

Adoption of Free Open Source Geographic Information System Solution for Health Sector in Zanzibar Tanzania

Abubakar D. BAKAR^{a,b,1}, Honest C. KIMARO^c, Abu Bakar MD SULTAN^a,
S. HAMIAR^d

^a*Faculty of Computer Science & Information Technology, University Putra
Malaysia, Selangor, Malaysia*

^b*The State University of Zanzibar, Tanzania*

^c*University of Dar Es Salaam, Tanzania*

^d*Zanzibar University, Zanzibar, Tanzania*

Abstract. The study aims at developing in-depth understanding on how Open Source Geographic Information System technology is used to provide solutions for data visualization in the health sector of Zanzibar, Tanzania. The study focuses on implementing the health visualization solutions for the purpose of bridging the gap during the transition period from proprietary software to the Free Open-Source Software using Key Indicator Data System. The developed tool facilitates data integration between the two District Health Information Software versions and hence served as a gateway solution during the transition process. Implementation challenges that include outdated spatial data and the reluctance of the key users in coping with the new Geographical Information System technologies were also identified. Participatory action research and interviews were used in understanding the requirements for the new tool to facilitate the smooth system development for better health service delivery.

Keywords. Free Open source software; geographical information system; health information system; district health information software; participatory research.

Introduction

Computer software is rapidly becoming one of the most deep-seated building blocks of human interaction and their intercommunication [1]. Free Open-source Software (FOSS), in contrary to proprietary software, is a newly fastest growing technology in the recent years. Existing literatures noted that many countries are now adopting the FOSS technologies to avoid the problems of proprietary software [2, 3, 4]. The close-source technology has experienced a numerous criticism of locking clients into a vendor's heavy burden of total cost of ownership [5]. Moreover, literature shows that, the proprietary software also contributes to a suppressing of innovations for software practitioners, especially in the developing world [6]. FOSS, as a software technology innovation that opposed to

¹ Corresponding Author Abubakar Diwani Bakar is a PhD student at the University Putra Malaysia, Faculty of Computer Science, 43400, Serdang, Malaysia. Working at The State University of Zanzibar, Tanzania. Email: cadin25@hotmail.com.

proprietary software, has been reported to dominate all disciplines ranging from health sectors, economy to education [7, 8, 9, 10].

One of the FOSS development innovations is the spatial technology called Geographic Information Systems (GIS). This advancement has been used in different fields of human interaction. In health sectors, GIS has played an important role as a new opportunity for public health administrators to enhance their planning, analysis and monitoring capabilities [11,12,13]. Being proprietary software, GIS technology bears the same disadvantages experienced in the other software-development discipline. The two technologies, FOSS and GIS have contributed in various ways in software-development paradigm. Huang and Mingqing [12] found the knowledge about healthcare systems in the community as an important attribute for their welfare. They concluded that the healthcare aspects highly depend on the knowledge of the healthcare status within their environment. Literatures widely documented that in proper health education, people become more aware of the risks and the prevention of the spread of the diseases. The free GIS technology has also been proven to provide notable advantages for the developing countries where the resources are scarce. Therefore, the area has attracted researchers to work more on integrating the FOSS and GIS technology in order to seize their opportunities [14]. Similarly, Fisher and Myers [15] introduced free GIS in mapping the health indicators for remote area in Indonesia. On the other hand, Vanmeulebrouk et al. [16] used a similar idea in South Africa to track HIV/AIDS information for the local health management. Another successful joint venture of GIS and FOSS was implemented by Tulpan et al. [17] when they developed FOSS-GIS application using Google' map technology to identify clinics and hospitals at one province in Canada.

For the past two decades, many public and private organizations have been on the move to computerize their information systems. Because, the proprietary solution was the only option, they were trapped in adopting this technology [18]. Recently, FOSS technology has emerged as an alternative open ground technology [14]. The technology advocated having many advantages which include embedded capabilities, ability to be integrated with other technology in different contexts and the eager of adopting more advanced technology. Because of the benefits obtained in this innovation, organizations decided to migrate to FOSS technology. This technology transfer from proprietary to FOSS solution is highly recommended in grabbing both the technical and ethical advantages. However, the task faces both practical and theoretical challenges that need to be addressed. Although, the harmonization mission requires efforts and time, especially when the two products are heterogeneous, the transfer is becoming more crucial when dealing with the existing components and data that are needed to be transferred from the old system to the new system.

