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Identification of Potential Crime Area Using Analytical Hierachy Process (AHP) and Geographical Information System (GIS)

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***Abstract*— Over the years the rate of crime in Malaysia has been increase and monitoring measures should be taken to reduce the case or the crime rate. Mapping analysis and geographical databases has been used by the police as one of the important tool in crime analysis and crime prevention. Crime analysis is the method used by the police to reduce, prevent and solve crime problems. The crime problem comes with criteria that determine the potential crime area. To solve this problem, we designed a model containing Multi-Criteria Decision Making (MCDM) technique that is Analytical Hierarchy Process (AHP) to handle the uncertainty situations and Geographical Information System (GIS) to identify the potential location. An application adopting the AHP idea was developed to calculate the weights of the criteria for evaluating each crime factors. The GIS was used to overlay and generate criteria maps and suitability map. This paper highlights and discusses how to identify the most potential crime area using AHP technique while the integration with GIS.**

Keywords — crime potential area, crime analysis, multi-criteria decision making (MCDM), analytical hierarchy process (AHP), geographical information system (GIS).

I. Introduction

Criminal activity continues to be a major concern in contemporary society. Most nations are faced with unacceptable levels of crime. The rate of crime incidents is increasing in all developing countries due to change of technology and also due to poor economic and environmental conditions [Oatley and Ewart, 2003; Brundson and Corcoran, 2006]. Traditionally analysis is an important tool in crime prevention which the previous system of intelligence and criminal record maintenance has failed to live up the requirements of the existing crime scenario [Fajemirokun et al., 2006]. Manual processes do not provide the reliable and accurate data and does not help in trend decision support and prediction [Loureiro et al., 2009].

Identifying the potential area crime is a complex decision making process. Potential area crime identification is dependent on a number of factors and constraints including demography, economic, land use, building use and transportation. These factors shall be considered when identify the location. Identifying these evaluation criteria, defining the effects of them on each other, assessing their importance and choosing a particular location necessitate a well-designed multiple criteria decision making (MCDM) based evaluation using AHP [Buonanno and Montolio,2008; Entort and Spengler, 2000].

Some areas will become one of the hotspots if there are no appropriate controls. There are several factors such as economics, demography, land use, society social, transportation and building use that can lead to crime [Wang et al., 2011]. But there was a problem facing the parties involved that is identifying the potential crime area. Potential area crime identification is a kind of decision making process that requires criteria to be weighted and alternatives to be evaluated and ranked [Su and Jianjun, 2000]. Integration between Multi-Criteria Decision Making (MCDM) that is Analytical Hierarchy Process (AHP) with GIS is needed to identify the potential area crime problem as GIS is used to handle spatial aspect of the problem and AHP is used to calculate the weights of the criteria and ranking of alternatives [Rogerson and Sun, 2001, Eric, 2012].

This paper is organized as follows sections which are in Section I, we present the introduction of this paper. In Section II, we present a study on crime definition and functionality of crime analysis. Then Section III, we discuss the abilities of multi-criteria decision making that is analytical hierarchy process in crime problem. Section IV provided the proposed approach framework. Experimental results are presented to prove the proposed approach in Section V. Lastly, Section VI discusses the idea of integrating MCDM using AHP and GIS for identification the potential area crime.

II. Crime Definition

According to Prentice Hall Dictionary (2005), a crime or act of evil means like robbing, stealing and killing is wrong in law or criminal acts. Crimes can be divided into several categories which are violent crime, sexual property and streets [Prasannakumar et al., 2011]. In general trends and patterns of crime in Malaysia were more or less similar to the situation in developed countries despite certain difference for example in terms of volume and rate of crime [Wen-you and Ye,2009; Zhang and Ji, 2010].

A. *Crime Analysis*

Crime analysis refers to the set of analytical and systematical processes that provide timely, crime trend correlation and pertinent information about crime patterns. Analysis approach such as clustering can find interesting patterns from specified spaces [Chen et al., 2010]. Crime analysis involves the collection and analysis of data related to crime, criminals and criminal target. The main purpose crime analysis is to generate and identify the information needed to assist in making decisions regarding the monitoring of the police to prevent the criminal activity. In addition, crime analysis can be used to evaluate the effectiveness of crime prevention programs and assist in identifying crime problems [Xuefei and Peihong, 2010; Chandra et al., 2008; Ferreira et al., 2012].

