The Importance of Site Selection for Radio Astronomy

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Abstract. Radio sources are very weak since this object travel very far from outer space. Radio astronomy studies are limited due to radio frequency interference (RFI) that is made by man. If the harassment is not stopped, it will provide critical problems in their radio astronomy scientists research. The purpose of this study is to provide RFI map Peninsular Malaysia with a minimum mapping techniques RFI interference. RFI mapping technique using GIS is proposed as a tool in mapping techniques. Decision-making process for the selection requires gathering information from a variety of parameters. These factors affecting the selection process are also taken account. In this study, various factors or parameters involved such as availability of telecommunications transmission (including radio and television), rainfall, water line and human activity. This study will benefit radio astronomy research especially in the RFI profile in Malaysia. Keywords: Radio Astronomy, Radio Frequency Interference (RFI), RFI mapping technique : GIS.

1. Introduction
Optimum coverage for radio astronomy observatory is important part need to consider. However interference from human activity are the main threats to radio astronomers. This due to the rapid urbanization result of the growth in industrial and commercial sector in the world has increased the demand of usage radio frequency. Radio Frequency Interference mapping using GIS is useful technique in order to identify interference. This technique helps to find and monitor spectrum occupancy in identifying and recognizing the most intense sources of interference, particularly from terrestrial transmitters. This paper demonstrates the potential of GIS and MCDA in selecting a suitable sites for a radio astronomy observatory in Peninsular of Malaysia. There are several factors in geographical and anthropogenic such as population density, contour shielding, road network and rainfall. This mapping technique is a tool in recognizing and identifying the most intense sources of interference. Parameters required were generated using data in GIS mode. This study offers tough, precise, cost a time effective procedure for preliminary selection for a radio astronomy observatory. However for the practical and final stage, site testing for RFI measurement need to do in order to see the profile of interference.
2. Related Research

Site selection studies are very important for decision makers to propose where to build an astronomical observatory especially in radio astronomy with a greatest efficiency. However, site selection not as easy as we think, it is a complex problem and involved multi criteria. In this selection there are two step must be taken namely site selection and the site testing. However in this paper we only do the site selection using several parameter interested. Drobne and Lisec, 2009 proposed a decision analyses involved systematic procedures in order to solve complicated problems namely MCDA. MCDA integrated with GIS a powerful tool with its ability to settle complex and various amount of data obtained from different sources offering many benefit such as cost effective, efficient and rapid management especially for the site selection problem. GIS is the collection, processing, storage [1]. There are many studies on the site selection for different purposes have been performed by using MCDA integrated with GIS such in order to improve the efficiency of dangerous and harmful species monitoring [2], looking for best site in optical astronomical observatory [3], flood risk assessment which is a case study of Huaihe River Basin in China [4], used in siting sanitary landfill in Northern Cyprus [5], to identify locations for ecotourism in Qeshm Island, Iran [6], using in the earthquake proof division of construction site [7], fire sites planning in China [8], used in environmental quality monitoring.

The major elements involved in the spatial multi-criteria analysis are shown in Figure 1 [9]. Figure 1 presents a three-stage hierarchy of intelligence, design, and choice to represent the decision making process. In the intelligence phase, data are acquired, processed, and exploratory data analysis is performed design phase usually the involves formal modeling/GIS interaction in order to develop a solution set of spatial decision alternatives. Integration of decision analytic techniques and GIS functions is critical for supporting the design phase. The choice phase involves selecting a particular alternative from those available. In this phase, specific decision rules are used to evaluate and rank alternatives. The three stages of decision making do not necessarily follow a linear path from intelligence, to design, and of choice [9].

3. The Study Area: Peninsular of Malaysia

Malaysia has been selected as the study area in order to select the best site which is pinpointed as good a possible site to build radio telescope in Peninsular of Malaysia. Malaysia can be divided into three main regions: Peninsular Malaysia, Sabah and Sarawak. Sabah and Sarawak also called Borneo. Approximate location of these three regions are given below. Peninsular : 06°45' and 01°02' N latitude and 99°40' and 104°20'E longitudes, Sabah : 04°00' and 07°00' N latitude and 115°20' and 119°20'E longitudes and Sarawak : 00°50' and 05°00' N latitude and 109°35' and 115°40'E longitudes.

