Proceedings of the IASTED African Conference
HEALTH INFORMATICS (AfricaHI 2010)
September 6-8, 2010 Gaborone, Botswana

GIS TAILORED QUESTIONNAIRES FOR ASSISTING HEALTH CARE MANAGEMENT IN DISTRIBUTING RESOURCES

Marlien Herselman (Meraka Institute, CSIR, South Africa & Nelson Mandela Metropolitan University, Faculty of Engineering, the Built Environment and IT, School of ICT, Port Elizabeth, South Africa, mherselman@csir.co.za)

Engelbert Niehaus (University of Koblenz-Landau, Campus Landau, Fortstr 7, 76829, Landua i.d. Pfalz, Germany, niehaus@uni-landau.de)

Nkqubela Ruxwana (Nelson Mandela Metropolitan University, Faculty of Engineering, the Built Environment and IT, School of ICT, Summerstrand, Port Elizabeth, South Africa, nkqubz@yahoo.co.uk)

Patricia D'Souza-Niehaus (University of Koblenz-Landau, Campus Landau, Fortstr 7, 76829, Landua i.d. Pfalz, Germany,niehausbert@gmx.de)

Nora Heyne (University of Koblenz-Landau, Campus Landau, Fortstr 7, 76829, Landua i.d. Pfalz, Germany, heyne@uni-landua.de)

Melanie Platz (University of Koblenz-Landau, Campus Landau, Fortstr 7, 76829, Landua i.d. Pfalz, Germany, platz@groupewaremath.uni-landua.de)

Ralf Wagner (University of Koblenz-Landau, Campus Landau, Fortstr 7, 76829, Landua i.d. Pfalz, Germany, wagner@groupewaremath.uni-landua.de

ABSTRACT
A tailored questionnaire focuses on dynamic generation of items and questions according to the location where the questionnaire is used. The approach is connected to the management of resources and the support of decision making processes which is based on collecting data for a certain geographical region. The article shows how Geographic Information Systems (GIS) can be used to tailor a questionnaire to match the risk and demands of specific areas where the questionnaire will be applied. The GIS based generation of a questionnaire is used to provide tailored information for informed decision making in health care systems. Resource Management can only be optimized if the ICT-based representation is based on tailored information according to the area in which the process of optimization should be performed. Areas with a lack of resources and with heterogeneous environmental and social conditions should get a tailored response based on tailored information, which can be provided by this type of questionnaire. The article will show how mathematical modeling can be applied to an appropriate temporal and spatial generation of questionnaires for deployment of human and medical resources according to risk and demand in rural health care.

KEY WORDS
Geographic Information System (GIS) and GIS Tailored Questionnaire (GIST-Q), Resource Management System (RMS), decision support system, Health care Management, mathematical modeling.

1. Introduction

Geographic Information System tailored questionnaires (GIST-Q) can best be explained by using a question as an example: “How many people are suffering from malaria in this area?”. This question makes sense in areas in rural communities in South Africa, but it does not make sense to ask this question to a group of researchers located close to the South Pole. Heterogeneous environmental, economical and social conditions differ in space and time. Thus, the mathematical concept of GIST-Q derives the priority to ask certain questions which is based on GIS information.

Information Communication Technologies (ICT)s are increasingly playing a crucial role in most communities' capacities to produce, access, adapt and apply information and thus offer enormous opportunities for facilitating the transfer and acquisition of knowledge [1]. They present (at least theoretically) a promising potential to lead developing countries into the ‘highways’ of development. [2;3]. According to Ruxwana [1] the “Modern ICTs drive the worldwide economic system and the process of globalisation. In this process we see enormous growth worldwide with opportunities for overcoming poverty and promoting human rights but also with major threats to sustainability and to social justice".

This rapid evolution and the potentials which ICT's can offer have been realized in the world and many organizations and individuals have used them as weapons for competitive advantage to improve their quality of life, as well as a way of reducing cost, while rapidly meeting the information needs of organizations and those individuals that use them. On the other hand, developing countries are seeing the ICT potentials as a possible vehicle to bridge the digital divide as well as a medium for socio-economic development. ICTs are viewed to have capabilities that create new economic, social and political opportunities for developing countries and the poor [4;5].

