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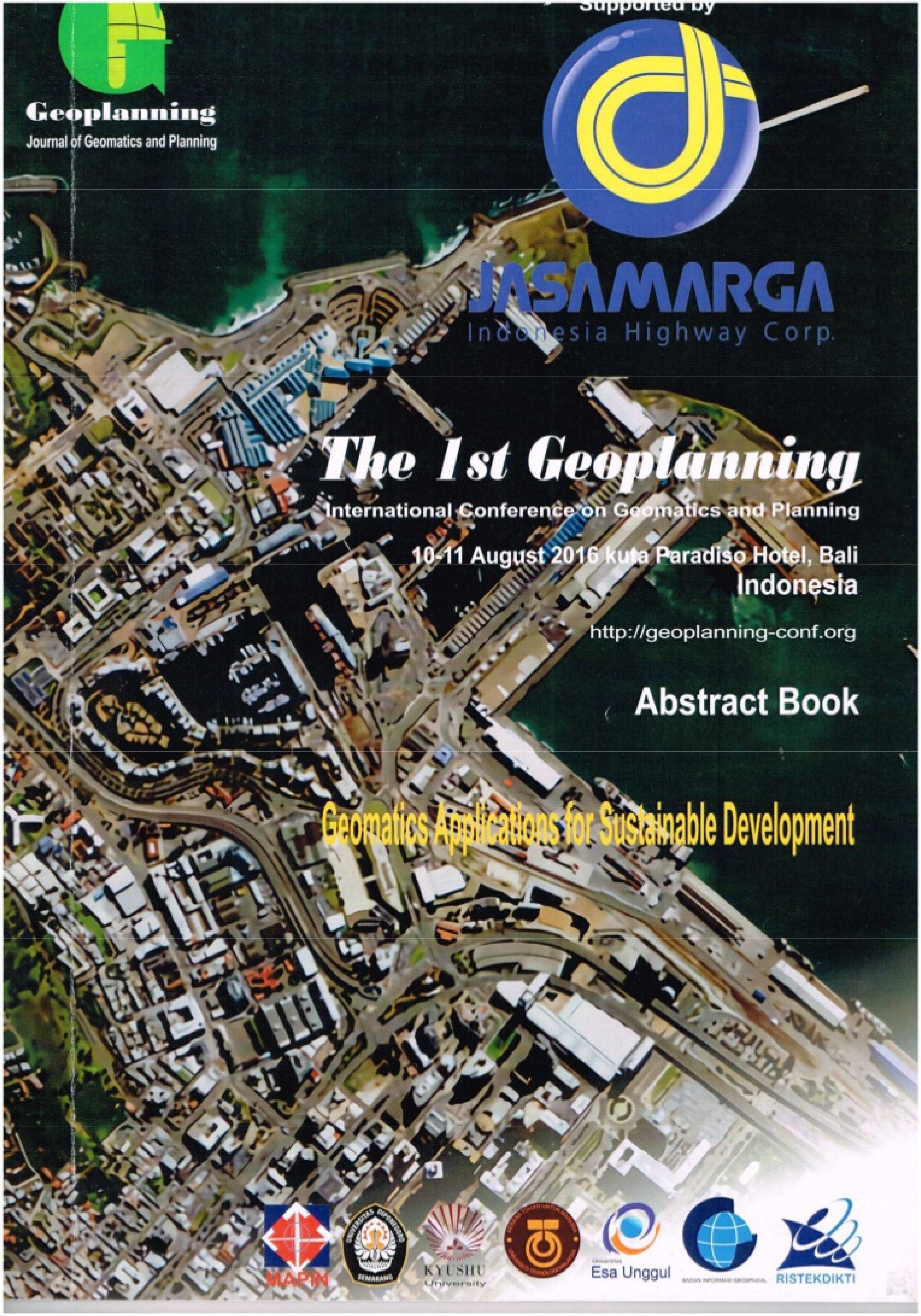

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*Name of Article*:

**A GIS-BASED MODEL FOR URBAN FIRE RISK AND FIRE STATION ALLOCATION ASSESSMENT. THE CASE OF CENTRAL BUSINESS DISTRICT (CBD), KENDARI CITY, INDONESIA**

*Name(s) of Contributor (s)*:
SABRILLAH TARIDALA, ANANTO YUDONO, M. ISRAN RAMLI, ARIFUDDIN AKIL, M. YAHYA SIRADJUDDIN

# A GIS-based Model for Urban Fire Risk and Fire Station Allocation Assessment. The Case of Central Business District (CBD), Kendari City, Indonesia