The Fig. 1 neighboring countries of Malaysia are Thailand and Brunei on the north and Singapore and Indonesia on the south (Fig. 2). The capital of Malaysia is Kuala Lumpur. The population stands at over about 35 million. Peninsular Malaysia borders by Thailand, Indonesia and Singapore however Borneo border with Brunei and Indonesia. In this study we only concentrate to the Peninsular of Malaysia. This country is located near the equator and experiences a tropical climate. This country also free from earthquake and volcano as well, this give an advantage of location of observatory. The country is generally warm throughout the year with temperatures ranging from 21°C to 32°C in the lowlands. This can however be as low as 16°C in the highlands. Annual rainfall is from about 164 cm - 241 cm but sometime heavy at 250 cm. On the rainy day thunder and lightning often accompany the heavy downpour which normally lasts for about an hour or two. The high humidity level at 80 percent throughout the year favors light and sweat-absorbent material like cotton for drying season. In general, Malaysia has two distinct seasons. The dry season occurs during the southwest monsoon from May until September. The Northeast monsoon brings the rainy season to the country during
mid-November until March. The Peninsular Malaysia is divided into the east coast by the Main Range, known as Banjaran Titiwangsa which runs from the Malaysia-Thailand border in the north to the southern state of Negeri Sembilan. Geographically, East Malaysia is rugged, with a series of mountain range encompassing the interior regions of both states.

4. Method

Multi-criteria decision analysis (MCDA) is a popular and useful technique that explicitly considers multiple criteria in decision-making environments. If one needs to make a choice which deals with multiple conflicting criteria, he has to consider the factors that may influence or affect the final result. He has also need to evaluate the ability of various activities and then the
corresponding attributes or indicators are identified to fulfil a given objective. The indicators are often defined based on scores achieved, rank and weightage. This method is capable to support decision makers facing such problems.

In this study, the MCDA technique is the best, well known structured approach to be practiced. As a result, the region in all around peninsular Malaysia will be ranked out from the lowest RFI (the best site) to the highest RFI (the most inappropriate place to consider for observation).

The step-by-step in methodology process of RFI map is shown in Fig. 3. Once the parameters have been set up, the Multi-Criteria Decision Analysis (MCDA) plays the role to produce the predicted RFI map. In this analysis, three main step are involved: determine the threshold value for each of the parameters, combine the data to produce a map for each parameter, and perform an Analytical Hierarchy Process (AHP) method. The MCDA integrated with the GIS process is illustrated in.

### 4.1 Source of datas

The data was requested directly from various agencies such as Malaysia Geo-Spatial Data Infrastructure (MyGDI), Department of Statistics Malaysia, Malaysian Meteorological Department, the Malaysian Communications and Multimedia Commission (MCMC) and the Department of Malaysia Map and Survey data including spatial and attribute data. Spatial data is a map of Peninsular Malaysia, which we get from the Department of Mapping and Measurement Malaysia. Other sources of support also in the spatial data, including topology maps to high places in Malaysia and GIS maps obtained from previous studies of the Faculty of Social Sciences and Humanities (FSSS), University of Malaya.

### 4.2 Processing of data sets using GIS

In this section we will split data with two sets of anthropogenic and geography. In anthropogenic data, we have the population density and road. However, we have a set of geographic data and raindrop contour. A set of data associated with human activity for example distance to roads and population density are the anthropogenic. They directly affect the quality of the observations, this is the same as in the case of optical observation. Another important parameter is the geographical situation near the observatory. As we know that the expensive equipment in the observatory should not be built in areas that are not safe in terms of geological conditions such as landslides and earth quake zone. Geography can help to reduce the level of interference as we know that the contour and raindrops become one of the options parameter by ALMA and SKA project to protect from interferens for example.
4.3. Anthropogenic data sets

4.3.1. Population density data  There is a parameter which is very related to human activity is population density. This population density represent the residential and commercial. This population density data was digitized as raster data and reclassify from 0 to 100. value of 100 represent best site meanwhile 0 least suitable site.

