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Spatial Pattern and GIS-Based Model for Risk Assessment – A Case Study of Dusit District, Bangkok

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Abstract**—**The objectives of the research are to study patterns of fire location distribution and develop techniques of Geographic Information System application in fire risk assessment for fire planning and management. Fire risk assessment was based on two factors: the vulnerability factor such as building material types, building height, building density and capacity for mitigation factor such as accessibility by road, distance to fire station, distance to hydrants and it was obtained from four groups of stakeholders including firemen, city planners, local government officers and local residents. Factors obtained from all stakeholders were converted into Raster data of GIS and then were superimposed on the data in order to prepare fire risk map of the area showing level of fire risk ranging from high to low. The level of fire risk was obtained from weighted mean of each factor based on the stakeholders. Weighted mean for each factor was obtained by Analytical Hierarchy Analysis.

Keywords**—**Fire Risk Assessment, Geographic Information System: GIS, Raster Analysis and Analytical Hierarchy Analysis.

I. Introduction

DUSIT area is in the internal area of Bangkok, consisting of 42 communities, classified as slum 19 communities and urban area 23 communities. Most land ownerships belong to Bureau of the Crown Property. The area consists of commercial and residential areas, military zone, historical and art-cultural tourist attractions. Moreover, it is the location of Thai parliament, Ministries and royal palaces. Nowadays, the Bureau of the Crown Property has a policy to develop residential areas in the communities, selecting pilot communities because there is a royal palace area and historical and art-cultural tourist attractions in this zone, including it has many educational institutes. As a result, the researchers has realized the importance of such an area and aware of people safety who are coming in the Dusit area. This includes local people and travelers who are travelling between the Dusit and nearby areas. So it requires application of geographic information system to define vulnerable areas for fire hazard extension in the area and use it as a warning tool for every group of people. It is also a database used for vigilance by the communities and government units for fire hazard propose**.**

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II. Objective of Study

The objectives of the research are to study patterns of fire location distribution and develop techniques of Geographic Information system application in fire risk assessment for fire planning and management.

III. Methodology

A. Spatial Pattern Analysis

The Average Nearest Neighbor tool measures the distance between each feature centroid and its nearest neighbor's centroid location. It then averages all these nearest neighbor distances. If the average distance is less than the average for a hypothetical random distribution, the distribution of the features being analyzed is considered clustered. If the average distance is greater than a hypothetical random distribution, the features are considered dispersed. The average nearest neighbor ratio is calculated as the observed average distance divided by the expected average distance (with expected average distance being based on a hypothetical random distribution with the same number of features covering the same total area [1].

1.Calculations

The Average Nearest Neighbor ratio is given as

$$ANN = \frac{\overline{D}_O}{\overline{D}_E} \quad (1)$$

where $\overline{D}_o$ is the observed mean distance between each feature and its nearest neighbor.

$$\overline{D}_o = \frac{\sum_{i=1}^{n} d_i}{n} \quad (2)$$

and $\overline{D}_E$ is the expected mean distance for the features given in a random pattern:

$$\overline{D}_E = \frac{0.5}{\sqrt{n/A}} \quad (3)$$

In the above equations, d_i equals the distance between features i and its nearest neighboring feature, n corresponds to the total number of features, and A is the area of a minimum

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enclosing rectangle around all features, or it's a user-specified Area value.

The average nearest neighbor z-score for the statistic is calculated as:

$$Z = \frac{\overline{D_O} - \overline{D_E}}{SE} \quad (4)$$

where

$$SE = \frac{0.26136}{\sqrt{n^2 / A}} \quad (5)$$

2. Interpretation

If the index (average nearest neighbor ratio) is less than 1, the pattern exhibits clustering. If the index is greater than 1, the trend is toward dispersion.

