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Expert System Development for Urban Fire Hazard Assessment. Study Case: Kendari City, Indonesia

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Abstract. Kendari City is a coastal urban region with the smallest area as well as the largest population in Southeast Sulawesi. Fires in Kendari City had rather frequently occurred and caused numerous material losses. This study aims to develop a model of urban fire risk and fire station site assessment. The model is developed using Expert Systems with the Geographic Information System (GIS). The high risk of fire area is the area which of high building density with combustible material, not crossed by arterial nor collector road. The fire station site should be appropriately close by high risk of fire area, located on arterial road and near with potential water resource.

1. Introduction

Event Development and growth of urban areas in Indonesia has increased in each year. This can be seen by the increasing area of urban, the new growth centres and the increasing number of population living and doing activity in urban area. Currently, there is 53 percent of Indonesian population being the urban community and living in urban area [1]. Generally, the driving factors for urban area development are the increasing population naturally and/or by the migration process. These factors impact on the urban itself, namely the increasing demand on the public service facility and infrastructure, service and trade service facility, transportation, clean water and other infrastructures. The urban population growth also impacts on the change of land use, population density, transportation demand, entertainment, increasing security and other aspects.

The general reality of urban development in Indonesia currently is the physical growth of urban space not supported by environment carrying capacity, strict devices and regulation. These lead to the uncontrolled urban growth and development. The appropriate urban spatial will create harmony between natural environment and artificial environment as well as create the protection on spatial function and prevention on negative impacts on the environment caused by urban spatial utilization. The urban spatial will also increase the area ability or decrease its vulnerability on various possible negative risks, both naturally or non-naturally. One of the important aspects and often neglected in urban and area spatial is the planning. Indonesia is a country with quite high disaster potency because geographically, the area is located in the equator area having morphology with various lands until high mountains, the movement activity of active tectonic plate around the Indonesian seas, so that it creates earthquake track, series of active volcanoes and geological fault as earthquake and landslide-prone areas. The disaster potency includes the main hazard potency, such as earthquake, landslide, volcano eruptions, tsunami, flood, and collateral hazard potency such as fire, epidemic and social conflict. The

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highest potency of collateral hazard is in urban area having high population density, land use complexity, urban population activity centre, building materials and urban slump areas.

The high risk of urban area in Indonesia on the disaster can be seen from the area vulnerability, including the physical area vulnerability, social and economic population. The physical vulnerability describes the estimation on damage level on the environment facility and infrastructure if there are any certain hazardous factors, in social and economic population aspects related to the community capacity and condition in facing the disaster. The fire is one of the disaster types often found in urban area, mainly in area in dense population or area with high activity, such as commercial area. The area with dense population contributes on the increasing vulnerability on urban fire. The danger risk of urban fire can be decreased by good urban planning concept, such as efficient land use and the road system supporting on the accessibility of fire engine [2].

Kendari City is one of the cities with the populous number of population in Southeast Sulawesi Province, in 2014, it reaches the number of 335.889 people, with the mean of population growth flow per year is 3,51 percent. Kendari City has the smallest regional area, namely 295,89 Km^2, or 0,78 percent of the area of Southeast Sulawesi Province region [3].

The large number of population by relatively small regional area has bigger potency on urban environmental problems, such as building density, disorderly of land use, bad sanitation, improper road facility, and the arising temporary semi-permanent or urgent buildings. Mantra wrote that the vulnerability on the fire disaster including the environment condition (width of entrance, availability of community field/parking lot), building materials, building structures and inter-building distances [4].

The fire disaster in Kendari City often and it causes quite large material losses. There was one of the biggest fire events in 2015, it caused losses until billion rupiah. The fire was in company building, namely PT. Daka Samudera. The firefighter arrived at the location in 15 minutes after the warning on the fire [5]. The high urban city intensity and risk level in Kendari city is mostly caused by the very limited number of firefighter station, namely one station is for the service of all urban area, as well as the slow firefighter response time service, namely the mean service time is ≥15 minutes since the fire is started.

