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Building GIS Framework based on Multi Criteria Analysis for Hospital Site Selection in Developing Countries

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Abstract:

There was a great important to enhance the healthcare services in developing countries. The biggest challenge in many developing countries is the large populations with a lowest economy in these countries. The limited and disturbed medical resources like hospitals, health centers, equipments and so on, which is the main focus to improve health in the developing countries. Geographic Information System is a specialized system for site selection through different spatial analysis tools that can help the health professionals and administrators in decision making. Previously, the analytical hierarchy process (AHP), weighted overlay analysis (WOA), and rank order method (ROM) are methods that weighted multi criteria. The main focal point in this paper, that there are no plain criteria for hospital site selection in developing countries. So that the purpose of this paper is to build a GIS framework based on multi criteria analysis (MCA) for hospital site selection (HSS) in developing countries. The proposed framework can be used as guidance for selecting the suitable and safe site selection for hospitals in developing countries.

Keywords — **Geographic Information System (GIS), Hospital Site Selection (HSS), Developing Countries, Multi-Criteria Analysis (MCA), Analytical Hierarchy Process (AHP), Weighted Overlay Analysis (WOA), Rank Order Method (ROM).**

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I. INTRODUCTION

Geographic information system is a science that can be used in different fields such as health. GIS is a special case of information system because GIS has all the capabilities of information system such as capturing, storing, updating, analysing and integration through a spatial definition. So the main vital purpose of GIS is decision making. GIS has complete spatial tools that help decision makers in different areas. These tools contain observation, analysing, measurement, predicting, and description. GIS can integrate multi criteria based on spatial proximity to select the best site selection.

Furthermore, GIS is a Cross-disciplinary because GIS is related to Digital mapping, surveying, computer aided design, database and remote sensing. GIS can be used in many aspects in healthcare like hospital site selection, epidemiology, needs analysis and service inventory.

In developing countries, there is an importance to improve healthcare services to reach to the better healthy communities. The improving of healthcare services is very essential for the development [1].

In the developing countries, the percentage of population is rapidly increasing in the two previous decades. The selection of hospital location is a critical outcome to survive people in disasters and crisis and present the healthcare services to high population in non emergency periods. There a need to reduce the costs and maximizing the benefits of selecting the right location of the hospitals [2].

There are many studies focused on different criteria for hospital site selection. Some of these criteria are crucial factors according to the continuous changes in these criteria.

II. HOSPITAL SITE SELECTION BASED ON GIS

GIS is a powerful tool for site selection in different fields. GIS has the ability to present all factors in layers. The GIS can classify, analyse, process, generate reports, display results on maps, GIS is the vital policy where data can be captured and stored. New GIS packages that presented by Esri offered applications and digital models that assist many applied fields to take decisions for complex and multi dimensional problems in easy, fast, accurate and visual way [3].

Intelligent GIS based on data mining techniques can assist in extract, integrate and analyze huge amount of spatial data in order to gain knowledge and insights that help the decision makers. Also digital mapping and location based techniques have effective tools in all activities that can help in problem solving. GIS technology consists of effective tools that can make relationship between spatial data by using topological mapping in order to present a spatial modeling [4].

In health sector, the adoption of using GIS is increasing to improve the healthcare outcomes. In developing countries, there are many challenges in the health sector such as the increasing of population, increasing of urban areas and slowing economic growth [5].

GIS has different analytics tools that can help in spatial analysis, selecting the locations and assisting the decision making. These analytics tools contain Euclidean allocation, distance and direction, network analysis, shortest path, buffers, and overlay analysis.

III. GIS-BASED MULTI-CRITERIA ANALYSIS (MCA)

There are many weighing methods for multi criteria, these methods for decision makers based on some tools that can give weights for the decision making criteria through the comparisons of the criteria. Previously the analytical hierarchy process (AHP) is a structured technique for decision makers [6]. Rank Order Method (ROM) is weight method that can arrange criteria according to the importance of each one.