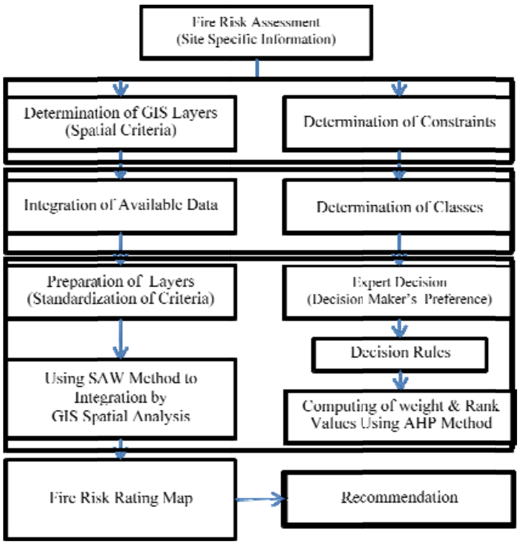

Fig. 1 Framework for GIS-based and spatial multi-criteria decision analysis (MCDA) for fire risk assessment

B. Fire Risk Assessment

In this analysis process, the study provides a geo-referenced building footprint map was made available in digital format by the Public Works and Town & Country Planning Department, Ministry of interior, of the Government of Thailand. The footprints of the building had been extracted from aerial photographs that were taken in 2004. The GIS layer maps with buildings, roads and drainage information were printed at a scale 1: 4000 in order to be used as a base map for subsequent field surveys. Each building block on the footprint map was given a unique identification number as a reference number to identify the individual buildings in the field. Hence, fire risk areas could be selected based on the results from spatial patterns analysis before the occurrence of the fire, as well as significant factors influencing inflammability or potential fire vulnerability in cities. There are 5 significant vulnerabilities related to fire spread and 6 significant factor related to fire handling capacity. Each factor was considered; base on score measurement and weighting, as well as the application of GIS. The approach of the fire risk assessment is illustrated in Fig. 1.

GIS-grid-based fire risk assessment model development A GIS-grid-based fire risk assessment was developed to determine the level of fire risk zones in term of mapping fire vulnerability by assessing in relative importance between fire hazard criteria and the locating of fire incidents [2]. A developed the fire hazard model. This model was developed based on stakeholder analysis, considering the influence of several factors in fire hazard [3]. There were 4 groups of stakeholder firemen, city planners, local government officers and local residents-involved in defining the weight of alternative comparison factors. For this research, the methodology was modified so that an analytical hierarchy process (AHP) was used to identify the score and weight of each, followed by a summation of the results to yield a fire risk assessment model:

$$H = \sum W_i X_i \quad (6)$$

where H is the composite fire risk assessment value, W is the weight of factor i, and X is the vulnerability criterion score of factor i

To determine weight, The AHP method developed by Saaty [3] was applied. AHP is a theory-based approach to computing the weights representing the relative importance of criteria. Weights are not assigned directly, but represent a "best fit" set of weights derived from the eigenvector of the square reciprocal matrix used to compare all possible pairs of criteria [4].

3. Determination of Fire Risk Assessment Factors

The selection of variable affecting fire risk assessment is an important step in this research. There are 2 main factors affecting the spread of fire risk assessment: The vulnerability factors and the capacity of mitigation factors [5].

TABLE I
WEIGHTING OF FACTOR FOR FIRE RISK ASSESSMENT

Factors	weights
a. Vulnerability factors	
(1) Building material types	0.46
(2) Building height	0.167
(3) Building density	0.207
(4) Population density	0.065
(5) Building hazard occupancy	0.053
(6) Availability fire source	0.048
Consistency Ratio (CR)	*0.1*
b. Capacity of mitigation factors	
(1) Accessibility by road	0.518
(2) Distance to fire stations	0.222
(3) Distance to hydrants	0.113
(4) Fire history	0.096
(5) Distance to water supply	0.051
Consistency ratio (CR)	0.08
c. Main factors of fire hazard	
(1) Vulnerability factor	0.75
(2) Capacity of mitigation factor	0.25
Consistency ratio (CR)	0.001

Mapping of fire risk assessment by combining weights and scoring in GIS Spatial Analyst

The final step is to combine all the weights and score the equation:

$$H = \sum W_i X_i \quad (7)$$

The summation of all the weights values for each factor was done using the map calculator in GIS Spatial Analyst.