The previous research on comparison of fire service response time on the number of firefighter station in Dubai shows that the 5 (five) minute-response time requires 13 stations, 4 (four) minute-response time requires 20 stations and 3 (three) minute-response time requires 25 stations [2][7], described most urban area in California had service standard, the firefighter arrived on the incident location with 9 minute-response time since the fire. This is addressed that the protection on urban fire disaster must be done by quick response. Standard of fire response time according to NFPA 1710 (2001) is four minutes (240 seconds) or less for the arrival of the first arriving engine company at a fire suppression incident and/or eight minutes (480 seconds) or less for the deployment of a full first alarm assignment at a fire suppression incident [8].

This research tries to conduct the assessment model on the fire disaster risk level and site of fire station, as the mitigation efforts of fire disaster in urban area based on some physical aspects and availability of facility and infrastructure in the affecting area.

Table 1. History of fires on 2012-2016 in Kendari City, Indonesia (Source: Fire Department of Kendari City, 2016)

Years	Location (Subdistrict)	Caused	Fire types	Constraint of firefighting	Material looses (IDR)	Fatalities
2012	Abeli, Baruga, Kadia, Kambu, Kendari, West Kendari, Mando-nga, Poasia, Pu-watu, Wua-wua	Candle lamp, electrical short circuit, fireworks, bursting stove, mosquito coils, garbage burning, fireplace, undetected	Bladygrass, storehouse, kiosk, cooperation, stall, market, coconut trees, residence, shophouse	High elevation, narrow roads, throng, water exhaust-machine not optimal	22.493.500.000	None
2013	Abeli, Kadia, Kambu, Kendari,	Electrical short circuit, bursting stove, mosquito	Bladygrass, machine shop, hotel, office, kiosk, car, market	Fire engine not optimal, electric current hazard,	24.227.000.000	None

Years	Location (Subdistrict)	Caused	Fire types	Constraint of firefighting	Material looses (IDR)	Fataliti es
	Mandonga, Poasia, Puwatu, Tobuuha and Wua-wua	coils, land combustion, garbage burning, stub, fuel oil spilled, fireplace, burnt by person, undetected	residence, shophouse, place of business	road damaged, narrow roads, unavailable water for firefighting		
2014	Abeli, Baruga, Kadia, Kambu, Kendari, West Kendari, Mandonga, Poasia, Puwatu and Wua-wua	Candle lamp, electrical short circuit, bursting stove, oil overflowed, land combustion, garbage burning, stub, gasometer, undetected	Bladygrass, bulk asphalt, tire, warehouse, compa-ny building, worker base camp, machine shop, powerhouse, generator, storehouse, office, homestead garden, kiosk, peatland, sago trees, car, motorcycle, crackers factory, market, residence, shophouse, garbage, bunk, woodpile	Fire engine not optimal, smoke, electric current hazard, traffic jam, road damaged, narrow roads, the rising road, far travelled distance, traffic density, not accessed by roads, woodpile	21.679.500.000	2 person (pass away)
2015	Abeli, Baruga, Kadia, Kambu, Kendari, West Kendari, Mandonga. Poasia. Puwatu and Wua-wua	Electrical short circuit, fuel pipe leakage, regulator hose leakage, fireworks, mosquito coils, land combustion, garbage burning, stub, piece of electrical weld, fireplace, undetected	Bladygrass, warehouse, company building, worker base camp, machine shop, powerhouse, storehouse, college, office, home-stead garden, kiosk, peatland, sago trees, car, market, hospital, school, residence, shophouse, garbage, gasometer, weld tube, woodpile, sawmill, shrubland	Smoke, road damaged, narrow roads, electric current hazard, high elevation, slippery road, traffic jam, roadwork, not accessed by roads	141.724.500.00 0	None
2016 (inclu-sive to August)	Abeli, Baruga, Kadia, Kambu, Kendari, Mandonga, Poasia, Puwatu, Wua-wua	Electrical short circuit, gas leakage fireworks, bursting stove, gas explosion, land combustion, garbage burning, stub, undetected	Bladygrass, powerhouse, motor boat, kiosk, peatland, school, residence, shophouse, barbershop, gasometer	Electric current hazard, traffic jam, road damaged, narrow roads, fire on the sea, not accessed by roads, un- available fire-escape	10.225.000.000	1 person (injur ed)