**Sabrillah Taridala[a], Ananto Yudono[a], M. Isran Ramli[a], Arifuddin Akil[a], M. Yahya Siradjuddin[a]**

[a] *Hasanuddin University, Indonesia, email: abhytaridala@yahoo.co.id*

**Abstract**: *Fire is a type of disaster that frequently occurs in urban areas, especially in high population density and activities area, such as commerce areas. High population density and the complexities of land use contribute the most to increase the vulnerability of urban fires. Kendari City is an urban area 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. The largest fire incident in 2014 resulted to billions rupiahs losses. The fire occurred in a commerce area, "Pasar Higienis Kendari" destroying about 1,000 kiosks/market stalls. The fire risk may occur when hazards meet with vulnerable community and area, which of short capacities or without capacity at all in responding the hazard. This study aims to develop a model of risk assessment and fire station allocation of urban fire disasters based on the physical conditions and infrastructure in urban areas. The model is developed using Expert Systems Approach with the Geographic Information System (GIS). Amongs the variables used i.e. population density, building materials, accessibility, topography, land use and distance to potentially water source. The research conducted in the Central Business District (CBD) of Southeast Sulawesi Province as location of test cases shows that 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 allocation should be appropriately close by high risk of fire area, located on arterial road and near with potential water resource. The urban area capacities in facing, reducing, or breaking of the risk of urban fire disasters, improving the structure of the urban space and integrating disaster aspects in urban spatial planning.*

*Keywords:* Urban fire, Risk fire, Fire station, Expert system, GIS

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## 1. INTRODUCTION

There is an increasing development of urban area in Indonesia each year. This can be seen by the increasing area of urban, the new growth centers 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 (Ministry of Public Work and People Housing, 2015). 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.

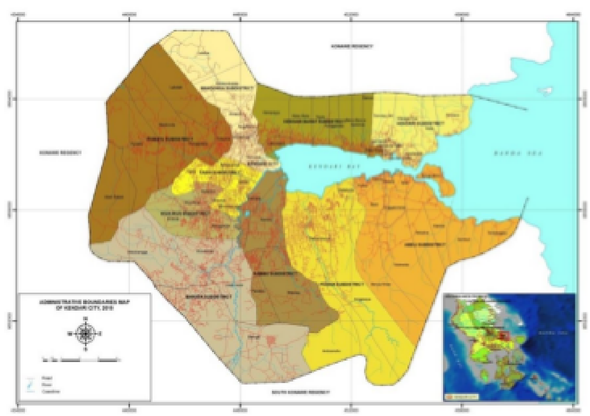
One of the important aspects and often neglected in urban and area spatial is the planning. Indonesia is a country with quite high disaster potency because geographically, the area is located in the equator area having morphology with various lands until high mountains, the movement activity of active 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 highest potency of collateral hazard is in urban area having high population density, land use complexity, urban population activity center, 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 pattern system supporting on the accessibility of firefighter vehicles (Chainey & Ratcliffe, 2005).

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 (Central Agency on Statistics, Southeast Sulawesi Province, 2015).

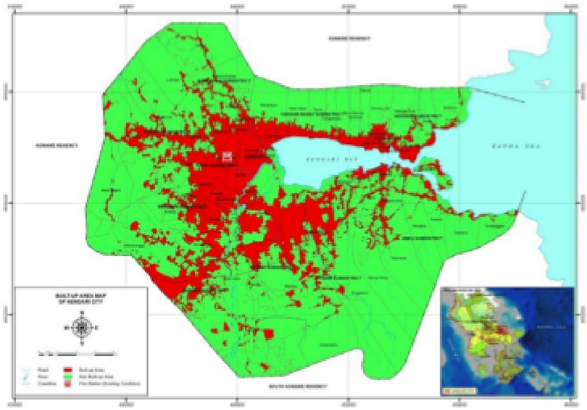
**Figure 1.** Administrative Boundaries Map of Kendari City (Source: Authors, 2016)



The large number of population by relatively small regional area has bigger potency on urban environmental problems, such as building density, irregular use of land, poor sanitation, improper road facility, and the arising temporary semi- permanent or urgent buildings. Mantra (2005) 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.