Also weighted overlay analysis (WOA) is an overlay analysis that weighted multi criteria. The multi criteria analysis (MCA) is another method that can be used in complicated problems in order to give weights and ranks for multi criteria [7]. In MCA the criteria is arranging by the importance of each criteria. GIS-based MCA contains two critical parts: basis criteria and limitation criteria. Each criterion is transferred to a map layer or map theme. Moreover, whether the criteria is basis or limitation for selecting the location of the hospital, all these map layers are comprises by the weight of each criteria to assist in the decision making. GIS-based MCA contains many tools such weighted summations and Boolean overlay operations.

As seen in figure 1 there are two sides in GIS-based MCA model, the side contains the entering of the constrains map layers then the second step is integrating all the map layers. In the other side the maps of the factors or basis are entering then giving weighting to each factor map next integrating the weighted factor map. Finally, the outcome is a result map that can assist the decision makers. GIS-based MCA has been presented as useful and successful analysis tool that helping in decision making.

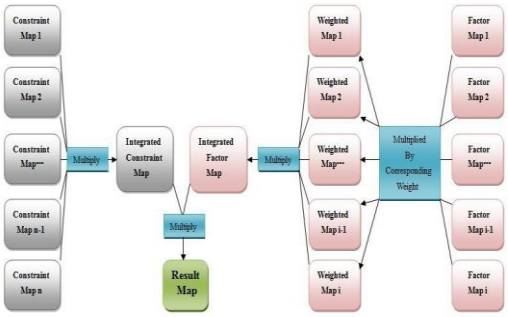

Fig . 1 GIS-based MCA model

Moreover, the new trends are focusing on multi criteria decision analysis (MCDA) as a decision making tools. Many researchers have proposed multi criteria decision analysis (MCDA) in hospital site selection because this approach includes different dominations which help in decision making.

IV. MULTI CRITERIA FOR HOSPITAL SITE SELECTION

The developing countries faced by many problems when selecting hospital's site. These problems refer to the poor planning and urbanization with the large growing in the population in specific areas. Also there are some problems related to social and economical factors, environmental factors, and changes in lifestyles from area to another area in the same country [8].

According to world health organization (WHO), the variety of medical services offered by the hospitals differs from one country to another remaining to differences in many factors that affected on the location of the hospital. These factors include epidemiology of regular or complex cases, the population and demographic data of the citizens; environment and climatic conditions; rates of economic growth; socio-cultural factors; national policy in the country, the equipments and human resources; quality of healthcare services.

Effective hospital site selection is a key opportunities for societies to enhance the quality of healthcare services that presents to citizens in developing countries. The hospital site selection depends on many criteria there are some international criteria and others are local or nation criteria which is different from country to another. Many of the previous studies focused on the cost and benefit of hospital site selection. This paper will scope on different other criteria that have a great importance for selecting the location of the hospital.

As, Moradian. M .J. et al demonstrated risk criteria in hospital site selection in six areas as following cost, demand, environmental factors, administrative factors, disaster risk and others. As shown in table 1 Moradian M.J et al presented six groups and each group contains subgroups [9].