2. Methods

According The high urban population activity leads to bigger opportunity of fire in urban area. The general conditions including physical, social economic and political factors are one of the potencies for a group of community to be more vulnerable to get a disaster. Toki stated that most fire in dense areas in urban area relates to human habits or behavior, but the fire disaster risk can be reduced or eliminated overall by the availability of appropriate environmental infrastructures, such as the availability of hydrants in dense residence area [9]. Murray (2013), wrote that all of urban areas must be protected from fire disaster hazard, the firefighter must give rapid responses and services. The fire station services have long been a perquisite in the availability of urban facilities [7]. The use of service response time standard by the fire station tries to reduce the risk for human and property losses.

Expert systems are computer programs that apply artificial intelligence to narrow and clearly defined problems. Expert systems typically combine rules with facts to draw conclusions; the process relies heavily on theories of logical deduction. Both heuristic methods and conventional computer programs (e.g., FORTRAN programs) are often used in expert systems. The expert system for site selection helps a user develop a set of site attributes and determine their weighted relative importance. The site selection knowledge base of expert system consists of four parts: the knowledge acquisition, induction, design, and decision analysis units [10].

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The major research area for artificial intelligence includes natural language processing, symbol processing, rule-based system and logic systems. The development of functional expert systems is always centered on the organization of a knowledge base. Knowledge engineers collects and organizes knowledge gathered from domain expert then convert the expert knowledge into a form which computer expert system understands and save those converted knowledge into the knowledge base. Users enter the collected facts into the system via the user interface and save the data into the fact base. Finally, users get the results, recommendations and explanations from the system [11].

Study about urban fire hazard which covered fire risk assessment and fire station site was done by expert system approach method. This expert system came from knowledge-based expert system, i.e. a system using human knowledge which then was inserted into computer to solve problem that generally needs an expert's expertise. This expert system procedure works by imitating knowledge and thinking process of an expert in solving complicated problem. The system designing uses hardware, i.e. personal computer (PC) or notebook and software, i.e Geographic Information System (GIS) application (ArcGIS, ArcView, etc.), Fortran and Quick Basic. This system was operated in Microsoft Windows Operation System.

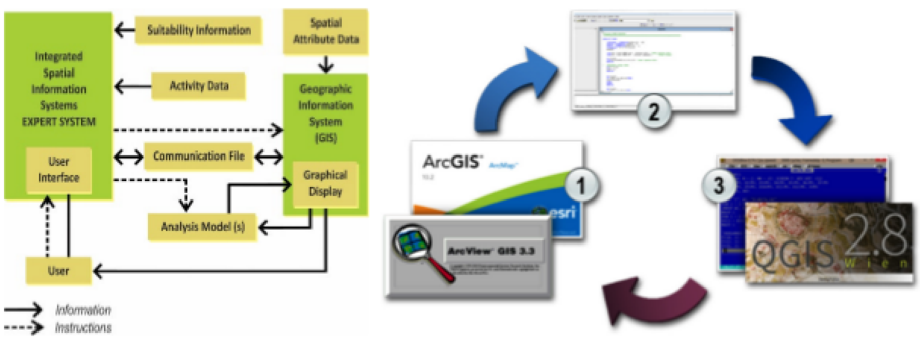

Figure 1. The expert system model procedure for urban fire. Source: Kim *et al*, 1990, Author, 2016