4.3.2. Road network data  Another important variable need to take care of was road network. Road information was present the usage of vehicle and develop area as well. When we discussing the road network, it also present the type of vehicle usage on the highway used. value of 100 represent best site meanwhile 0 least suitable site.

4.4. Geographical data sets

4.4.1. Contour shielding data  To locating of radio telescopes to avoid spectrum pollution most of radio observatories are often placed in valleys to further shield them from ground interference. So that altitude is a one factor in the site selection of radio observatory. Most of radio observatory in the world especially for high frequency study located at highest site. Meanwhile radio observation for low frequency normally located at lower in altitude. value of 100 represent best site meanwhile 0 least suitable site.

4.4.2. Rainfall data  Rainfall is one of important variable to radio propagation. It will affect penetrate of wave radio propagation where the water occupied in atmosphere will reflect or refract and attenuate as well the signal penetrate in the atmosphere. We need to find driest place in peninsular of Malaysia. In this study, rain fall range in Malaysia is from 164 cm$^3$ – 241 cm$^3$. Value of 100 represent best site meanwhile 0 least suitable site.

4.5. The analytic hierarchy process

After representing the criteria map layers in raster data format and rescaling the values between 0 and 100, all these layers were combined into a GIS. AHP was used for obtaining the weights connected with criteria map layers. In generally, AHP is based on pairwise comparisons for each data layer using numerical grade in an absolute scale of numbers (Saaty, 1980 and Saaty, 2008) and provides a very simple hierarchy to solving complicated problem. In AHP, single number value within the range of 19 was assigned as a degree of importance between two criteria.

These numbers were assigned to each pairwise by decision makers who are experts in astronomical observations, geosciences, meteorology and urban planning. These experts collaborated with each other to complement their knowledge and skills for deciding on suitable astronomical observatory site. In order to construct an AHP matrix which contains grade of importance between pairwise data, pairwise comparison is performed. The intensity of importance scale has a range between 1 and 9. If the compared data have equal importance, then the value in the matrix is one. When the reference data has extremely more important than the compared data, the value of the comparison is given as the highest number in AHP matrix which is nine.

5. Result

Each comparison grade is written on the pairwise comparison matrix (AHP matrix). In pairwise comparison matrix, matrix element is formed as $a_{ij} = (1/a_{ji})$. Due to the fact that column and row data layers are equal to each other; diagonal values on this matrix are equal to one ($a_{ii} = 1$, $a_{jj} = 1$, $a_{nn} = 1$ etc.). The grading values of all pairs are normalized to one using maximum absolute eigenvalue (Eqs. 1 and 2).
\[
\lambda_{\text{max}} = \frac{1}{n} \sum_{w_i} (AW)_i
\]

referring to Eq.1 base on report by [?]

\[
AW = \begin{bmatrix}
a_{11} & \cdots & a_{1n} \\
\vdots & \ddots & \vdots \\
a_{n1} & \cdots & a_{nn}
\end{bmatrix} \cdot \begin{bmatrix}
w_1 \\
w_i
\end{bmatrix}
\]

Where A is pairwise comparison matrix. W and wi (i = 1, 2, ..., n) stand for corresponding eigenvector of kmax and the weight value for ranking, respectively. At the beginning of the processes, pairwise comparison matrix was constructed using 4 criteria, which are previously created from different data sources (Table 2). After generating matrix, weights were computed for each parameter. kmax value was obtained as 4.055 in this study. Before using these weights, consistency of the pairwise comparison matrix should be confirmed that is consistent or not by using consistency index (CI, Eq. 3)

\[
CI = \frac{\lambda_{\text{max}} - 1}{n - 1}
\]

Where \(\lambda_{\text{max}}\) and n are the consistency index, the largest (principle) eigenvalue of the matrix and the dimension of the matrix (number of input parameters), receptively. CI value was calculated as 0.0184 in this study. In order to test the consistent of matrix we construct, the consistent ratio (CR) value was calculate base on value studied by Saaty 1980 (cite Saaty). CR formula given as equation below (Eq. 4);

\[
CR = \frac{CI}{RI}
\]