III. Analytical Hierarchy Process

AHP was applied MCDM tools in many areas which this method was introduced and developed by Saaty 1980. In the AHP method, obtaining the weights or priority vector of the alternatives or the criteria is required. The AHP procedures involve six essential steps [Ibrahim et al., 2011; Vahidnia et al., 2008; Chakraborty et al., 2011; Samad et al., 2012]

i Define the unstructured problem
ii Developing the AHP hierarchy
iii Pairwise comparison
iv Estimate the relative weights
v Check the consistency
vi Obtain the overall rating

This study focuses on the utility of the AHP as a model capturing expert knowledge on environmental systems where data may be lacking. AHP. AHP method commonly used in multi criteria decision making exercises was found to be a useful method to determine the weights. When applying AHP, constraints are compared with each other to determine the relative importance of each variable in accomplishing the overall goal [Arquero et al., 2009; Liu et al., 2008].

IV. Geographical Information System (GIS)

Since crimes have situational relevance, and hence have a positional element attached to them, GIS can be a very useful tool to display and apply analysis to data, which reside in large databases, in order to obtain a strong visual appreciation of the patterns of crimes [Zhang and Peterson, 2007]. GIS is software tools that allow the crime analyst to map crime in many different ways from a simple point map to a three-dimensional visualization of spatial or temporal data [Hawkins et al., 2003].

GIS technologies facilitate the decision making process based on their analytical capabilities with spatial information. In addition to this, many of them are equipped with a graphical user interface, which increases the decision- maker's comprehension of the spatial information that is involved in the problem being addressed. Based on these two potential additions to the decision making process, a GIS is often included as a major component in the development of Decision Support Systems (DSS). Because of the spatial component that a GIS adds to conventional DSS, this combination of technologies has been referred to as Spatial Decision Support Systems (SDSS) [Mitchell et al., 2007; Galletti, 2011].

A. *GIS in Crime Analysis*

GIS as a tool can be used by police personnel to determine mitigation priorities, plan effectively for emergency response, analyses historical events and predict future events [Hawkins et al., 2003]. GIS helps to determine potential crime sites by examining complex seemingly unrelated criteria and displaying them all in a graphical, layered, spatial interface or map. Figure 1 show the flowchart of AHP and GIS [Junfu et al., 2010; Zhang et al., 2011].

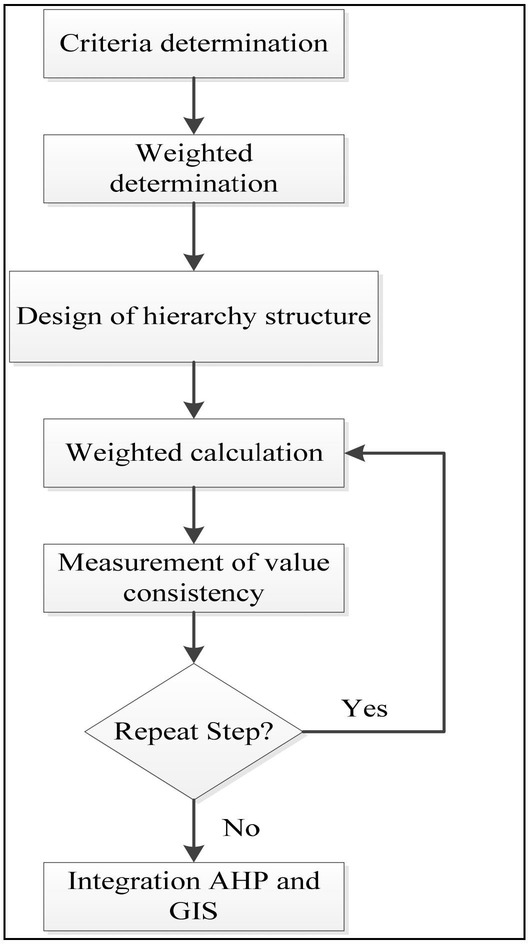

Fig. 1. Flowchart AHP and GIS

V. THE PROPOSED INTEGRATING AHP AND GIS

Based on the observation made in previous section, we present the idea of integrating AHP and GIS for the crime analysis to identify the potential area crime. The central idea of this approaches to identify the potential crime area based on two factors that used in this research which are land use and building use. The proposed approach framework is designed in a simple figure to make it clear.

Figure 2 shows the structure of proposed approach which consists of a data collection, data analysis from the distribution questionnaire, applying MCDM/AHP technique and integrating AHP with GIS. Each phase contributed the output which each output from previous phase will then lead to the next phase. Finally, integration between criteria weights and maps is accomplished producing the suitability maps which have the potential area for crime.