The development of GIS has provided a powerful tool for managing and solving emergency management problems. GIS is a professional computer system for collecting, storing, managing, retrieving, transforming, analyzing, and displaying of spatial data. It can be used for many kinds of purpose in both macro and micro scales. GIS were designed to support geographical inquiry and, ultimately, spatial decision making. Especially in the natural disaster area, GIS has been applied in the simulation and early warning system, emergency management system, and disaster damage assessment, etc. [12]

GIS approach can be assess of the fire risk, based on historical and current data and translated under cartographic shape, can be a remarkable contribution to the forest managers and a tool for a better preventive decision, based on logical bases. Indeed, these cartographic documents of the degree of risk reveal sectors of high sensibility at the fire risk [13]

Substances used in this urban fire research, were obtained from several sources which covered primary and secondary data. Primary data was obtained from field survey activity, included data about land use, building material types, and potential water source location. Secondary data included satellite imagery, administration boundaries map, forest area status map, road hierarchy map, etc. Apart from those two, we also use our own analytic data i.e. GIS grid based map (amount 4529 grids, each 250 m x 250 m or 62.500 m^2) and map of high risk fire area based on grid.

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3. Result and Discussions

3.1 Urban fire risk

According to The urban fire risk was analyzed by determining factors which influence urban fire rate, i.e. combustible or non-combustible building material, building density, whether the area was crossed by arterial or collector road, and the distance from potential water source. Every influencing factor was then given weight based on its influence on fire risk, in the form of Certainty Factor (CF). Those factors were then made into a knowledge represented method i.e. risk rule in the form of the pair of condition-action or if-then. Risk rule is stated as implication of two part i.e. "if" part and "then" part. If "if" part is fulfilled, then "then" part will be valued as right. If "if" part is not fulfilled, then "then" part will be shifted to the following "then" part.

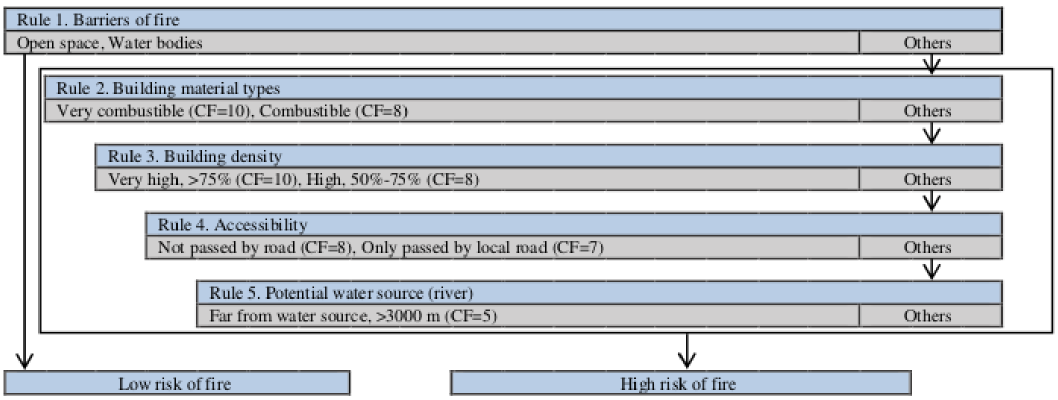

Figure 2. System chart for urban fire risk (Source: Authors, 2016)

The fire risk in Kendari City, was rated by expert system approach by using GIS Grid shows the risk degree which was then classified into four classes, i.e. (1) Very high risk, amounting to 586 grids, (2) High risk, amounting to 441 grids, (3) Low risk, amounting to 1861 grids, (4) Very low risk, 1641 grids. The influencing factors of fire risk rate are: (1) area infrastructure, included road dimension and fire engine accesibilty, and water source for fire fighting, included hydrant, (2) building material type, included combustible and non-combustible building, (3) response time service of firefighting.