This paper addresses the data visualization solution proposed during the transition period from DHIS 1.4, which was proprietary, to free open-source software solution DHIS 2.0 and how the proposed GIS solution acted in the middle to bridge the visualization gap between the two systems. Prior to the development of the solution, the study conducted the interviews, participant observation techniques, document reviews and software analysis.

The paper composes of five major sections, excluding the introductory chapter. In section 1, the background of the health information system is presented. The methodology and the context of study are expounded in section 2. The general concept of geographical information system is offered in section 3. The geographic information system solution is

presented in section 4. The dissemination and discussion of the findings are elaborated in section 5. Conclusive remarks are provided in section 6.

1. Health Information System in Zanzibar

Health Information System (HIS) in any country is a practice area in providing specific information to support the decision-making processes for the welfare of its citizens. Better management and the healthcare interventions depend on the availability and the use of comprehensive and easily accessed quality health information. The Ministry of Health Zanzibar, as the responsible body for the healthcare sector for the well-being of Zanzibaris, conducted health sector reform at all levels. Igira et al. [19] explained how Zanzibar's HIS initiatives played a great role in improving healthcare management decisions from lower level to higher level. Through National health strategy, the Ministry of Health Zanzibar put an emphasis on supplying the quality information on a timely basis for different users. This attractive practice encouraged the exchange of information with other related sectors. The Ministry highlighted this movement by enhancing the availability of health information and promoting the culture of Information-based management.

To achieve this strategy, the Ministry computerized HIS by adopting DHIS software version 1.4 from Health Information System Project (HISP) in 2005 [5]. The software solution used for collecting, analyzing and displaying information through excel pivot tables. The DHIS 1.4 adopted was stand alone and proprietary. Therefore, the software experienced a lot of critical problems including the relaying on the Microsoft office package and window platform. These dependent problems lead to incompatibility constrains where the software was not working on different versions of the office package. In solving these crucial problems, HISP introduced FOSS technology in its previous version to produce a new edition called DHIS 2.0. The introduced software shared the same philosophy implemented in DHIS 1.4 though, it was developed using advanced programming and database software. In its front end, Java programming language was used, and MySQL was used as its back end database.

The concern of losing the bulk of information in previous version and fear of new technology among the ministry's management personnel, the ministry was reluctant in shifting from DHIS 1.4 to DHIS 2.0 overnight. Therefore, the Ministry of Health deeply trained its staffs about the functionalities of the earlier version strategically until they were confident enough to migrate to DHIS 2.0. Another notable approach is the initiative of a parallel implementation for the two versions in order to get enough trust in the new system before abandoning the earlier solution. This gave them the courage of engaging in FOSS technology and obviates the concepts of rigidity and misconception on the difficulties of newly technology adoption.

2. Methods and Settings

The research aimed at solving a practical problem of data visualization in the Health sector of Zanzibar. The solution was implemented after the gathering of enough information. Interviews, participants' observations, documents review and software analysis were used in this study. The information gathered using these qualitative approaches helped in gaining the insight of the existing systems and the flow of information within and outside the ministry. The information was based on the researchers' participation in the action research project under the HISP project as local consultants at the Ministry of Health Zanzibar. Apart from researchers' involvement in the Ministry of Health information system unit, the study was also part of principal researcher's fulfillment for Master of Science from 2007 to 2010.

The study interviewed stakeholders from different sections of the Ministry of Health by asking open-ended questions to obtain their viewpoints related to the Health Information System (HIS) reporting processes. Table 1 show the illustration of twenty eight (28) informants who were interviewed across the ministry. DHIS users, HMIS officials and technical experts from HISP teams were the type of informants interviewed. The views of the program managers and other staffs in regards to the reporting flow and format were gathered and analyzed in order to acquire clear requirements for the developed system.

Table 1. DHIS and non-DHIS users interviewed

Types of respondents	Number of interviewees
DHMTs	10
EPI Program	4
Ministry of health headquarter	4
HISP team members	4
RCH Program	3
HIV and AIDS Program	1
Malaria Program	2

As part of the HISP consultancy team, researchers conducted numbers of discussions with various stakeholders and solved the problems reported from all levels of the ministry. The researchers also conducted on-job trainings to different stakeholders within and outside the ministry as part of their job description. That in turn created a feeling of trust between the health workers and the researchers, and thus helped in extracting more information needed.