Where CI is the consistent index and RI is random Inconsistency (refer paper Saaty 1980 and Tran 2007). After we have obtain the value is less than 0.10 for example, the value of consistency generated by pairwise comparison is reasonable (Saaty 2008). We noted that RI value for n = 4 was 0.90, this value given by Saaty and Tran 2007. So that from the formula we CR obtained 0.0204 in this study. Therefore our aur pairwise for matrix is acceptable. if the value computed larger that 0.1 means that pairwise comparison should be renewed to get the value under limit (0.1). Table 1 show all value computed weight for all variables, CI, \(\lambda_{\text{max}}\), RI and CR value computed in this paper. In the final stage, each data layer that we analysis will combined by using the calculated weight coefficients to obtain the best sites result for radio observatory using GIS tools.

**Table 1.** AHP pairwise comparison matrix and computed weights. * A: Population density; B: Contour shielding, C: Road network and D: Rainfall

|     | A   | B   | C   | D   | Weight |
|-----|-----|-----|-----|-----|--------|
| A   | 0.052 | 0.021 | 0.045 | 0.081 | 0.0503 |
| B   | 0.263 | 0.195 | 0.045 | 0.285 | 0.197  |
| C   | 0.105 | 0.195 | 0.090 | 0.0633 | 0.113  |
| D   | 0.210 | 0.586 | 0.545 | 0.5701 | 0.478  |

The resultant map that indicates candidate sites was produced after performing the dense computation for obtaining weights of corresponding criteria and multiplying each criterion with
these weights using AHP and GIS. The best possible sites that were obtained by applying
a threshold value to select the areas having highest scores are presented in Fig. 4. In this
figure, the suitable areas in terms of meteorological, geographical and anthropogenic conditions,
which were extensively located in western and eastern part of the study area, are illustrated in
red1 colors (Fig. 4). The best site could be low in RFI is map represent by grey and yellow.
Moderate RFI could be present by green colour and High in RFI represent by blue and red
colour as illustrated in Fig. 4.

![Figure 4. After consider four parameters](image)

6. Conclusions
One of the most important factors that affect the resultant map is the construction of pairwise
comparison matrix for AHP. The values on that matrix should be given by the expert who has an
idea about observatories and their locations, geographical and meteorological conditions. The
expert must know the effect and importance of each criterion for astronomical observatory site
selection. If the values inside the matrix are not reliable, then the weights of the parameters
cannot be correctly computed and the final map may not represent the accurate places. In this
study, the meteorological data sets, which include cloud cover and precipitate water factors,
are important as mentioned before. The remotely sensed data for meteorological data sets (i.e.
MODIS data) provide spatial.

This study provides an example application of the MCDA, remote sensing and GIS
technologies for the purposes of site selection for astronomical observatory. By handling and
evaluating complex criteria, our approach proves to be an efficient and powerful method for
astronomical observatory site selection studies. This study will be followed by astronomical site
testing and meteorological observations on the spot at those selected sites for a final decision.
The developed approach in this study for the selection was implemented in Antalya province of Turkey. However, it can be applied efficiently to any city or region, in which an astronomical observatory site construction is planning.

Besides of the site selection, the other benefit of this study can be helpful to find best season or month within a year for astronomical observations. If more time series of meteorological data is available, then suitable astronomical observation periods can be computed statistically for future work.

Stronger than typical radio astronomical source can be refer in [10]. Another example of the problems that can arise is provided by the iridium mobile communications system, which has a group of satellites transmitting signals to every point on the surface of the Earth. Unfortunately in this case, there is some leakage into the passive band about $1612\,MHz$, with signal levels up to $10^{11}$ times as strong as signals than sources from the early universe [11].

For the future research not only population density (human generated RFI) but another factor or parameter such as telecommunication transmitters and airplane route could be important in order to find suitable place in least RFI [12]. Radio windows focus also should be extend to the high frequency such as S-Band and K-band not only in hydrogen line located at L-band [13].

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