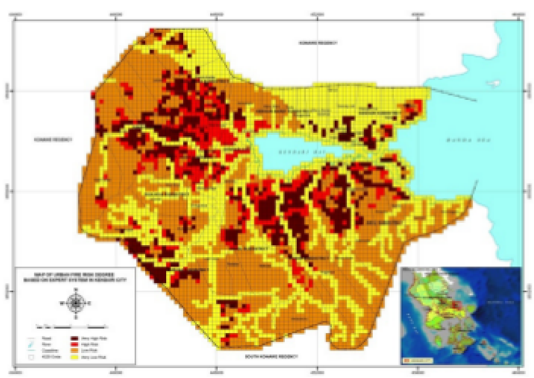

Figure 3. Map of urban fire risk degree based on grid.
Source: Authors, 2016

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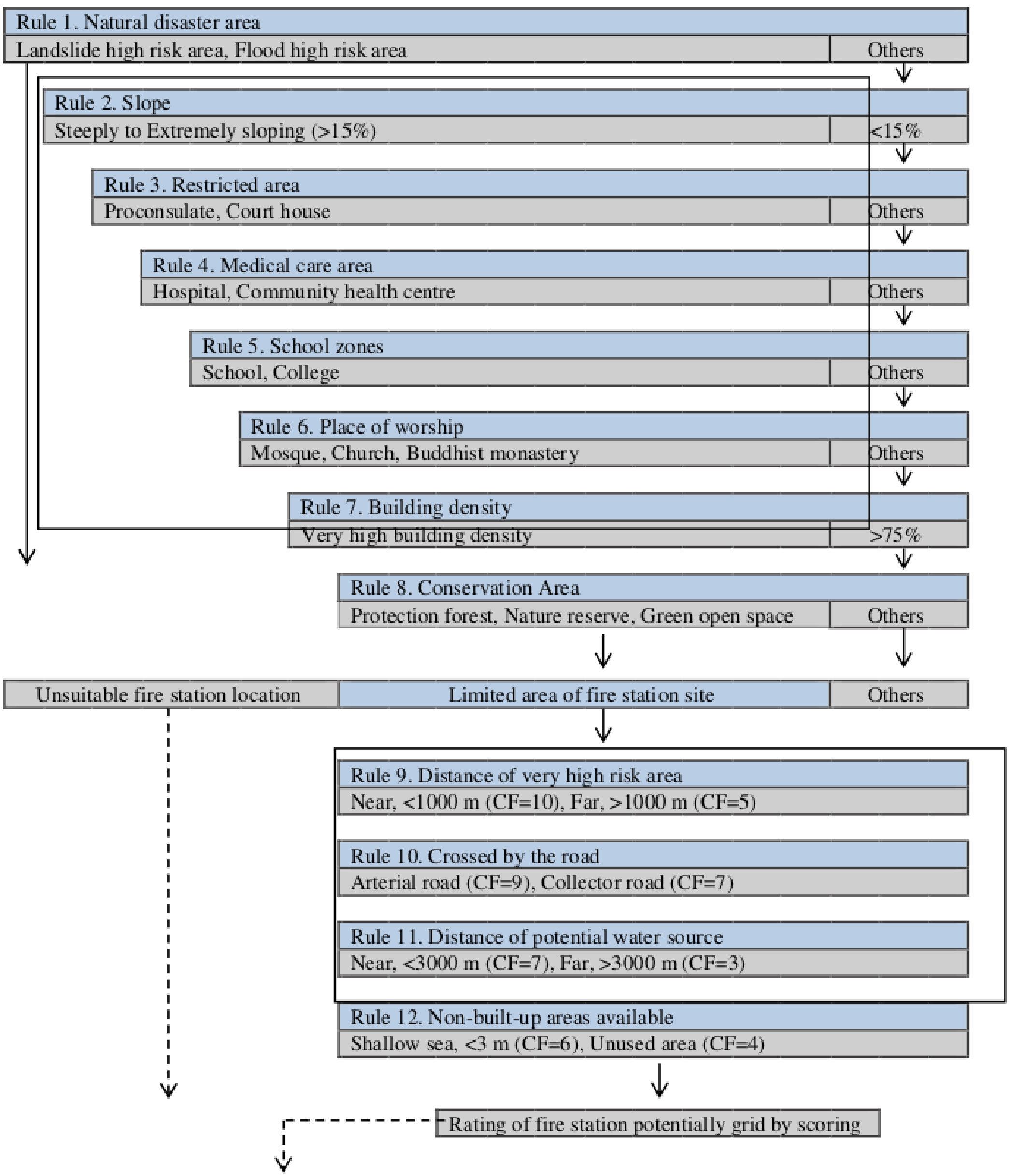
3.2 Fire station site