There is often the fire disaster in Kendari City often and it causes quite large material losses. There was one of the biggest fire events in 2014, it caused losses until billion rupiah. The fire was in commercial area, namely *Pasar Higienis* Kota Kendari (Hygiene Market Kendari City) burning 1000 market stalls. The fire burnt buildings taking for only 20 minutes to burn the buildings in the area. The firefighter arrived at the location in 15 minutes after the warning on the fire (Fire Department Kendari City, 2015). 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 ≥20 minutes since the fire is started.

**Figure 2.** Built-up Area and Fire Station Location Map of Kendari City (Source: Authors, 2016)



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 (Badri *et al*., 1998). Murray (2013), described most urban area in California had service standard, namely 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.

This research tries to conduct the assessment model on the fire disaster risk level and location of firefighter 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.

## 2. CONCEPT AND THEORY

### 2.1. Urban Fire

The rapid urban development and growth is a protection effort on fire disaster as an important part for the city in the disaster risk prevention and reduction effort. Himoto and Tanaka (2012) wrote that there was a decrease on the frequency of city fire in Japan from 1950 until 1960's significantly by modern fire handling system, namely by fire prevention before the fire spreads massively. The reduction on urban fire is also done by the improvement of urban spatial structure namely by land function arrangement; these can be done by expanding narrow road dimension, allocating new open spaces, and replacing wooden structure buildings by fire resistant buildings.

The high urban population activity leads to bigger opportunity of fire in urban area. The general conditions including physical, social economic, political and cultural area factors are one of the potencies for a group of community to be more vulnerable to get a disaster. Toki *et al* (2011) 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 settlement area.

All urban areas must be protected from fire disaster hazard; the firefighter stations must give rapid responses and services. The firefighter station services have long been a perquisite in the availability of urban facility. The use of service response time standard by the firefighter station tries to reduce the risk for human and property losses (Murray, 2013).

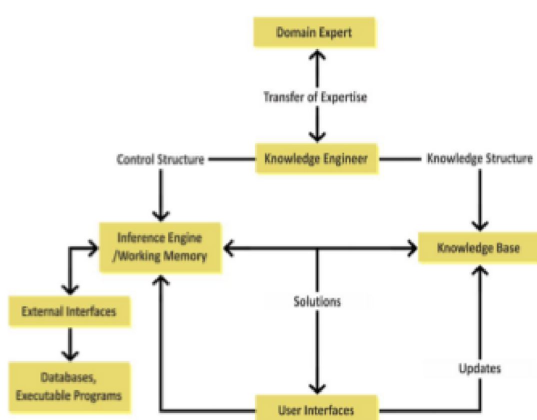
Mantra (2005) mentioned that in order to overcome the fire hazard, it is necessary to know to the fire flame time and amount to know the mean response time required to extinguish the fire before it burns combustible building materials passed by the fire. The stage of appropriate fire development to extinguish and reduce the losses is the transition era between the growth stage and flashover stage.

## 2.2. Expert System

Expert systems are computer programs that apply artificial intelligence to narrow and clearly defined problems. They are named for their essential characteristic: they provide advice in problem solving based on the knowledge of experts. Expert systems typically combine rules with facts to draw conclusions; the process relies heavily on theories of logical deduction developed by mathematicians and philosophers, and adapted to particular applications by engineers, scientists, planners, and managers across a wide range of disciplines. Both heuristic methods and conventional computer programs (e.g., FORTRAN programs) are often used in expert systems. The subject area of an expert system, such as site planning or zoning administration, is called its domain. The collection of facts, definitions, rules of thumb, and computational procedures that apply to the domain is called its knowledge base. Sources of that knowledge include published materials, quantitative analysis programs, and the intuitions and problem-solving strategies of experts in the subject area (Kim *et al.*, 1990).

Ikram & Qamar (2014) wrote that during 1980s, researchers began research artificial intelligence. United States, Japan, as well as many countries in Europe, began investing in the area of artificial intelligence and expert systems and during these time, many expert system tools began to emerge. The purpose of artificial intelligence is to broaden the application of computers to not only include numerical calculations but also to possess knowledge and therefore enhance the utilization of computers. 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.

**Figure 3**: Expert System Component (Source: Ikram & Qamar, 2014, Modified)




An expert system communicates with the end users through the user interface while gathers the knowledge it required through a knowledge acquisition interface which is used by knowledge engineers. The expert system has two features: (1) Frequent user interactions: An expert system collects data from the users and formulates the end results based on these data, and (2) Independent and dynamic knowledge base: The major difference of an expert system from a traditional program is that the knowledge is independent from the program flow.