The documents and written materials helped in understanding more about a ministry hierarchy in order to set proper information flow within and outside the ministry and other related institutions. Furthermore, the researchers participated in a number of meetings, such as data use workshops, quarterly feedback meeting and other managerial meetings that were conducted within the ministry departments. In these gatherings, top management of the ministry and its allied health programs discussed the reports from all districts presented by the district health officers.

For the technical part of the study, Open Source software, Key Indicator Database Systems (KIDS) and Java development kits were used as the framework to design the tool. KIDS is recommended tool advocated by the United Nations body for Food and

Agricultural Organization (FAO) to capture the spatial information for livestock. Java on the other side is the most popular free and open-web programming in the software world. It has gained a lot of credits in developing sophisticated web application. Currently, millions of devices run Java applications.

3. Free and Open Source Geographic Information System

In recent years, the importance of FOSS in a different field of an information system has inspired the GIS technology [20, 21]. FOSS in GIS has been granted many advantages in the software development paradigm. The availability of code gives self-supports and the possibility to modify the FOSS to increase the applicability and compatibility. The features enable the development of more applications at different context. Literatures provided detailed information on how the open-source GIS can be adopted with easy interoperability with other application domains [22]. To elaborate the needs and impact of the two technologies, the following subsections present a detailed analysis of FOSS-GIS health information system globally, with particular reference to the Zanzibar context.

3.1 Geographic Information System (GIS) in Health

It is explained that most of the health data have relation with the spatial geographic component. Johnson [23] identified the vast majority of health data explicitly relate to human activity. Since humans exist within a spatial structure, moving from one place to another, intermingling with themselves and their interaction within the environment, thus the spatial distribution is an important factor in understanding the mechanisms of public health issues. The matters include the spreading of diseases and services utilization to the communities. Many problems within the health sector are related to the epidemiological questions 'where' and 'when'. The questions around "where" are location-based and those for 'when' are timely-based and can be effectively answered based on spatial information. Spatial analysis and mapping in epidemiology have a long history, though there are still limited uses in public health regardless of the important role that can be played with GIS technology.

Through GIS technology, health providers and managers can easily understand the location in the risk community, geographic dimension, and distribution of factors related to disease dispersion and service availability. This helps the timeliness of interventions, and thus, improves the quality of service provision [24, 25]. The GIS implemented in this study not only contextualized the GIS-FOSS in Zanzibar but also promoted health awareness to the community about the availability, use and benefits of spatial data within the health sector.

3.2 FOSS Geographic information system in Health: Zanzibar context

GIS technology seemed to have a great impact on health sectors. This is because of the diversity of health data that are based upon geographical location. This work seized

practical advantages by introducing a GIS system in the Zanzibar health information system. Zanzibar, like other low-income countries, is engaged in FOSS to reduce the total costs of ownership and to be benefited by free support from the diversity of FOSS community as well as free codes that enabling self-supports. The technology also solved the institutional problems of budgeting deficits, low capacity and lack of knowledgeable expertise [26, 27]. Using a new GIS tool developed, the ministry managed to introduce GIS technology in its visualization with few available staffs and zero cost in its implementation.

3.3 Geographical Information System Solution in Health Sectors of Zanzibar

Any object that is made by humans, its quality is highly depended on the designing. A design involves an analysis, developing and generating possible courses of action, and provides detailed specifications for system components, structure and their features. In ensuring the achievement of the desired goal of the system, a careful analysis of what the system need is important. The study employed the exhaustive participation to reach many users and other stakeholders in order to gain more suitable and enough requirements for the system. The design considered the openness of the system by accommodating the HMIS technical staffs in engaging themselves during the development of the system. The participatory approach made the designing of the systems to be easily understood by the HMIS technicians and other stakeholders. Additional advantage is the fact that the technical personnel at HMIS have been trained on how the tool operates and how to deal with system faults. The strategy ensured the sustainability of the system when it is handled to the ministry.

Figure 1 illustrates the architectural design of the development tool. This GIS tool using Kids was designed to extract data from both parallel databases implemented. The tool mines the data from the Microsoft Access database used in DHIS 1.4 and MySQL database used by DHIS 2.0. The reports are then generated through a map based. It then projects the values based upon the color set in the database.