TABLE 1

RISK CRITERIA IN HOSPITAL SITE SELECTION

Groups	Subgroup	Criteria
Cost concerns	Basic costs	Land
		Construction
	Infrastructure availability	Accessibility to main streets/roads, intersections and squares
		Proximity to social service (like metro) and Green space
		Proximity to Infrastructure (electricity, natural gas, Drinking water, Sanitation and sewer system)
		Accessibility to public transportation
	Land/ Space	Land specifications (availability, Use, Capability, Texture of the ground, Vacant, Ownership, altitude, Visual aspects)
		Enough areas/ site dimensions (Construction, Green and parking)
	Traffic	Traffic volume/flow
Demand concerns	Target Community	Socio Economic status of the population
		Population number/ density (Maximize)/ Distance to population (Minimize)
		Population age distribution
		Community Health Status
		Travel time (minimal)
	Health service utilization	Total number of needed beds
		Patients transfer rate
		Number of patients rejected by hospitals
		Number of visits to doctors
		Health care spending per household
	Existing Hospital	Distance to existing hospital and Faculty of Medicine
		Rank of competing hospitals
Disaster Risk concerns	Natural Hazards	Distance to High Risk Area (ground movement event)
		Distance to Faults (Seismic activity)
	ManmadeHazards	Distance to Industrial centers
Environmental concerns	Climate And Air quality	Air pollution (Minimal density) Distance to industrial area (Maximize)
	Noise Pollution	Distance to industrial, workshop, installation and railways (Minimize)
	Biodiversity	
	Water pollution	Distance to sewerage system, Public toilet
		Distance to rivers , canals and water bodies
Administrative concerns	Context	Governmental regulations
		Policymaker's attitude
		Economic constrains
		Social inconvenience
		Temporal restriction
		Interested and Affected Persons
		Hospital personnel
	Future development	Urban planning
Other	Unforeseen circumstances	Chance
		Other Competitive Hospitals

From the previous studies, this paper will add another criteria which are very essential in hospital site selection in developing countries these criteria as following:

1- Infrastructure: The availability of the infrastructure of water, electricity, sanitation and communications.
2- Position: a hospital can be located near the main roads and streets. So the location of the hospital is a quite distance about 200 meter from the main roads
3- Transportation: the hospital site selection must be near the transport methods in the big cities with high population.
4- Services: the location of the hospital must be near different services like police stations, fire brigade, police departments and others health and security services.
5- Pollution factors: there a need to select the location of the hospital far away from different pollution factors such as air pollution, water pollution, noise pollution, garbage points, gas stations and so on.
6- Population: the location of the hospital must be selected in the area that can service a large number of populations with different demographic data.
7- Land use: there are many land specifications for selecting the hospital's location and also the area of the land.
8- Crisis and disaster: the location of some hospitals in sometimes must be close or near the industry area or the places that can be affect by natural disaster in order to present the fast services to these types of areas.

V. GIS Framework based on Multi Criteria Analysis for Hospital Site Selection

The key spotlight of this paper is proposed a GIS framework based on Multi-Criteria Analysis (MCA) in hospital site selection. The GIS framework based on MCA provides a general framework for site selection which presents an effective orientation to the decision makers, and public administration through the using of spatial data.

The GIS framework displays the effectiveness of using MCA in hospital site selection that will present the optimum sites for the establishment of new hospitals. Through the using of GIS tools, Building a Digital Model with GIS that using Multi Criteria to hospital site selection to create a disseminated map for land suitability for hospital site selection. The Factor criteria necessity tests and sensitivity tests can be done by AHP or ROM. These tests will combine in MCA in order to determine the weighted for each factor.

The goal of the GIS framework based on MCA is find the best hospital site coming from a sequence of weighted criteria. The process of weighted criteria contains two steps the shattering and evaluation. Depending on the some international selection standards for hospital site selection, there are many outcomes with maximum value of some criteria. Then a final evaluation with national standards on these alternatives should be accepted to select the best location of the hospital.

Figure 2 shows the proposed GIS framework based on MCA method. First there a need to determine the criteria as shown in the figure these criteria may be international or national criteria. Then through the necessity tests and sensitivity tests, each criterion will get a weighted vale through weighted maps. All these data will store in a geographic database. When a decision maker does a query for selecting a location for a new hospital, the GIS tools can integrate, transform and analyze the spatial data in order to help the decision makers to select the optimum location for the hospital. Finally, the outputs of the queries can be displayed visual through a map result or by reporting and charting.

In new versions of ArcGIS, model builder is a visual programming tool that can use to build geoprocessing data flows in order to help in site selection. The model builder evaluates each factor according to spatial calculations in order to determine the cost allocation of each factor through weighted values for each factor.

The proposed framework in the transformation and analyzing process includes rasterizing data or convert layers from vector to raster by using spatial tools, reclassifying the layers according to the importance of each layer and the distance between cells so that the digital model builder can calculate and weighted each cell, and weighted overlay analysis in order to reach the result map which contains classification range for each layer that shows the validity of the location of the hospital.