Fire station location determination was based on several supporting factors i.e. it's near with high risk of fire area, being crossed by arterial and collector road, the distance from potential water source (<3000 m), and categorized as unused area. In addition to supporting factors, the analysis was also conducted to several inhibiting factors in fire station site, i.e. natural disaster area, conservation area, slope degree >15%, restricted area, school zone, and place of worship area. Supporting factors are scored, ranged from lowest score 4 (CF=4) to highest score i.e. 10 (CF=10). While inhibiting factors are scored 1 if it exists and 2 if it doesn't.



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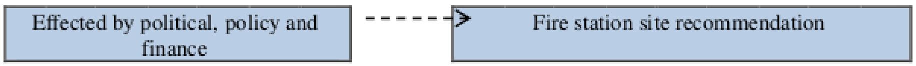

Figure 4. System chart for fire station site (Source: Authors, 2016)

The analysis of fire station location based on expert system approach by using GIS Grid resulted fourty nine chosen locations, i.e. (1) Suitable I, consists of grid no. 1268 and 1337, (2) Suitable II, amounting to 33 grids, (3) Suitable III, amounting to 14 grids. Out of these 49 grids, the others are unsuitable areas to set the location of the fire station.

Table 2. Chosen grid for fire station site suitability in Kendari City

No.	Suitability	Grid number	Value
1.	Suitable I	1268, 1337	37-40
2.	Suitable II	1033,1034,1037,1042,1043,1044,1110,1115,1118,1123,1183,1198,1267,1269,1335,1396,1496,1501,1552,1553,1609,1807,1808,1812,1967,1968,2040,2041,2202,2277,2460,2559,3507	33-36
3.	Suitable III	1167,1178,1201,1237,1343,1345,1450,1451,1752,1834,1985,1986,3328,3496	29-32
4.	Unsuitable	Out of these 49 grids	<29

Source: Authors, 2016

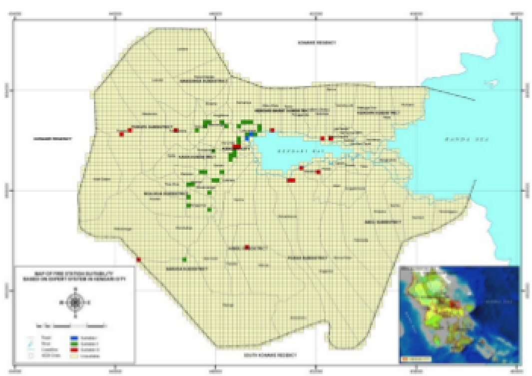

Figure 5. Map of fire station site suitability based on grid. Source: Authors, 2016

4. Conclusion

The research result studied in Kendari City through Expert System Approach, based on GIS Grid shows that:

1. The high risk of fire area is the area which of high building density with combustible material (wood and mixed material) also not crossed by arterial nor collector road (only crossed by local road). The low risk area is generally the non-built-up areas which consist of water body, open space and vegetation.
2. The fire station site should be appropriately close by high risk of fire area, located on arterial road and near with potential water resource to extinguish the fire. The response time service of fire extinguishing (from chosen fire station) toward high risk of fire area should be 4-5 minutes since fire alert.
3. The Expert System approach as a model for urban fire hazard assessment can be shows of the fire risk, including the degree of fire risk, based on existing data and selecting one or more of the fire

station site available alternatives).

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