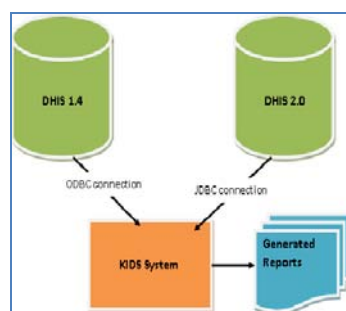


Figure 1. Zanzibar GIS data visualization model

4. Findings and Discussions

The main objective of this participatory action research was to develop an open-source and web GIS based data visualization tool to facilitate timely processing and sharing of

information from the ministry of health, Zanzibar. Prior to the development of proposed tool, researchers conducted qualitative data collection. The goal was to gather impressions and perceptions of the health stakeholders in relation to the software systems, which ultimately helped the researchers to learn more challenges that impose the integration processes of the tools.

The data collection practice also helped to create the ownership perceptions for the practitioners. In this case, the stakeholders felt like they were involved in the introduction of the new solution. Apart from the idea of bringing the practitioners' closure and feel familiar with the developed system, those pre-requisites for software development process have been mentioned as the top secret of the successful software development. Scacchi [28] identified the inclusion of the community in order to understand their needs are among the key factors in the achievement of the quality software development. Moreover, this technique of gathering information saves time and resources during the maintenance phase. It also broadens the outlook of the developers in informing the understanding through the exploration from more diverse sources.

The following list outlined some of the useful information gathered during the research:

- Practitioners generated information based on Microsoft Excel pivot tables.
- There was a lack of flexibility as the reports were based on ready made Microsoft Excel templates. This caused troubles whereby managers could sometimes request reports that do not match to the standard of the reports employed within the system (built in reports).
- Inconsistency was also observed during the feedback and data use meetings where data reported from the districts differed with those reported from National level. This was the critical scenario as the data comes from the same source.
- Lack of feedback from upper levels was a major concern. Feedback is considered to be the key concepts of self-analysis. Through the comments from the upper level, practitioners at the lower level can get a chance to make corrections as well as to see the performance of their efforts.
- The problems of flexibility, inconsistency and lack of feedback were also mentioned by the top managements from the ministry and their allied health programs. They complained the reports extracted from them are entrusted as the errors appear in the lower level can cascade up and amplified through the whole system.

Thus, the effective information gathered is used as an input into the development of the tool. Together with the researchers' experience, the information collected is used as the requirements for the development of the system. The tool has brought about the solutions in the health field where the two rival technologies of FOSS and proprietary works together. The study also introduced a visualization solution for the strategic migration from proprietary to FOSS. The GIS solution bridged the visualization gap by generating the reports from the old and the new versions of DHIS. Long term information comparisons and trends are an important source of health analysis in terms of diagnosis trends and consistency of health services. The study showed the direction on how the practitioners can deal with the ethical and technological situation when they wanted to move from one solution to another especially heterogeneous solution.

Being in the center of both systems, the tool generates reports from either version of the software based on the users' location and demand. This helps the health practitioners to visualize map-based reports regardless of the location they are, which is the basic principle of health activities. Together with another source of non-spatial data (in our case DHIS) the tools jointly provided an excellent and sustainable health information system that enabled all health workers to use their own information, to improve the coverages and providing the quality of healthcare of the communities. For example, the health managers in one district can produce maps-based on health facilities location to support real time intervention for a particular place. Figure 2 shows the generated map of one of the Zanzibar Islands. It projects the antenatal first visit before twenty weeks indicator for each health facility. The color indicates the prevalence in a district wise.

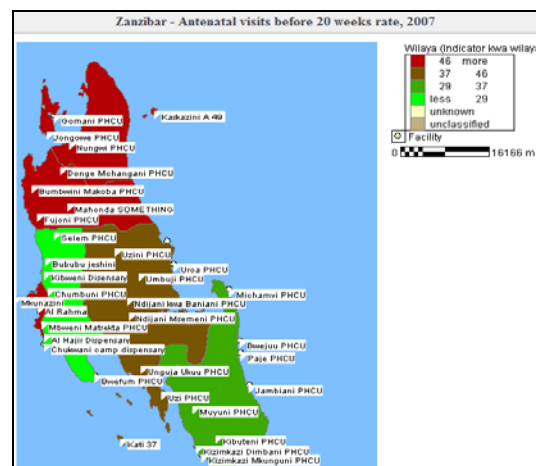


Figure 2. The Unguja Island map generated by the tool

two zones (Unguja and Pemba). This fragmentation was also the source of the problems when the ministry wanted to compile health data for the whole country. In the GIS reporting tool, the system was integrated with both databases regardless of the differences in hierarchical levels.

