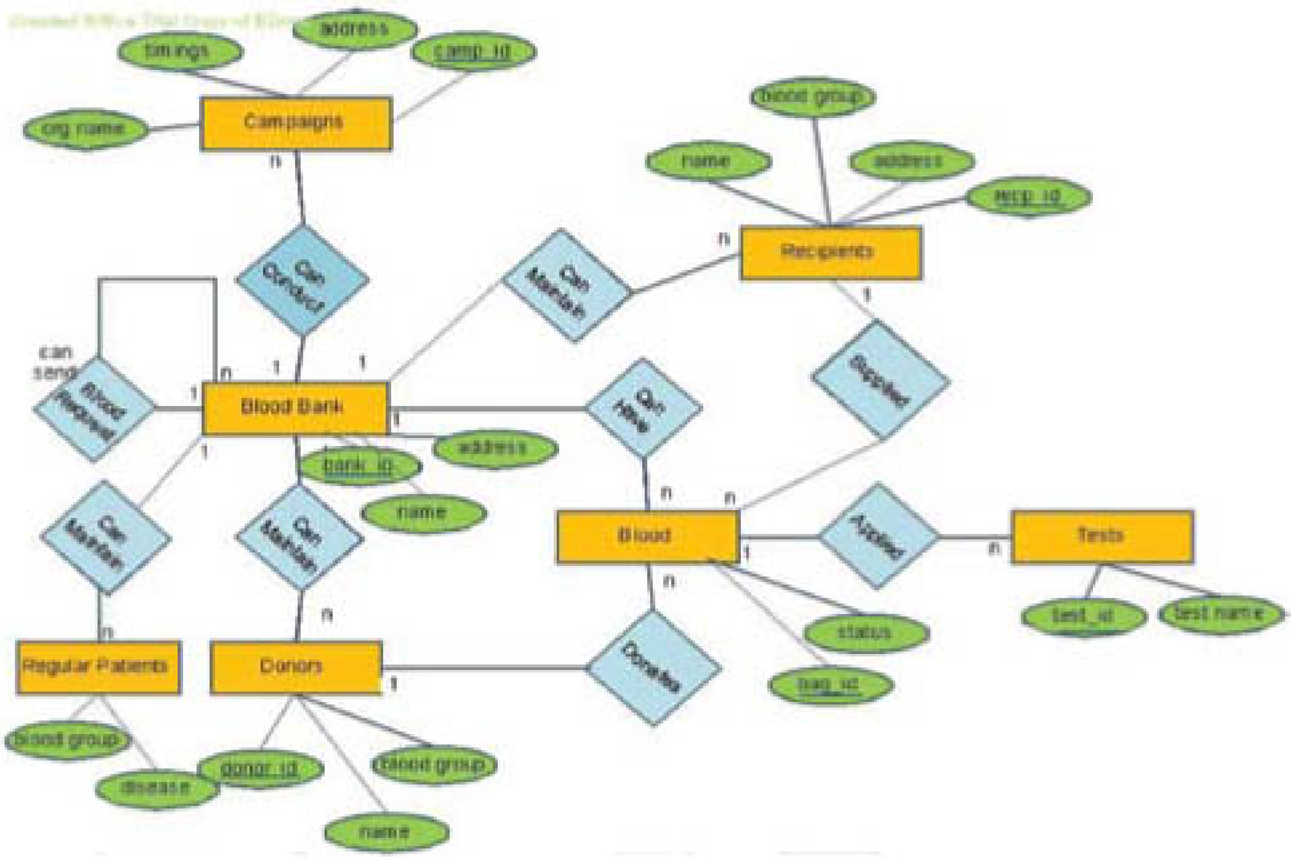

Figure 1: System design of blood bankinformation system

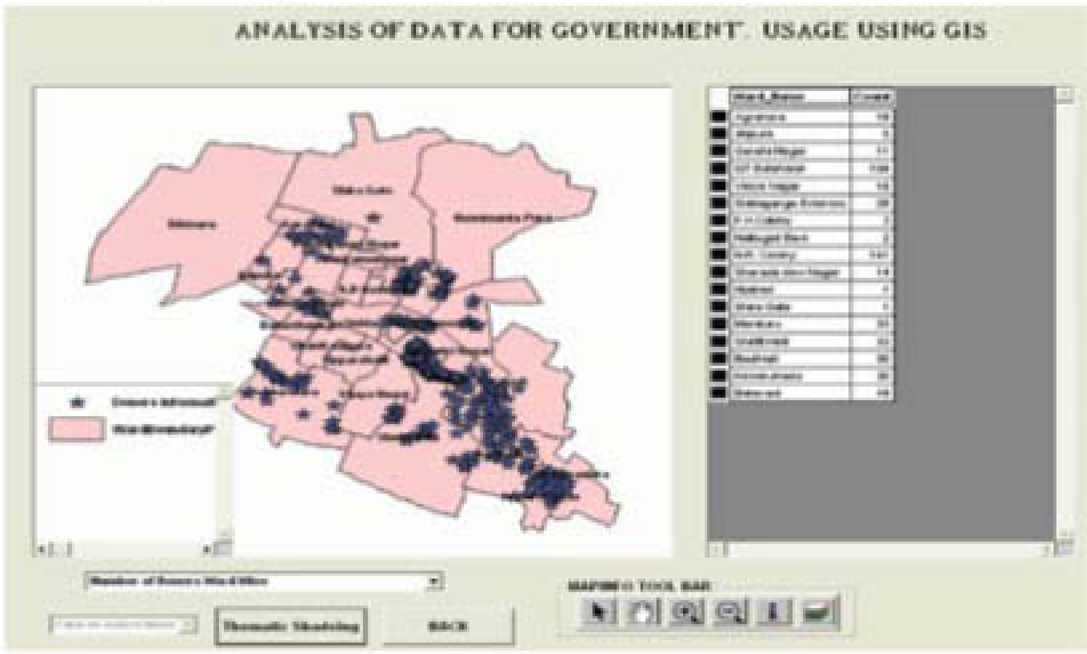

Figure 2: Sanjeevini blood bank donor distributions on Tumkur city map

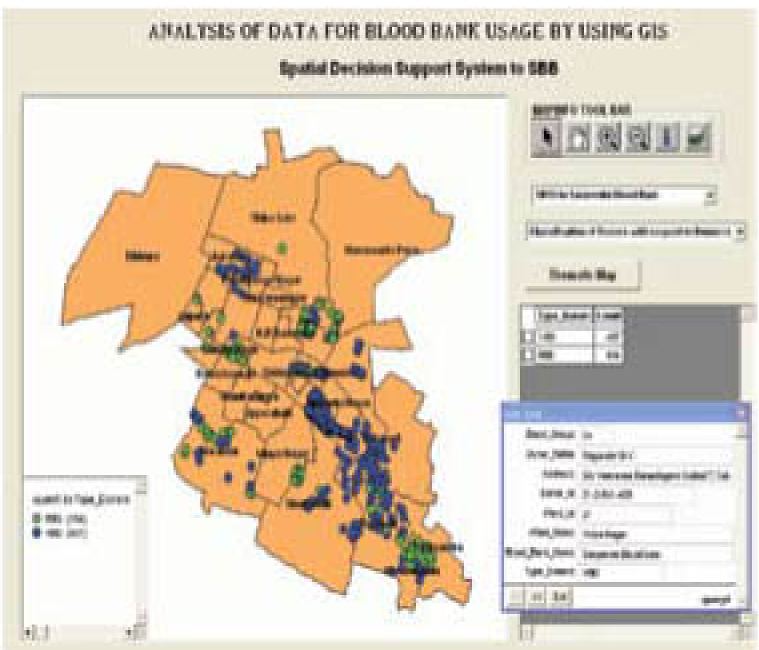

Figure 3: Classification of VBD and RBD blood donors

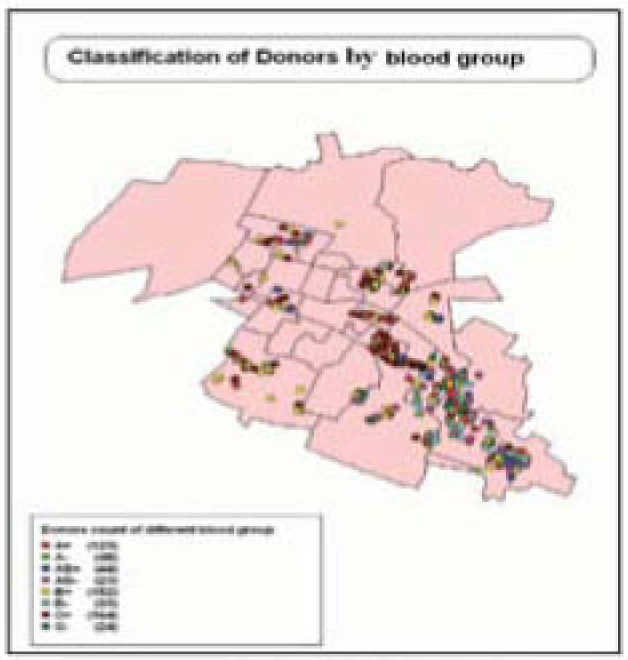

Figure 4: Classification of donors by blood group

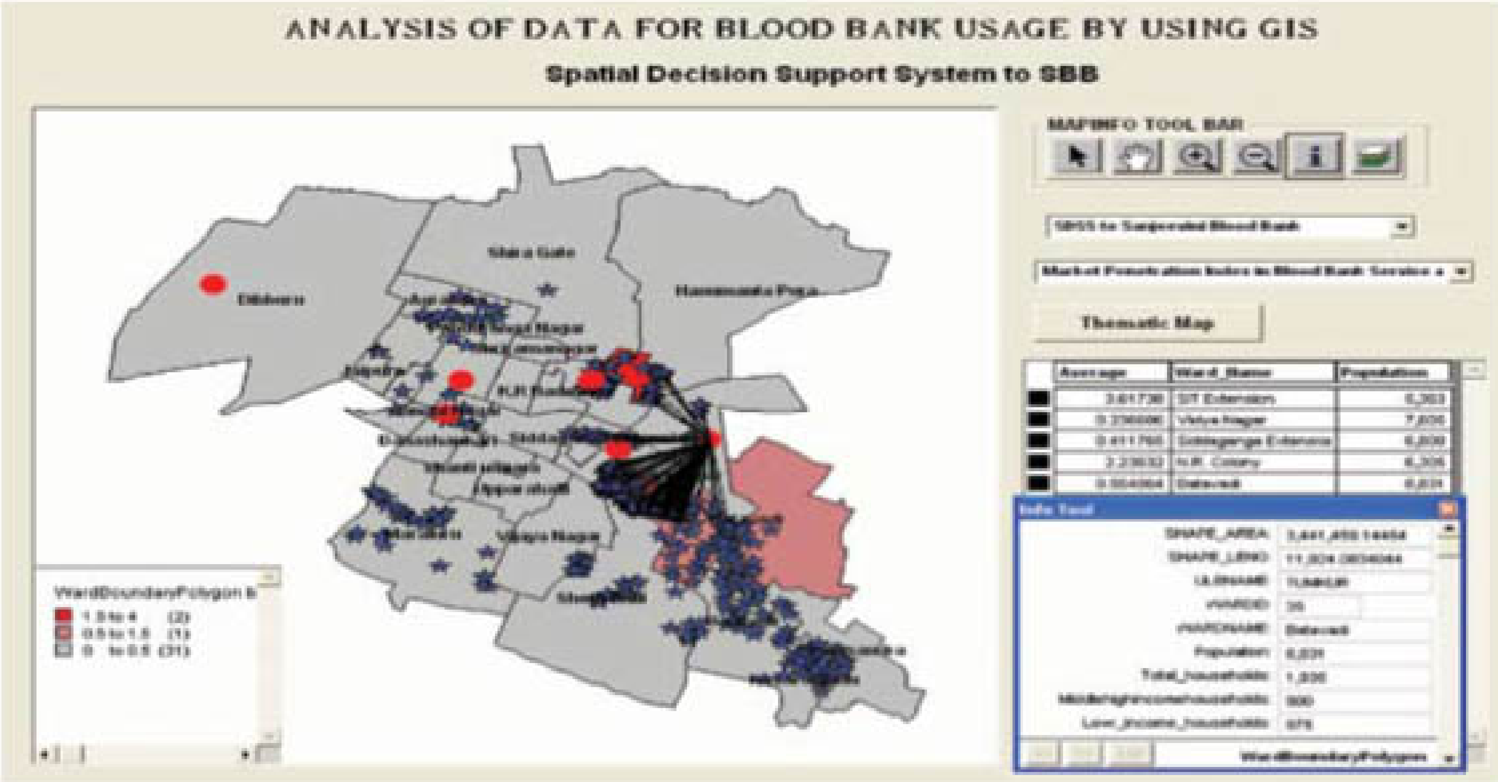

Figure 5: Market penetration index of Sanjeevini blood bank service area

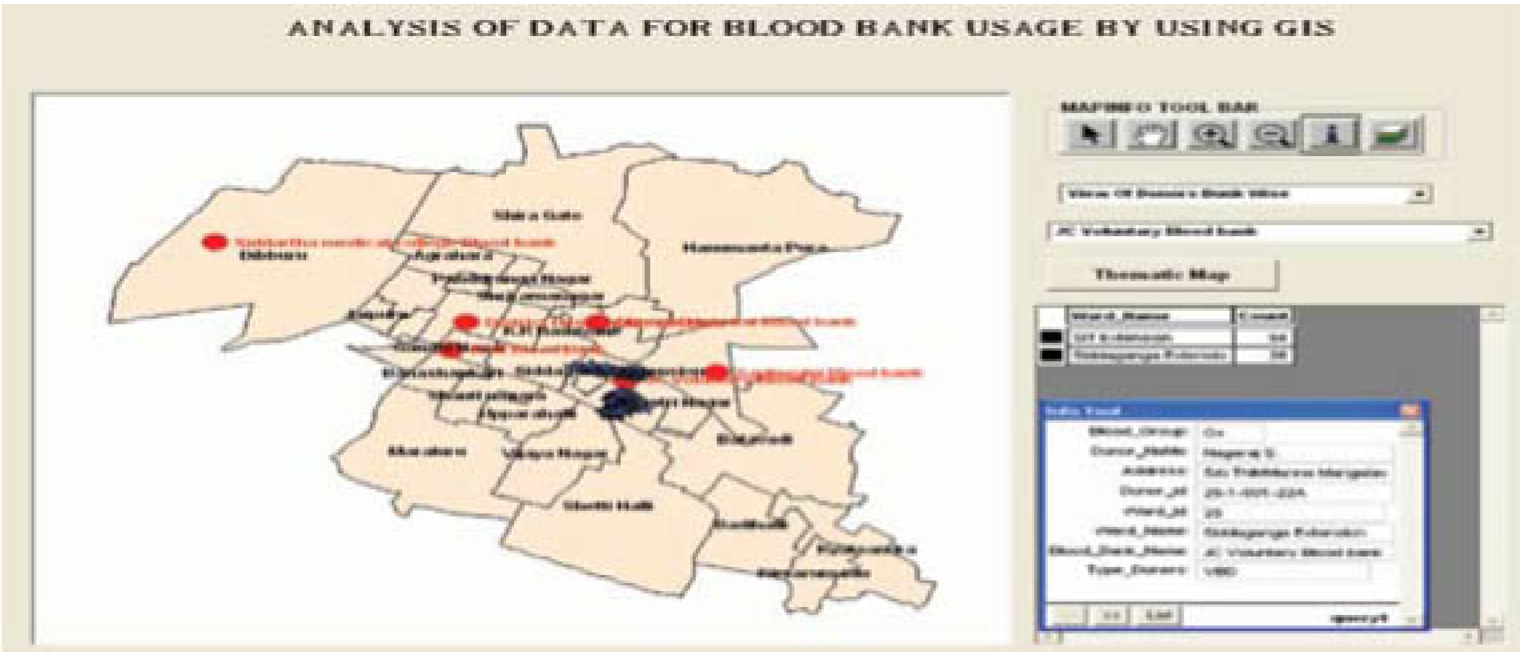

Figure 6: Blood donors of JC voluntary blood bank service area

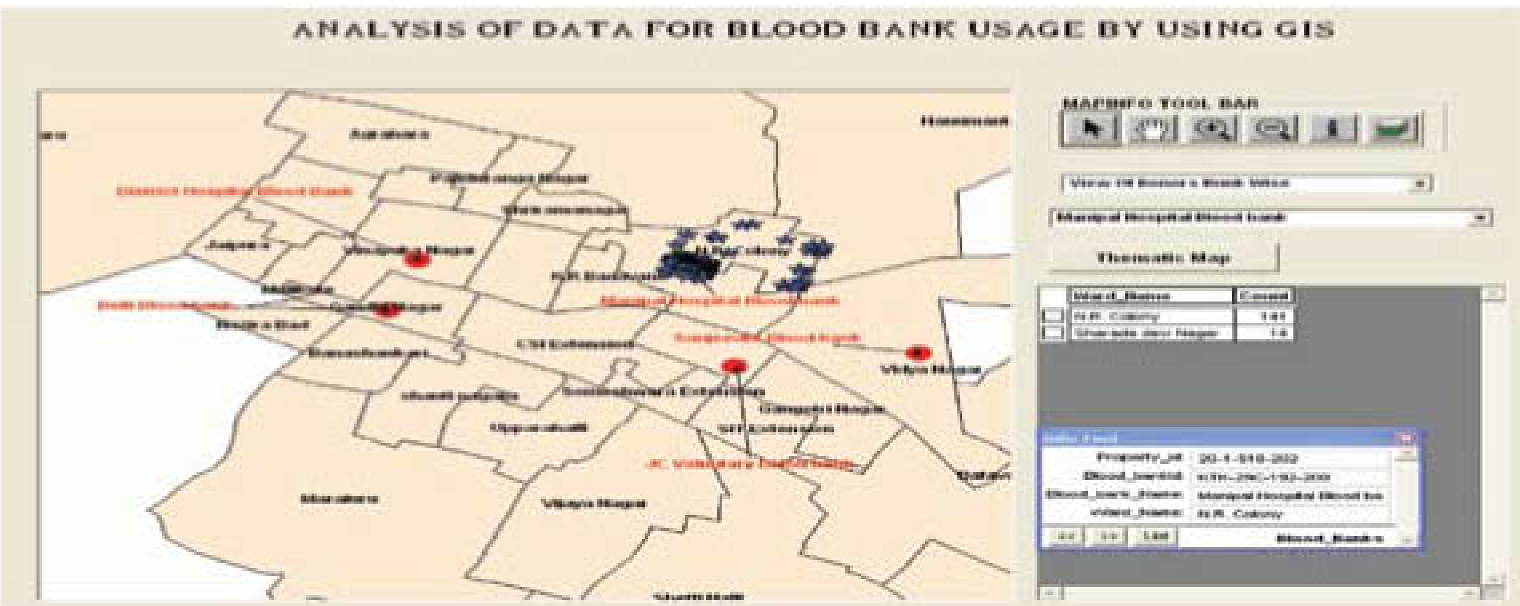

Figure 7: Blood donors of Manipal blood bank service