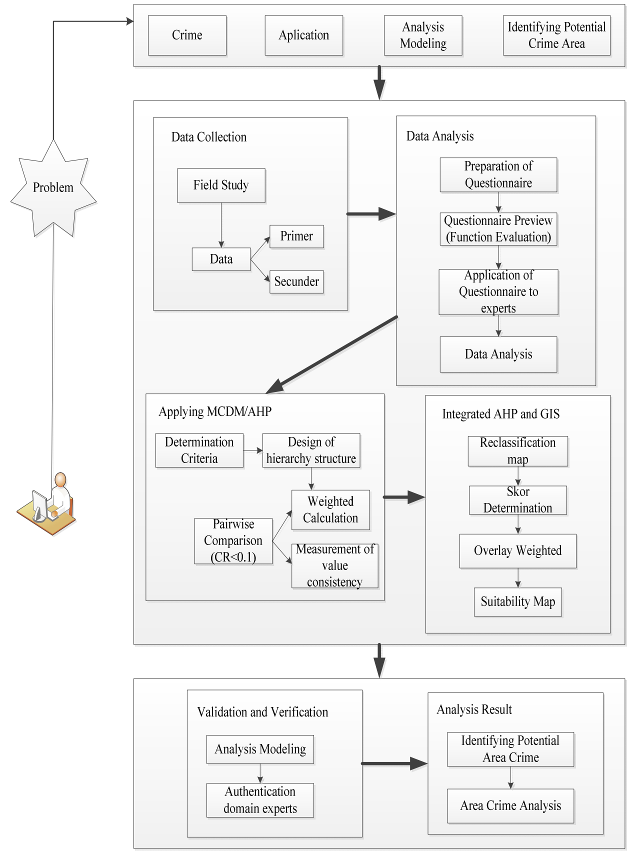

Fig. 2. Proposed Approach

A. *Study Area*

This study was conducted in Dewan Bandaraya Kuala Lumpur (DBKL). Federal Territory of Kuala Lumpur (243 sq km) is regional municipality located on the west side of Peninsular Malaysia and has population around 1.6 million. Population is expected to reach 2.2 million by 2020. Population density is 6696 inhabitants per square kilometer (17 340/sq mi) make this state the densest area of administration in Malaysia. Figure 3 shows the location of study area. Population increase occurred without proper controlling and monitoring has lead to several of problems such as criminal activity [Mohd and Ali, 2011].

B. *Data Collection*

Spatial data were obtained from the Jabatan Perancangan Bandar dan Daerah (JPBD) supported by company from UGISP Sdn Bhd. Then, layers of the selected area were generated and new layers were created using ArcGIS as the software to do the operations.

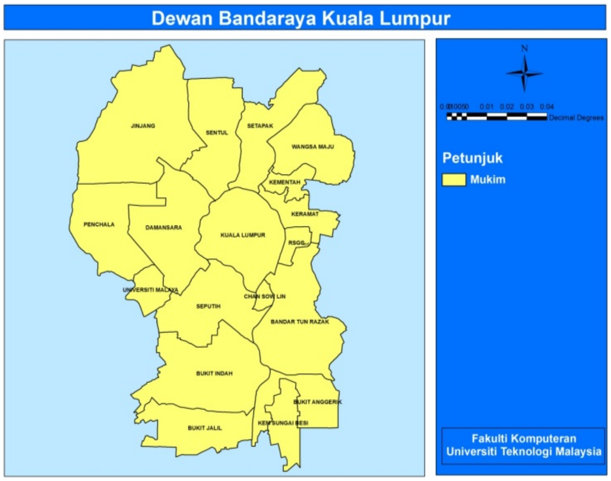

Fig. 3. Location of Study Area

VI. Experiments And Results

This section briefly describes the experimental results obtained in four phases which are data preparation phase, analytical hierarchy process and mapping phase.

A. Data Preparation Phase

This is a quantitative descriptive study using a questionnaire as the main instrument. Data analysis was carried out by questionnaire that replied by respondents and then collected based on question to ease the process of analysis. To perform the analysis, the data obtained were analyzed using descriptive statistics so that the information will be presented in a clear and easy to understand. Statistics Software Package for Social Science 16 (SPSS) was used to process the data that involves frequency, mean cross tabulation and correlation.

B. Criteria Evaluation

According to studies conducted from the questionnaire, the most important criteria used to determine the potential area crime in DBKL were recognized. Based on questionnaire, land use and building use was chosen as the potential factors.