The potential and capabilities of ICTs have further been recognized as a vehicle that can be adopted for rural development, especially improving the health care system which directly impacts the health care of the people in rural areas. The potential and capabilities of ICTs to enhance development for those who effectively use them has lead to an exaggerated lure and increased rush in implementing ICT solutions , especially in the developing countries which are faced with several challenges, with the hope to achieve their full benefits. This has been proven by the increased budget for ICTs and several projects that attempts to adopt ICTs in order to gain socio-economic development, competitive advantage, effectiveness, and to some extent to overcome challenges faced.

In South Africa the majority of its citizens are living in rural areas and many ICT related solutions are promised to harness development especially in the health care sector. This sector has challenges ranging from disease pandemic, shortage of skilled healthcare professionals and poor service delivery and several ICT health care projects or e-health projects are launched with the aim to enhance service delivery, reduce cost and improve quality of care. However, the majority of these projects attempts to reduce costs by eliminating medical errors or unnecessary transferring patients or to improve service delivery by mitigating the lacking health care skills, promoting skills transfer, and reduced time to serve the patients. Furthermore some solutions aim to support health care service related decision making, from the health care staff to the health care management. Thus, there are an increasing number of e-health solutions projects, such as HIS, DHIS, EMR/EHR, telemedicine, that aim to achieve such benefits [6].

However, the movement supporting the rural communities is under pressure to improve service delivery but with the deadlock of several challenges and with the views that ICTs are the solutions to some problems, they adopt solutions hoping for a real resolution to the many existing problems. To some extent these ICT projects fail or partially resolve the problems [1].

These failures may be due to several elements, such as those relating to the correct requirement, limited user involvement or purely because the solution adopted was not the correct solution for the problem as this solution is not tailored to the demands, needs and prerequisites of the rural communities. In rural hospitals some solutions are provided with the aim of resolving many of the challenges but those solutions are not used, not necessarily because they are not functioning, but they were not the required solution for the problem. Therefore it is important to recognize that ICTs cannot replace human resources even if e-health solutions have the potential to overcome challenges of the health care sector in rural hospitals. Solutions alone will still not deliver quality health care services; hence the shortage of skills is still a challenge in rural health care and it directly influences the application and maintenance of resources that are dependent on the skills of people living the rural areas.

With this challenge where many problems have to be solved with limited resources, the health care management is faced with the challenge of making decisions that at times are based on assumptions. Capital cannot be wasted due to its limited availability when the health care management are making decisions on whether to deploy an e-health solution or a human resource to resolve the problem at a specific health care centre. This paper suggest that the consideration of tailored data acquisition via questionnaires can results in a tailored distribution of resources via Resource Management Systems that will facilitate informed decision making to the health care management in making resource related decisions. Whether the best solution is to make use of a human resource, an e-heath solution and/or medical equipment deployment at a rural health care centre in times of need can be provided by the questionnaire results.

This proposed GIST-Q becomes even more important when time constraints are considered and to limit questions in a questionnaire to focus on that information which is relevant to a specific geographic location. Priority to resources is linked to specific questions based on relevance of these to solve a problem.

A GIS based representation of available and non-available information allows for tailoring a questionnaire spatially to the location in which the questionnaire is used.

The main objective is to deploy inefficiently used or idle resources in one health care centre to be applied in another health care centre where a greater need exist.

2. Background and methodology

The study involves a collaboration of research done in Germany and in South Africa. In Germany the Resource Management System (RMS) prototype has been developed, using certain algorithms which are linked to the use of medical equipment within a specific clinic. In South Africa a feasibility study was conducted where a questionnaire was developed to test the use of certain questions within a possible GIST-Q within a rural setting. The aim of the study in South Africa was to better understand how ICTs can be used more effectively to improve the health system in a selected number of rural Eastern Cape health care centers and to make recommendations for their implementation. The use and implementation of ICTs in five rural hospitals in the Eastern Cape Province were determined through the application of multiple case studies as a methodology. This is a type of qualitative research design whereby the researcher investigates a chain of single entities, phenomena or cases confined by time and activity and collects detailed information by using a variety of data collection procedures during a sustained period of time [7].