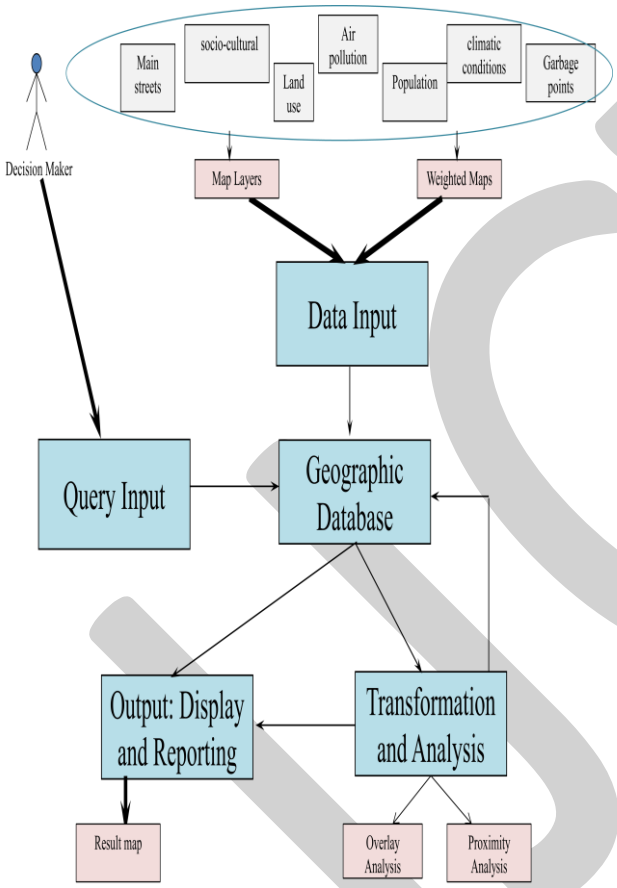

Fig .2 GIS Framework based on Multi Criteria Analysis for Hospital site selection (HSS)

The continually growing population of urban areas increases the require for new hospitals where their building must contain multi criteria including environmental factors, social and culture factors, economic factors, political and legal restrictions, and so on. The criteria of hospital site selection will be assigned by weights for each criterion besides affected by related factors. Hospital site selection requires a location with definite geographical specifications and environmental conditions.

GIS framework based on MCA provides a more technological, suitable and defined method for hospital site selection than the traditional methods. GIS framework based on MCA contains spatial and non-spatial data to build visualized map result that can be without doubt explicit and analyze by decision makers. By using such clarifying result maps, decision makers can take the right decision in the right time very accurate and fast.

In developing countries there are many Challenges of applying the proposed GIS framework. These challenges include lack of infrastructure and of skilled human, lack of understanding the benefits of using GIS in health sector.

VI. CONCLUSIONS

The location of the hospital is very important to rescue people in the right time and service a large number of populations. From the previous studies, there were different studies in HSS these studies didn't add the using of GIS tools in order to assist multi criteria evaluation methods. In developing countries, it's very important to sustain the development in health sector by using GIS tools to improve healthcare services. The main goal in this paper is building GIS framework based on MCA method for helping the decision makers in HSS. Any developing country can use this GIS framework for HSS by entering multi criteria which is difference from country to another.

From the above, a GIS framework based on MCA by the necessity tests and sensitivity tests can help the administrators and decision makers to be understand the multi criteria of the hospital site selection and weighted each criterion and integrate all these criteria to reach to the optimum location. Using GIS tools besides MCA is predictable to eliminate the redundancy of number of operations in MCA models.

VII. FURTHER WORK

GIS framework based on MCA can be applied in many developing countries. In the future, the researcher will apply the proposed framework for HSS in the new urban areas and new cities in the developing countries.

Furthermore, the proposed GIS framework can be applied in other site selection problems like school, police stations, gas stations, metro stations, power stations and so on. Moreover, the proposed GIS framework can be very important to decision makers as guidance for site selection that is based on multi criteria.

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