C. Pairwise Comparison

After structuring a hierarchy, the pairwise comparison matrix for each level is constructed. During the pairwise comparison, a nominal scale is used for the evaluation. The scale used in AHP for preparing the pairwise comparison matrix is a discrete scale from 1 to 9.

D. Weighting Criteria

There are different evaluation criteria to determine the potential crime area; however the importance of these criteria is different for different factors. AHP is a multi-criteria decision method that uses hierarchical structures to represent a problem and the develop priorities for alternatives based on the judgment of the user.

Comparison matrix of main attributes which are LU represent for land use, BU represent for building use and NW represent for normalized weight as presented in Table I. Table II present the pairwise comparison matrix of criteria with respect to land use which are HS represent for housing, BS for business and services, RA for recreational areas, PA for no area development, IC for institutional and community, IA for industry areas, UI for infrastructure and utility, VL for vacant land, FA for forestry. Table III presents comparison matrix of criteria with respect to building use. HM represent for home, PM for public market, RT for restaurant, SM for supermarket, SC for school, HT for hotel, BK for bank, IU for institution and university and PS for petrol station. Table IV show the comparison matrix of criteria with respect to transportation. PL represent for parking lot, BS for bus station, RN for road network and TS for train station.

This step is to find the relative priorities of criteria or alternatives implied by these comparisons. The relative priorities are worked out using the theory eigenvector and the consistency check should be done at each stage of the selection process. To evaluate the consistency of the obtained result, the components are needed from the analysis namely Consistency Index (CI), Random Consistency Index (RI) and Consistency Ratio (CR). It is always appreciable that the value of CR should less than or equal to 0.1 or 10% then the computed result is said to be consistent or acceptable. At the final step of the calculation, the overall preference matrix would be constructed by multiplying all the weights with the factors, therefore the results are added to get the composite score of each factors.

Based on Table I shown that the comparison matrix of main attributes which the land use factor has the highest value, 0.571 than the factor of building use. From that, the land use factor was the potential crime factor. Table II shown the housing area has the highest value, 0.200 than others area. However, the lowest value in this table was forestry area which 0.022. Besides that, Table III shown that the house and public market has the highest value for normalized weight which is 0.200 and 0.178. As the conclusion, the location will become as the potential crime area if the value for the normalized weight is highest.

TABLE I. COMPARISON MATRIX OF MAIN ATTRIBUTES

	LU	BU	NW
LU	1.000	1.333	**0.571**
BU	0.750	1.000	**0.429**

TABLE II. PAIRWISE COMPARISON MATRIX OF CRITERIA WITH RESPECT TO LAND USE

	KD	PN	KR	KT	IK	PI	IU	TK	PH	NW
KD	1.000	1.125	1.286	1.500	1.800	2.250	3.000	4.500	9.000	**0.200**
PN	0.889	1.000	1.143	1.333	1.600	2.000	2.667	4.000	8.000	**0.178**
KR	0.778	0.875	1.000	1.167	1.400	1.750	2.333	3.500	7.000	**0.156**
KT	0.667	0.750	0.857	1.000	1.200	1.500	2.000	3.000	6.000	**0.133**
IK	0.556	0.625	0.714	0.833	1.000	1.250	1.667	2.500	5.000	**0.111**
PI	0.444	0.500	0.571	0.667	0.800	1.000	1.333	2.000	4.000	**0.089**
IU	0.333	0.375	0.429	0.500	0.600	0.750	1.000	1.500	3.000	**0.067**
TK	0.222	0.250	0.286	0.333	0.400	0.500	0.667	1.000	2.000	**0.044**
PH	0.111	0.125	0.143	0.167	0.200	0.250	0.333	0.500	1.000	**0.022**

TABLE III. PAIRWISE COMPARISON MATRIX OF CRITERIA WITH RESPECT TO BUILDING USE

	RM	PR	SM	PA	SK	BK	RT	HT	IU	NW
RM	1.000	1.125	1.286	1.500	1.800	2.250	3.000	4.500	9.000	**0.200**
PR	0.889	1.000	1.143	1.333	1.600	2.000	2.667	4.000	8.000	**0.178**
SM	0.778	0.875	1.000	1.167	1.400	1.750	2.333	3.500	7.000	**0.156**
PA	0.667	0.750	0.857	1.000	1.200	1.500	2.000	3.000	6.000	**0.133**
SK	0.556	0.625	0.714	0.833	1.000	1.250	1.667	2.500	5.000	**0.111**
BK	0.444	0.500	0.571	0.667	0.800	1.000	1.333	2.000	4.000	**0.089**
RT	0.333	0.375	0.429	0.500	0.600	0.750	1.000	1.500	3.000	**0.067**
HT	0.222	0.250	0.286	0.333	0.400	0.500	0.667	1.000	2.000	**0.044**
IU	0.111	0.125	0.143	0.167	0.200	0.250	0.333	0.500	1.000	**0.022**