Data was collected through the use of interviews, observation, and questionnaires. GIST-Q is contributing to the optimization of data collection tailored to the location where the questionnaire is used.

2.1 Participants

A total of 56 people were interviewed in five different rural health care centers across the Eastern Cape Province in South Africa, 38 of whom had completed a questionnaire prior to interview. Participants were grouped into three categories: (a) hospital managers, (b) staff (doctors, nurses and administration clerks/personnel), and (c) hospital inpatients at the time of data collection. More detail on the outcomes of this study can be found in the Health Information Management Journal Vol 39, No 1, 2010 [8]

The question list that was developed from this study made it possible to link various questions to various resources where they are located in specific hospitals. A similar study was conducted of Germany in a one specific hospital to determine where a resource is located and how it can be linked to a specific question based on its need at a specific point in time. This information allowed the German researchers to apply secondary sources and mathematical models to adapt the concept from Germany to address the complexities of the rural health care centers in the Eastern Cape Province and via versa.

The consideration of sustainability by application of integrated logistic support principles to deliver health services as described by [9] start with the precondition that the available resources do not meet the requirements and that there are not enough resources to provide the health care. If resources are available, they can sometimes not be appropriate or not applicable for rural communities conditions.

The GIST-Q supports the tailoring of the questionnaire according to the resources. If it is not known, which resources are available in a certain area a dynamically generated questionnaire will include a certain item in the series of questions. If it is known that there are resources available only the questions on the usage of these resources will remain in the questionnaire.

3. Results of the two studies

The study conducted in South African focused on how ICTs can be used to support e-health implementation. The South African Study conducted a full technology assessment, but this paper will only discuss findings relating to the dynamic generation of questionnaires based on spatial information which is processed in a GIS. The following needs to be highlighted:

- Firstly it is important to mention that the GIST-Q approach will not solve the resource optimization problem but it can reduce costs for data acquisition by reducing the time that is spent on collecting the data or in turn if the financial resources are limited to identify the items in a questionnaire that have the highest priority. So the approach focuses on the optimal use of the available resource in areas which has the highest priority.

- When the participants in South Africa were asked about the challenges they have, lacking access to accurate information timely and in a much secure environment were the main concerns of all the participants, followed by tedious reporting efforts as answered by managers due to the manual-based system currently in place.

- It was astonishing to find that in most health care centers in the Eastern Cape Province, which participated, had some kind of an e-health solution, however only one of the five health care centers was using, with one in operation for 6 months, and the rest have never been used since they were deployed.

- It was further observed that in addition to the unused tele-medicine equipment, there were several of the available medical equipment which was in good working condition but were not used as there was not a need to use it in that specific health care center.

- Limited resources, especially skilled medical professionals, medical equipment, and water, were also identified as challenges in the South African study.

The preliminary study conducted in Germany, within one rural clinic, investigated the impact of RMS. This study revealed that the working environment is improved, time to attend to the patients is also reduced and that positive impacts in the service delivery was found. Within this study this clinic shared medical equipment and they had trouble in the past to optimize the application of some of the equipment within the clinic, so that patients had to wait longer and sometimes medical doctors had to re-schedule a meeting with the patient as they could not locate and apply certain equipment. This further created problems between health care professionals within the clinic.

The essential approach for the RMS model was the spatial and logistical analysis of the demand of the medical device. Afterwards a decision support algorithm was developed. This algorithm considers several dynamic requirement factors like using procedures and demand orders and then calculates the optimised stockroom for the device after use, in order to generate the shortest possible access time for the next use of the medical device.

In that process, the RMS model had to fit the tasks required for the decision support system. Both are necessary: "sufficient accuracy to meet the needs of the intended application, and sufficient simulation speed to enable swift and reliable weighing of alternative decisions"[12].

The introduction of RMS for all the medical equipments were all registered and managed through the RMS. So it was easier to monitor where, with whom, and when the equipment is free and it can be booked in advance. This promoted cohesion amongst workers, reduced the time to attend on the patient and eliminated the appointment re-schedule due to the missing equipment. This study further assisted management to identify the equipments mostly in use by doctors and the departments and that aided decision making and budgeting with regarding to which equipment to purchase or replace.