Furthermore, Kim *et al* (1990) described that the expert system for site selection has been designed to aid land use planners, developers, or prospective land users. The system 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. The knowledge acquisition unit is used to collect and organize information provided by expert decision makers. The induction unit evaluates this information and generates rules and entity evaluation functions expressing the expert judgment. The decision unit uses the rules generated by the induction module and employs decision theory techniques for selecting one or more of the available alternatives.

**Figure 4**: Schematic Structure of The Expert System for Site Selection (Source: Kim *et al*., 1990)


2.3. GIS for Fire

The development of GIS (Geographic Information System) 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 (Gai *et al*., 2011).

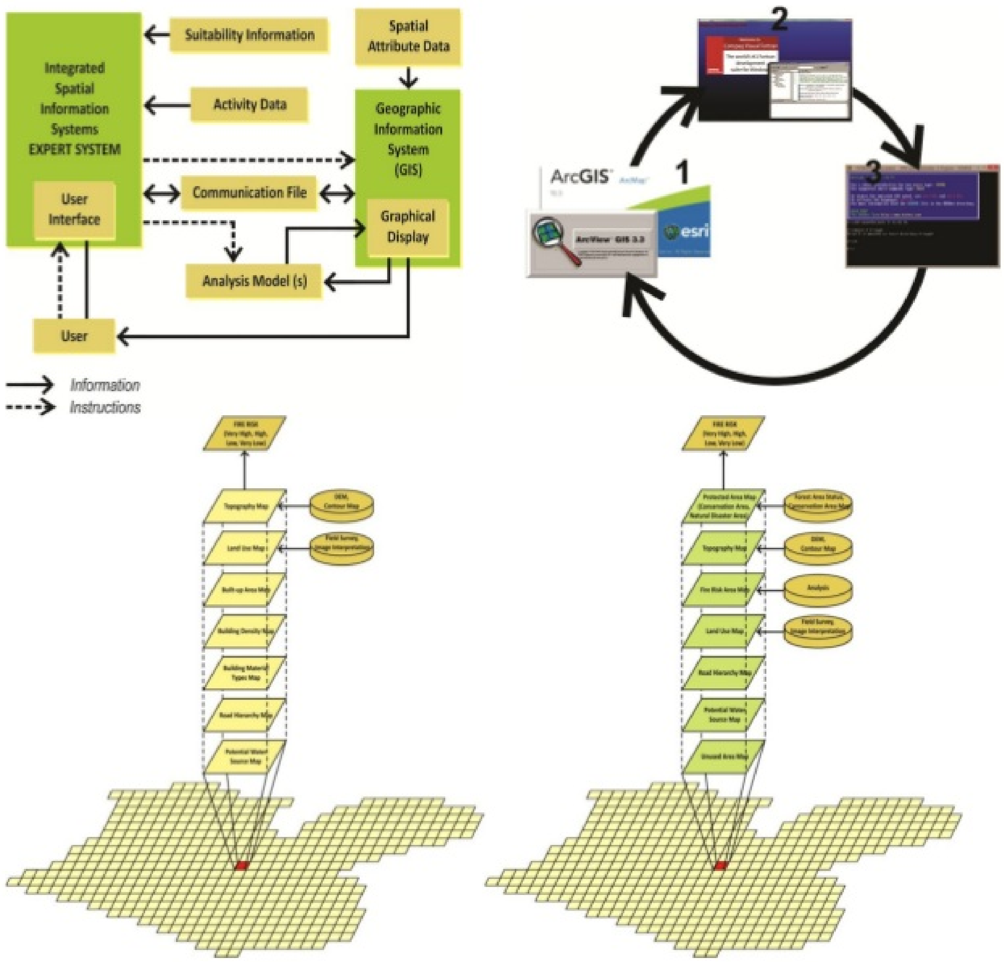
GIS approach can be assess of the fire risk, based on historical and current data and translated under cartographic shape, can be a remarkable contribution to the forest managers and a tool for a better preventive decision, based on logical bases. Indeed, these cartographic documents of the degree of risk reveal sectors of high sensibility at the fire risk (Guettouche *et al*., 2011).