IV. Result and Discussion

A. The Results of Spatial Pattern Analysis

A visualization of spatial pattern analysis of fire location presented a dispersed pattern, with characteristics mixed between clustered and random distribution patterns with in Dusit district.

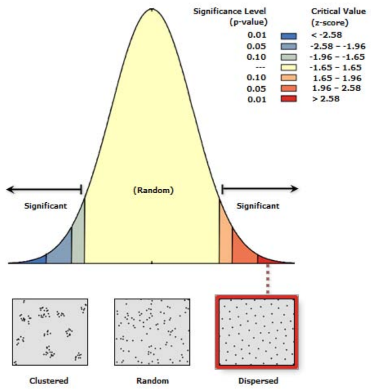

Fig. 2 The spatial patterns of fire hazard

B. The Results of Fire Risk Assessment

The overall picture of fire risk areas illustrated that there was no area that demonstrated non-fire risk. Based on this calculations showed evidence of a high level of fire risk 5 % of the total area, mostly at the slum and government office, demonstrated a low level of fire risk (Tables II and III).

TABLE II
Summary of Fire Risk Area

Capacity Score	Area	Percentage
High	751	5
Moderate	6,012	41
Low	8,056	54
Sum	14,819	100

TABLE III
Summary of Fire Risk Area from Sub District

Area	Low	Moderate	High
Dusit	2,190	1,023	132
Si Yeak Mahanak	136	229	1
Suan Chit Lada	861	808	40
Nakon Chaisi	3,880	3504	440
Wachira Phayaban	989	448	138
Sum	8,056	6,012	751

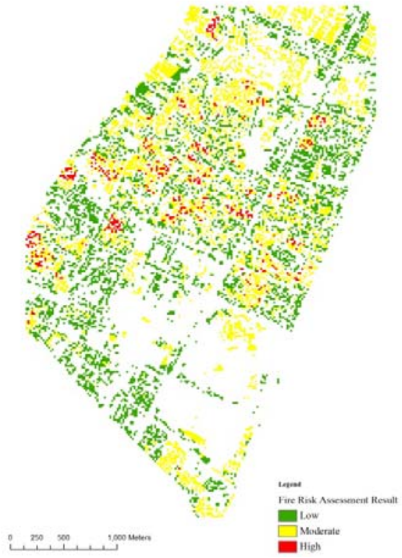

Fig. 3 Fire risk area

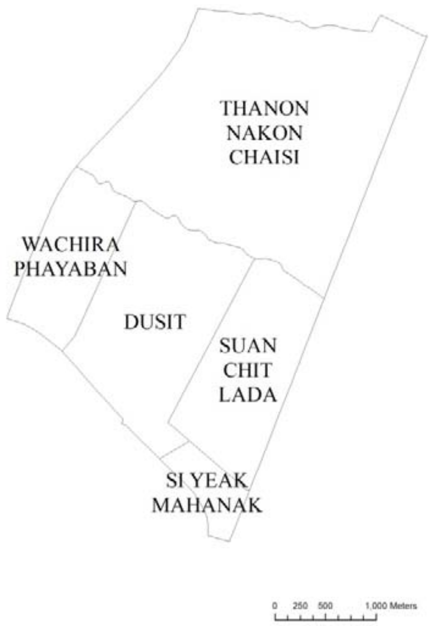

Fig. 4 Sub-district from dusit district

V. Conclusion

The findings found after the study would be beneficial for security-planning units in the area, communities and general people. The most benefits received would help reduce losses and damage from the fire hazard in the Dusit area. Furthermore the researchers expect that the application of the geographic information system would be a new solution for fire vigilance.

Information used in the geographic information system shall consider weather conditions and shall not apply the same vulnerable area factors for fire hazard and the weighting values for every area owing to each area has its own specific characteristic.

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