Considering the above with the challenges experienced in South Africa, the RMS has the potential not only for health care centers but also for senior level management. With RMS these challenges highlighted above can be resolved. If the RMS was used the Health care management would be able to see where the idle equipment is used or not used at all. They can also then identify the cause of this usage and make informed decisions on whether to train the staff on using it, as some are wiling to use it, but do not know how.

Having a RMS will not only resolve the issue of technologies and equipments, but can also support training needs as was stated in the findings of both studies in both countries that the shortage of skills is another challenge.

4. Discussing and illustrating the concept of how GIST-Q can work

This section will indicate how spatial visualization of a certain risk, demand, service or resource will determine the selection of questions. If one considers a spatial distribution of a certain risk it can be visualized by the following map in figure 1.

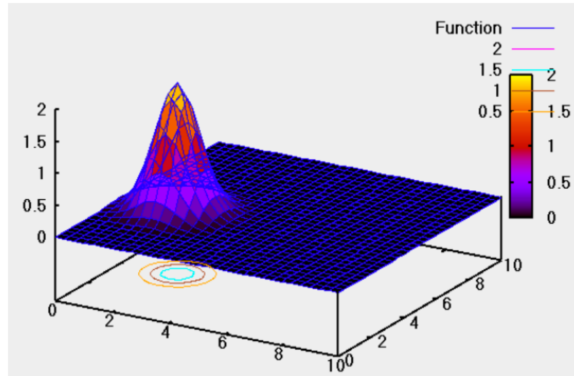

Figure 1: Spatial properties - risk maps

Generating maps from collected data can support the decision maker in getting a spatial understanding of a certain property e.g. showing the number of people getting infected with a disease *D* per day. The GIST-Q will include a questions about the application of a specific medical resource if and only if the spatial visualization indicates a frequency of more than 0,5 infections of the disease per day. If there is no time constraints for the questionnaire, the question can remain in the questionnaire for the whole area that is considered in the risk map, but if time to complete a questionnaire should be limited to t_{max} minutes, then questions will be dynamically removed from the questionnaire. The dynamic generation of the GIST-Q supports the researcher to produce time effective ICT based questionnaires that tailor the question according to the GIS based data, that is already available.

GIST-Q reduces the time for the gathering of data in all areas with a very low prevalence of the disease, e.g. 0.5 infections per day. Peaks of the surface (as illustrated in figure 1 above) indicate a high priority for a question to remain in the questionnaire.

The procedure of GIST-Q can be mathematically described. A spatial visualization of infections per day shows the highest priority for a response with appropriate medical resources like medication for the disease. The selection of a question from the questionnaire will be dependent on this simplified case by a single risk map that can be used by decision makers in an RMS to distribute the resources according to the identified risk.

A spatial map is generated by function $f: \mathbb{R}^2 \rightarrow \mathbb{R}$ and maps the coordinates $(x, y) \in \mathbb{R}^2$ to a real valued property $z \in \mathbb{R}$ that could represent e.g. a value z of risk in the location (x, y). We considered risk maps and questions that are dependent on risk.

For resource management, a spatial representation of resource distribution and the availability of information can be represented by a function $a: \mathbb{R}^2 \rightarrow [0,1]$, where $a(x, y) = 1$ means that there is information available at location $(x, y) \in \mathbb{R}^2$ and $a(x, y) = 0$ means that there is no information available.

Values in between could indicate the quality and age of the information. This leads to spatial Fuzzy Logic. Spatial Fuzzy Logic is an application of membership functions in Fuzzy Logic with a 2D domain, which can be used for spatial decision making.

In general 0 means "false", 1 means "true" and values in between represent the grade of validity or grade truth for a certain property. Lofti Zadeh (1965) in [10] introduced the fuzzy set theory where the membership functions define the grade in which the argument of the membership function belongs to the set. For classical "crisp" sets, the membership function is the indicator function for the argument being the element of the set. From the logical perspective the membership function describes a (fuzzy) logical expression that outputs the truth of the statement for the spatial argument.

The graph of the function shows the distribution of the validity of a considered property of logical expression. Considering the expression "the quality of the data is high in location$(x, y) \in \mathbb{R}^2$the graph is showing the truth of this location spatially.