E. Check the Consistency

The calculated CR was 0 and 0.095 from the Table V and Table IV indicates a reasonable level of consistency in the pairwise comparisons and the weighted are accepted. So the value of normalized weight has been validating using CR to get the consistent value. Then, the integration between AHP and GIS weights is done using Spatial Analyst extension which is raster calculator to multiply weights obtained with the criteria maps.

TABLE IV. THE EVALUATION OF CRITERIA

Criteria
Land Use Building Use
CI = 0 CR = 0 (≤ 0.1)

TABLE V. THE EVALUATION OF SUB CRITERIA

	Land Use	Building Use
CI	0.139	0.139
CR	0.095	0.095

F. Mapping Phase Using GIS

The criteria considered when determining the potential area: land use and building use. In this study, layers overlay to raster conversion, clipping processes using GIS function and calculating criteria weight using an application based on AHP technique makes out the manipulation of this study. Using GIS capabilities, criteria maps were converted to raster then they were classified into several classes. Finally, suitability map for potential crime area will be generated. Suitability map resulted by integrating criteria weights from AHP with the criteria maps into raster calculator function in ArcGIS software. This result will present a rank of highest and lowest suitability areas. Then suitability classification is divided into three classes to get the accurate result. The result is the suitability map shown in

Figure 4. Finally the map was classified into high suitability, medium suitability and low suitability.

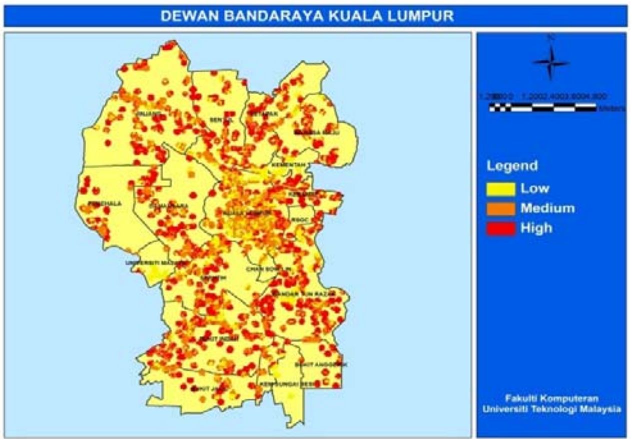

Fig. 4. Suitability Map for Potential Crime Area

G. Comparison Study

This section, we present comparison results of AHP and GIS with conventional MCDM and GIS. Therefore, using the same set data with full features, experiment using conventional MCDM is carried out. Figure 5 indicates that the result from the comparison techniques. The weight value from the conventional MCDM was not reliable because there is no validation process in how to determine the accurate value.

TABLE VI. COMPARISON RESULTS

Sub Criteria	Normalized Weight Using AHP	Validation	Weight Value Using Conventional MCDM	Validation
Land Use				
KD	0.200		9	
PN	0.178		8	
KR	0.156		7	
KT	0.133		6	
IK	0.111	CR = 0.095 (≤ 0.1)	5	No Validation
PI	0.089		4	
IU	0.067		3	
TK	0.044		2	
PH	0.022		1	
Building Use				
RM	0.200		9	
PR	0.178		8	
SM	0.156		7	
PA	0.133		6	
SK	0.111	CR = 0.095 (≤ 0.1)	5	No Validation
BK	0.089		4	
RT	0.067		3	
HT	0.044		2	
IU	0.022		1	

VII.

VIII. Discussion And Conclusion

This paper proposed integration between MCDM approach represented by the AHP and GIS to identify the potential crime area based on the factors that influenced. AHP method was found to be a useful method to determine the weights. In the proposed model, an application was designed in AHP environment to calculate the weights of the criteria and GIS functionality was used to extract the suitability map with the weights calculated. As a result of the study, we find that proposed model is effective and practical for identifying the potential crime area with respect to multiple criteria. The AHP method can deal with inconsistent judgments and provide a measure of the inconsistency of the judgment of the respondents. This study confirms that the integration of AHP method and GIS is a new trend in crime suitability analysis to identify the potential crime.

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