For the developing countries like Tanzania, the study has two-folded intuitions. The first advantage is the adoption of the GIS in health sectors. The second benefit is through integration of two rival technologies whereby the study managed to use the GIS as a mediator to ensure the two rival technologies communicate to each other. The integration into the OSS systems may help the organizations from the developing countries to have ideas on how to design and implement processes prior migration. The processes include data replication and synchronization, data cleaning and transformation, and controlling and data management. These are more beneficiaries especially in the third world countries where public and private organizations have been locked-in proprietary policies. This study found that, it is possible to migrate into OSS technology without fearing to lose the information from the previous proprietary software system.

Although, the study has shown potentials of solving problems related to costs, time and availability in health sectors, especially in the field of health [32, 33, 34], numerous challenges were identified. Availability of spatial data and the ability of other staffs to cope with the new technology were among the major challenges during the implementation. The systems used spatial co-ordinates of health facilities and hospitals on which some latest introduced health facilities were not included in the spatial repository. Lack of enough qualified staffs in the ministry who can work in both health and IT technology was also another hindrance to achieving the greatest success. In addition to that, most of the staffs were either medico phobia or IT phobia.

5. Conclusions

This study addressed the problem of HIS in Zanzibar, Tanzania. The context is the health sector of Zanzibar, Tanzania and the study advocates for FOSS-GIS technology in bridging the visualization gap during the transitional shifting from proprietary to platform independent open-source technology.

Practically, the research contributed towards the development and implementation of web-based and GIS data visualization tools using KIDS, that was integrated to two systems with different technologies and architecture. Theoretically, the fact that the tool fetched data from both versions, means the data from the two different software technologies were integrated at the presentation layer and merged regardless of the level they are collected.

Finally, while quality data are the key for information-driven management systems, the benefits available from the tools developed are not meant only to provide information to more appropriate approach using free technology but to promote information use thereby ensuring the timely and without border information availability. This is tantamount to encourage the information-use to assess and give an appropriate feedback to improve the quality of data collected and quality of the healthcare services in general. Lastly, the study considered the use of GIS technology and managerial strategies in the health information system development.