Going back to GIST-Q this spatial statement in Fuzzy Logic will determine the questionnaire in adding the question dynamically if the value of the membership functions $a(x, y)$ is lower than a certain threshold $s \in [0,1]$.This means that the quality of the information is to poor and new data has to be gathered. Because we have to focus on different levels of representations of multidimensional functions we consider a resource supply map of a single resource *R* now. The resource *R* is located at the coordinates (x_R, y_R)directly under the peak of the surface and the height$z_R$of the surface visualizes how well the environment of (x_R, y_R) is served with the resource$R$. Beside the quality of the resource itself the service quality is decreasing along with the distance to the resource$R$.

Even a good hospital cannot provide the good quality of service if the patients are not able to reach the hospital within a certain period of time. The spatial dependency of service results in tailored questions in the GIST-Q is dependent on each other, because questions about service quality for a specific hospital make sense if and only if the hospital can provide a medical service to that region in which the patient is living.

The quality of service can change in space and time and so the availability of an improved resource like a car that can transport a patient in much shorter time to the hospital allows for the resource supply map to change. To explain this better one can use the heart attack as an example. In an emergency case of a heart attack there is an acceptable time in which the patient should be in a hospital or under medical treatment. Improved transportation facilities that are accessible and affordable for patients can extend the resource supply map as is shown in the modification from figure 2 to figure 3 .

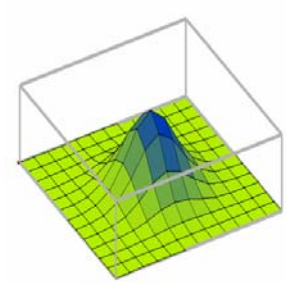

Figure 2: spatial quality for response time in case of an heart attack.

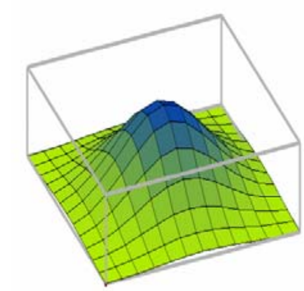

Figure 3: spatial quality with reduced response time and improved transportation facilities

In comparison to figure 3 the surface in figure 2 is much steeper and the area with acceptable quality in response is much smaller. A dynamically generated questionnaire will now introduce the question in the questionnaire according to the heart attack in figure 3 for an enlarged area.

The replacement of questions is another result for the spatial representation in the GIST-Q. Using the heart attack example again, in areas with no health care centers available the question on hospitals can be replaced with a question on response measure that can be applied when no medical service is available.

The tailored improvement of the quality of data must be distinguished from the quality of medical resources provided in the location itself, because you can have a good quality of data saying that the provision of medical services for disease D is very poor.

Both quality of data and quality of medical service according to the risk determine the selection and prioritization of questions in GIST-Q for improvement of health service delivery. In rural areas the demand and risk will not be covered by the available resources. A risk map in a GIS can support the decision maker in determining areas where available resources should be deployed first. Because more than one resource is available the supply from one resource R_1 might be poor because of quality and distance but there might be a R_2closer to the patient with much better support quality.

If a questionnaire focuses on the identification of the resources that are used by the people the questions on the two resources$R_1$and$R_2$are inserted in the GIST-Q because both resources are available. The results may indicate that the poor quality resource $R_1$is used instead of R_2.If the resource R_2 was introduced in the health care system recently then the people might not be aware of R_2.GIST-Q can be used to provide information about the possibility to use R_2 just by asking the question "Did you use

R_2 located in … for … in your community?". Generalizing this simple example to a mathematical description we want to identify the resources R_k which has the best quality of service and tailor the GIST-Q questions to this resource.

Human resources are mobile but it might be difficult to motivate medical doctors to work in rural areas. The spatial visualization can visualize these support levels as well. If doctors are not available the GIST-Q will not select questions that are dependent on the medical doctor and select only questions that are dependent on the absence of medical doctors. It has to be mentioned that GIST-Q does not automatically implemented the dependency between the availability or absence of resource R_k. The dependency $d_k: \mathbb{R} \rightarrow [0,1]$ related to a questions Q_k has to be defined prior to the dynamically generation of a questionnaire. A used GIST-Q will get the location $(x, y) \in \mathbb{R}^2$ as input and the questionnaire used in location $(x, y) \in \mathbb{R}^2$ as output.