On-screen digitizing is another GIS function that can be used for data entry purposes. It uses different draw tools such as point, line and polygon tools for identifying feature location. The present study has used this method (on-screen digitizing) for the purpose of identifying donor's location. Therefore, GIS coverage is created for showing location of every ward in the city and then the attribute data of donors is entered as records in the coverage table. After building the database of donors, the next step is to use GIS for identifying spatial distribution of donors. This step is achieved by using the graduated color function that subdivides numerical data into a set of classes. There are five main methods for classifying numerical data in GIS. These are natural breaks classification, defined interval classification, equal interval classification, quantile classification and standard deviation classification (Kang-Tsung, 2008). Each one of these classification methods can be applied on donor data for grouping and subdividing data purposes. The present study has used the natural breaks method that minimizes the variance within class and maximizes the variance between classes (James and Matthews, 1996). Figure 2 shows the resulted donor distribution of the selected blood bank in Tumkur city. One of the main results of this distribution is that donors comes mainly from the wards closer to the blood bank and there are very less donors for this blood bank coming from the other parts of the city. Accordingly, it can be said that this blood bank is not motivating people for blood donation in other parts of the city or there may be less awareness about blood donation.

3.3 Classification of Donors

The present study has created two types of donor's distribution like classification based on type of donors and classification based on different blood groups. The first type of classification divides donors into two main donor groups. These are called Volunteer Blood Donors (VBD), and Replacement Blood Donors (RBD). Each of these groups shows a distribution of two types of donors in the city. For example, a greater percentage of better quality blood comes from volunteer donors. Hence, there is a massive effort under way to recruit this class of donors. Volunteer donors are very important because the incidence of blood transmitted disease is much less in blood drawn from volunteers. The areas in the city with less number of volunteer donors are identified and some promoting programs can be conducted to improve voluntary donations (Glynn et al., 2002). One of the benefits of using GIS with donors' data is related to its ability of showing more than one attribute data in one view (Premasudha et al., 2009). This tool is known as multiple data classification method that lets the user to use two renders at once on a feature layer (Kang-Tsung, 2008). The second classification is based on donors with different blood groups. This helps to find the required grouped donors around the city and it helps to find the nearest required grouped donor from any blood bank or hospital. Figures 3 and 4 show the multiple data views for different donor types and different grouped blood donors respectively.

3.4 Defining Blood Bank Service Area

There are several methods that can be used for defining blood bank service areas. These methods are used by several health studies. For example, Kros and Pang (2004) have used travel time method for defining geographical variation in blood bank use. In Bosnes et al., (2005) presented another interesting study for defining blood bank service area, using, travel time and straight-line techniques (Birkin et al., 1996). All of these studies have concluded that distance to blood bank location is the main factor for identifying blood bank service area. The gravity model and spatial interaction have been modeled like Equation (1) as valid measures for blood bank service area (Haynes and Fotheringham, 1984). These models combine indicators of emissivity, attraction and deterrence in blood bank service area using the following formula:

$$I_{ij} = a\,E_i\,A_j\,C_{ij}$$

Equation 1

Where i denotes origin object (often an area), j denotes a destination object (a blood bank), I^*_{ij} denotes the observed interaction between area i and blood bank j, measured in appropriate units (e.g. numbers of donors, per defined interval of travel time), I_{ij} denotes the interaction predicted by the spatial interaction model, the predicted interactions per interval of travel time will be close in value to the observed interactions each I_{ij} will be close to its corresponding I^*_{ij} , E_i denotes the emissivity of the origin area i, A_j denotes the attraction of the destination area j like facility at blood bank and area of blood bank, C_{ij} denotes the deterrence of the trip between i and j (proximity relationship) and 'a' a constant to be determined. Overlay analysis functions of GIS software can be applied on predefined blood bank service areas to find out the population and blood donors that live inside the defined service area. In order to use these functions, two main GIS coverage should be created which are called the input coverage and the overlay coverage shown in the user interface of Figure 5. The former shows the boundaries of census data and the latter represent the area of interest e.g. 15 minute drive service area. Using these functions, portions of the input coverage that fall inside the overlay coverage will be saved as new output coverage. The GIS overlay functions merge spatial features on separate data layer to create new features from the original coverage. The main difference among these operations is the way in which spatial features are selected for processing. Two main coverages were used to produce these outputs like (1) the 15-minute drive-time service area is obtained by buffer analysis of the above said layers. (2) Blood donors within service area by considering blood bank layer and donor list layer. These two coverages are overlaid using spatial interaction function from Equation (1) to produce a third coverage that has donor's data for city that fall within the defined blood bank service areas. The Equation (1) is applied to Tumkur city map, to study the market penetration index of three blood banks service area index. A user interface designed to select the parts of the city that fall within the 15-min drive time service area of the selected blood banks in Tumkur city are as shown in Figure 5, Figure 6 and Figure 7. The study in Figure 5 shows that the wards like SIT extension are producing more number of donors to Sanjeevini blood bank. Figure 6 shows that the same SIT extension is producing more number of donors to JC voluntary blood bank and Figure 7 shows that N.R Colony is producing more number of donors to Manipal hospital blood bank. It is found that there are 437 donors who use the selected blood banks and live within 15 minute drive time from the blood banks. These donors represent fulfilling 60% of blood bank demand and the other areas that lie within the service area; those that are not producing maximum number of donors, need promotional activities to motivate blood donation. This indicates that donors to the selected blood bank come from the nearest residential areas around the blood bank location. Therefore, the results of the present study reconfirm that distance to blood bank service is the main factor for defining and evaluating donor's accessibility. One of the other possible usages of the resulted travel time service area is related to evaluating the share of donors and the market values of blood bank. This is called market penetration of blood bank services. The present study has defined market penetration rates for the selected blood bank by dividing existing size of donors over number of households living inside blood bank service area and multiplying the result by 100 to get the market penetration index. Figure 5 thematic shading shows market penetration index to Sanjeevini blood bank, which indicates that SIT extension is producing more number of donors while some wards located inside blood bank service areas like Vidyanagar, N.R colony, Siddaganga extension and Batawadi are not producing more number of donors. Blood bank planners and officers should find out the reasons why these nearby wards are not producing the desired donors to the selected blood bank? This can be achieved by a further study in these areas and by testing the residents' views about the selected blood bank.

4. Conclusions

This paper discusses a GIS application to a blood bank facility planning of Tumkur city in India. The application covers three main blood bank issues such as spatial distribution of donors, classification of donors and defining blood bank service area. Each one of these issues has a direct spatial dimension. Therefore, the use of GIS for analyzing and manipulating them was of greater value and benefit. For example, GIS is used to define all donor distribution in the location and produces an output showing city wards that are producing remarkable donors to the selected blood bank. Blood bank planners to define the motivating sessions for people to encourage blood donation can use this output. Classification of donors is another important issue covered by the presented application. Donors are classified based on the blood group and the results of this classification shows city ward such as Vidyanagar is having high O positive donor rates. The classification on donor's type's reveals that more number of donors are from SIT extension the reasons being more number of colleges in that ward and frequent blood donation camps. The third main issue that was focused upon is related to defining blood bank service area. GIS is used to produce a 15-min drive-time service area for the selected three blood banks. This output is used further to define the amount of donors living inside blood bank service area and to test the market share of the selected blood banks. A similar study can be made for any city, after digitizing their city map with the number of blood banks, donors and the population of each ward in the city. This may help in increasing the buffer stocks of all the blood banks by taking some motivation techniques to increase the number of donors throughout the nation.

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