References

- [1] M. Klang, Free Software and Open Source: The Freedom Debate and its Consequences, *First Monday Report*, **10** (2005), 5-11.
- [2] A. Bullinger, M. Rass, S. Adamczyk, S. Moeslein, Open Innovation in Health Care: Analysis of an Open Health Platform. *Health Policy*, **105** (2012), 165-175.
- [3] W. Raghupathy, W. Gao, An Eclipse-based Development Approach to Health Information Technology, *International Journal of Electronic Healthcare*, **3** (2007), 433-452.
- [4] S. Nagaraj, Open IT: Government to Rewrite Source Code in Linux, *Open IT report*. New Delhi, 2002.
- [5] J. Lungo, H. Twaakiondo, Open Source Software in Health Information Systems: Opportunities and Challenges, *E-health*, (2007) 1-6, Helena. Bamako.
- [6] P. Chikumba, N. Kaunda, Geographic Information System as a Tool for Integration of District Health Information System and Drug Logistics Management Information System in Malawi, *E-Infrastructure and e-Services for Developing Countries*, **92** (2012), 125-134.
- [7] M. Tsou, J. Smith, *Free and Open Source Software for GIS Education*. A White Paper. National Geospatial Technology Center of Excellence - GeoTech Center, (2011).
- [8] E. Poizot, Y. Mear, Using a GIS to Enhance Grain Size Trend Analysis, *Environmental Modeling & Software*, **25**, (2010) 513-525.
- [9] J. Bitzer, W. Schrettl, P. J. Schröder, Intrinsic Motivation in Open Source Software Development, *Journal of Comparative Economics*, **35** (2007), 160-169.
- [10] M. Oliveira, G. Bevan, Measuring Geographic Inequities in the Portuguese Health Care System. An Estimation of Hospital Care Needs. *Health Policy*, **66** (2003), 277-293.
- [11] Z. Omary, D. Lupiana, F. Mtenzi, W. Bing, Analysis of the Challenges Affecting E-healthcare Adoption in Developing Countries: A Case of Tanzania. *International Journal of Information Studies*, **2** (2010), 38-50.
- [12] K. Huang, Y. Mingqing, GIS-Based Environmental Health Management Information System, *Environmental Science and Information Application Technology*, **3** (2010), 85-87.
- [13] M. Riner, C. Cunningham, A. Johnson, Public Health Education and Practice Using Geographic Information System Technology, *Public Health Nursing*, **21** (2004), 57-65.
- [14] A. Bakar, Y. Sheikh, B. Sultan, Opportunities and Challenges of Open Source Software Integration in Developing Countries: Case of Zanzibar Health Sector, *Journal of Health Informatics in Developing Countries*, **6** (2012), 443-453.
- [15] R. P. Fisher, B. A. Myers, Free and Simple GIS as Appropriate for Health Mapping in a Low Resource Setting: A Case Study in Eastern Indonesia, *International Journal of Health Geographics*, **10** (2011), 1-15.
- [16] B. Vanmeulebrouk, U. Rivett, A. Ricketts, M. Loudon, Open Source GIS for HIV/AIDS Management. *International Journal of Health Geographics*, **7**, (2008), 53-59.
- [17] D. Tulpan, M. Mancuso, G. Durand, C. Regoui, L. Belliveau, CliFin: A Web-Based Geographical Information System for Time Dependent Point of Care Localization in New Brunswick, Canada, *International Journal of Healthcare Information Systems and Informatics*, **7** (2012), 32-47.
- [18] E. NYELLA, Challenges in Health Information Systems Integration: Zanzibar Experience, *Journal of Health Informatics in developing Countries*, **5** (2011), 1-14.
- [19] F. Igira, O. Titlestad, J. Lungo, M. Makungu, M. Khamis, Designing and Implementing Hospital Management Information Systems in Developing Countries: Case Studies from Tanzania-Zanzibar, *Health Informatics in Africa (HELINA) 2007*.
- [20] M. Jolma, D. Ames, N. Horning, Free and Open-source Geospatial Tools for Environmental Modeling and Management. *Environmental Modeling, Software and Decision Support*, (2008), 163-180. Amsterdam.
- [21] F. Donnelly, Evaluating Open Source GIS for Libraries, *Library High Technology*, **28** (2012), 131-151.
- [22] E. Steiniger, A. Hunter, Geospatial Free and Open Source Software 247, *In the 21st Century, Lecture Notes in Geoinformation and Cartography*, (2012), 47-261. Springer-Verlag Berlin Heidelberg.
- [23] C. Johnson, J. Johnson, GIS: A Tool for Monitoring and Management of Epidemics. *Map India Conference 2001*. New Delhi, Pune University Campus.
- [24] P. S. Singh, D. Chutia, S. Sudhakar, Development of a Web Based GIS Application for Spatial Natural Resources Information System Using Effective Open Source Software and Standards, *Journal of Geographic Information System*, **4** (2012), 261-266.
- [25] Z. Saugene, E. Makome, Challenges, Opportunities and Strategies of Implementing GIS for Public Health Management in Mozambique. *At HELINA Conference, January 9-12, 2007*. Bamako, Mali, highlighted in SDI-Africa.
- [26] J. Lungo, Y. Kaasbøl, Experience of Open Source Software in Institutions: Cases from Tanzania and Norway. *Proceedings of the 9th International Conference on Social Implications of Computers in Developing Countries* (2007). São Paulo, Brazil.

- [27] A. Longley, F. Michael, M. David, W. Rhind, Geographic Information Systems and Science. John Wiley & Sons, West Sussex, England, (2005).
- [28] W. Scacchi, Understanding the Requirements for Developing Open Source Software Systems. *IEE Proceedings--Software*, **149** (2002), 24-39.
- [29] Z. Zhen, J. Jing-min, L. Fang, The Application of Geographic Information System (GIS) in the Field of Public Health. *A Second IITA International Conference on Geosciences and Remote Sensing, GRS2010*, (2010), 442-445.
- [30] C. Pearce, M. Arnold, C. Phillips, S. Trumble, K. Dwan, The Many Faces of the Computer: An Analysis of Clinical Software in the Primary Care Consultation, *International Journal of Medical Informatics*, **81** (2012), 475–484.
- [31] B. Perera, E. Kruger, M. Tennant, GIS as a Decision Support Tool in Health Informatics: Spatial Analysis of Public Dental Care Services in Sri Lanka, *Journal of Health Informatics in Developing Countries*, **6** (2013), 422-433.