At first glance it seems counterintuitive that a reduced number of items in a questionnaire can improve the quality of support measures and the quality of spatial representation. But a tailored questionnaire that selects questions tailored to the needs and risks of a considered geographic region can be used as an ICT based instrument to ask only questions that are of relevance for the people in rural communities and that are linked to their major concerns and not to a predefined set of scientifically relevant questions. It will be in line with our expectations that the quality of medical services in rural areas is very poor in comparison to urban areas.

It is a challenge to provide health care in rural areas with limited or no medical resources. The selected questions of GIST-Q should be related to the available resources or to resources that can be made accessible by methods of resource optimization. GIST-Q can be used to tailor questionnaires to resources that can are used now or in the near future. So people are able to identify that answering the questions could help to establish for example an emergency transportation with a taxi driver living in the same community that will provide emergency transportation and get payed by a micro-insurance [11] set up for the community.

The results of the questionnaire can be transferred into spatial representations and in turn the decision maker can see the distribution of improvement of the action in a resulting risk map used prior and after the response measure. The GIST-Q can help to improve the quality of data and localize the areas where data collection is necessary with the highest priority. Furthermore evaluating the chosen response measures visualized in a GIS can support the decision maker in the process of optimization the health care service focused on the available resources with the highest priority to areas where the people are suffering the most. Looking at sustainability Ackermann [9] shows how integrated logistic support principles can help to optimize the delivery of health services.

For this mathematical approach it is important that trusted data is available directly from the rural communities to determine their needs and problems. However this data has to be updated regulary and has to be reliable for this method of optimization of resources to be effective. GIST-Q is an instrument that docks a data acquisition module in a Spatial Decision Support System. As mentioned above risk and resources have spatial aspects and do consider the improvement of a health care system. Time is an extra dimension which can determine the selection of questions in a GIST-Q. The complexity and the dynamics of a health care system can lead to the fact that changing environmental, social and economical conditions have an influence on health care in rural areas. GIST-Q is part of a developmental cycle and the following four phases should be run permanently:

- data acquisition via questionnaire;
- provide spatial data in a GIS;
- prioritization of response measures according to risk and demand; and
- generation of GIST-Q according to prioritization of questions and areas.

The aim here is to support the decision in all the four phases:

- where to construct and set up new resources (areas of highest demand, with participation of rural communities);
- where to provide the resource according to demand and trained people as human resources to perform the function of the resource;
- monitoring and refinement according to the spatial demands usage of resources; and
- deployment of the resource.

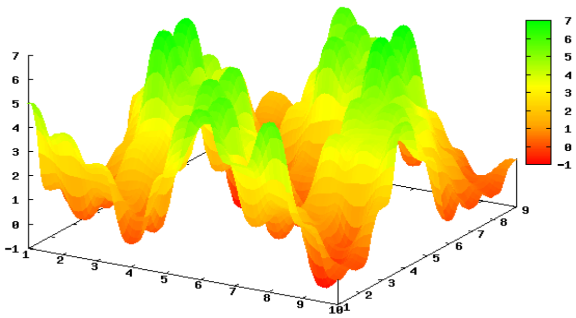

Figure 4: Spatial quality of supply with resources according to risk and demand

The map above is showing the differences between demand and available resources. The GIST-Q will be used to identify resources in areas with better medical service which can be used in areas where the quality of service is very poor. Furthermore in areas where there is a poor quality of medical services GIST-Q can be used to focus on questions that can help to solve a transportation problem when no ambulance is available. GIST-Q can also be used to identify failed approaches tailored to areas in which they were applied. This information is considered as valuable for spatial Decision Support Systems, which observes the risk/demands and resources in health service delivery and can be used in turn to determine the selection of questions for a GIST-Q. It can therefore:

- tailor questions to the available resources in the area where health care should be improved;
- reduce the time necessary to complete a questionnaire;
- identify areas with missing data and high priority to get the data via GIS and generate the GIST-Q with this information.

Therefore, adopting the RMS can eliminate costs of deploying unnecessary resources (human or technologies) in rural health care centers, and further provide a basis for informed decision-making. This system can further give international donors and other parties the opportunity to have accurate information on different needs of the different rural health care centers and to appropriately donate or collaborate solutions/projects that will effectively enhance health care services and improve quality of care for rural communities.

5. Conclusion

ICTs are continually revolving and they continue to provide solutions that are capable of overcoming the challenges faced by the health care sector in developing countries. With limited resources, and capital with the drive for socio-economic development, developing countries have to explore different ways in which they can use ICTs to harness their capabilities. In the health care sector, enhanced quality of care and improved service delivery becomes the key especially in rural health care centers where there is a lack of specialized skills. Since the health care management is faced with decision making challenges from time to time, especially with the resources, a RMS becomes vital as it aids informed decision making on resource location and further provides monitoring and control, as well as future forecasting to pro actively plan for disaster times.

Especially spatial visualizations in GIS are necessary to support a decision in getting a spatial understanding of the problem and prioritize the resource distribution according to the greatest demands. However developing such a system will need a collaboration of expertise in generating those maps with data that will show a true representation of the needs and resources in rural areas. This paper thus suggest the collaboration of systems development methods and those modes used in mathematics, such fuzzy logic, stochastic and neural networks; to monitor, focus, and control the resources deployed in rural health care centers

Remark: All the tools mentioned in this article are Open Source software including the Geographic Information System GRASS. Open Source Software was used for Mathematical Modeling so that software can be exchanged, shared and provided to the students without any commercial limitation. Additional information on the application of neural networks can be found in an article in the Indian Journal of Medical informatics [13].

References

[1] Ruxwana, N. *Technology assessment of rural hospitals in the Eastern Cape Province*. Publisher: Vdm Verlag Dr. Müller. ISBN-13: 978-3639125962. 2009.

[2] Friedman, T.L. (Eds.). *The World is Flat: The Globalized World in the Twenty-First Century*, UK: Penguin. 2006.

[3] Castells, M (Ed). T*he Information Age: Economy, society and culture*. Oxford: Blackwell. 2000.

[4] UNDP. *Workshop on E-Governance for Enhanced Service Delivery in the Context of a Capacity Development Framework.* [Online] Available at: http://www.undpsaci.co.za/documents/aide_memoire_revised_rev_4.pdf. 2006.

[5] World Bank Report, I*nformation and communications for development: extending reach increasing impact.* Washington DC. Available at http://go.worldbank.org/NATLOH7U0. 2009.

[6] Rolfe, B., Leshabari, S., Rutta, F., and Murray, S.F. 2008. *The crisis in human resources for health care and the potential of a 'retired' workforce: case study of the*

independent midwifery sector in Tanzania. London: Oxford University Press.

[7] Creswell, J.W. 2003*. Social research*. London: Sage Publications.

[8] Ruxwana, N.L., Herselman, M.E. and Conradie, D.P. (2010). ICT applications as e-health solutions in rural health care in the Eastern Cape Province of South Africa. *Health information management journal,* Vol 39 no 1 2010. ISSN 1833-3575.

[9]Ackermann, G. Sustainability application of integrated logistic support principles to delivery of health services. *Proc. 19th International Conference on Systems Research, Informatics and Cybernetics III, 1, 2007.*

[10] Malczewski, J. Spatial Decision Support Systems, NCGIA Core Curriculum in GIScience. [Online] Available from: http://www.ncgia.ucsb.edu/giscc/units/u127/u127.html. 2009.

[11]Anderson, S. 2002. The state of the World's pharmacy: a portrait of the pharmacy profession. *Journal of Interprofessional Care* 2002, 16:391-404.

[12] Rauschenbach, Th. & Wernstedt, J. ILM-RIVER – A General Design Tool for Simulation and Control of Rivers and Hydro power Plants. In: *European Control Conference ECC'99,* Karlsruhe, Germany. 2002.

[13] Niehaus, E., Herselman, ME. & Babu, A. 2009. Principles of neuroempiricism and generalization of network topology for health service delivery. *Indian journal of Medical Informatics*, Vol 4, No 1. http://ijmi.org.