ESRI (2012) described about calculating risk of fire. Risk is a chance of exposure to, or having an influence on, the conditions (hazards) that create harm or damage to people, property, or the environment. Using GIS to identify community hazards will provide accurate and accessible data with which to calculate risk. Hazard data modeled against the variables that influence the potential for harm provides the risk equation. Furthermore, described that response time analysis on GIS provides one good example of how many fire departments use the attribute data attached to the layers in a GIS to perform spatial analysis. Response times for service calls are critical. They can mean the difference between life and death and between the protection of property and damage or loss. GIS permits the powerful, yet intuitive, analysis of response times.

## 3. DATA AND METHODS

Study about urban fire hazard which covered fire risk assesment and fire station allocation 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 immitating knowledge and thinking process of an expert in solving complicated problem. The sytem designing uses hardware, i.e. personal computer (PC) or notebook and software, i.e GIS (ArcGIS or ArcView) application, Fortran and Quick Basic. This system was operated in Microsoft Windows Operation System.

**Figure 5**: The Expert System Model Procedure for Urban Fire (Source: Kim *et al*, 1990, Author, 2016)




### 3.1. Material

Substances used in this urban fire research, both for fire risk study and fire station allocation 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 was obtained from relevant institutions, included satelit 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 (100 m x 100 m or 10.000 $m^2$) and map of high risk fire area based on grid.

**Table 1**: Research Material for Urban Fire in Kendari City (Source: Authors, 2016)

| Types | Scale | Sources |
|---|---|---|
| Satellite Imagery (High Resolution) | 1:5.000 | August, 2015 |
| Administrative Boundaries Map | 1:25.000 | National Agency for Geospatial Information |
| Bathymetry Map | 1:500.000 | Regional Development Planning Agency |
| Topographic Map | 1:25.000 | National Agency for Geospatial Information |
| Forest Area Status Map | 1:250.000 | Department of Forestry |
| Natural Disaster Area Map | 1:50.000 | Regional Development Planning Agency |
| Land Use Map | 1:5.000 | Field Survey, Image Interpretation |
| Built-up Area Map | 1:5.000 | Authors Analysis |
| Building Density Map | 1:5.000 | Image Interpretation |
| Building Material Types Map | 1:5.000 | Field Survey |
| Road Hierarchy Map | 1:5.000 | Department of Public Works (modified) |
| Fire Risk Area Map | 1:5.000 | Authors Analysis |
| Potential Water Source Map | 1:5.000 | Field Survey, Image Interpretation |
| GIS Grid Based, amount 484 grid, (100 m x 100 m/1 hectare) | 1:5.000 | Authors Analysis |

**Figure 6**: Research Location Map of Kendari City (CBD of Mandonga) (Source: Authors, 2016)

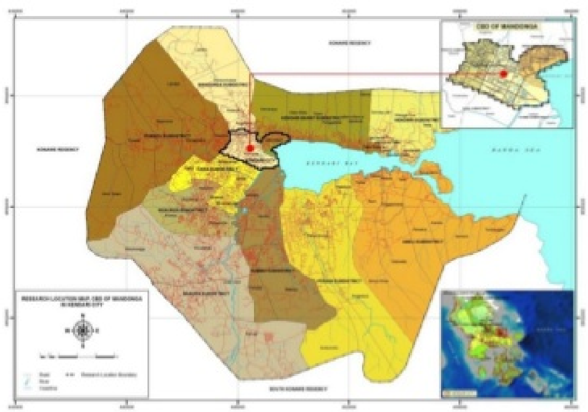
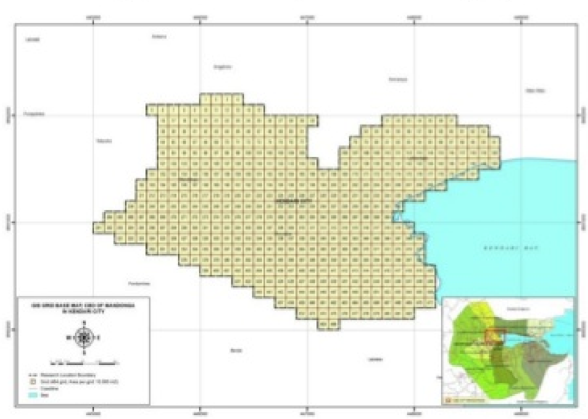


**Figure 7**: GIS Grid Base Map (100 m x 100 m), CBD of Mandonga (Source: Authors, 2016)



### 3.2. Urban Fire Risk (Applied in CBD of Mandonga, Kendari City)

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 influency 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 8**: System Chart for Urban Fire Risk (Source: Authors, 2016)

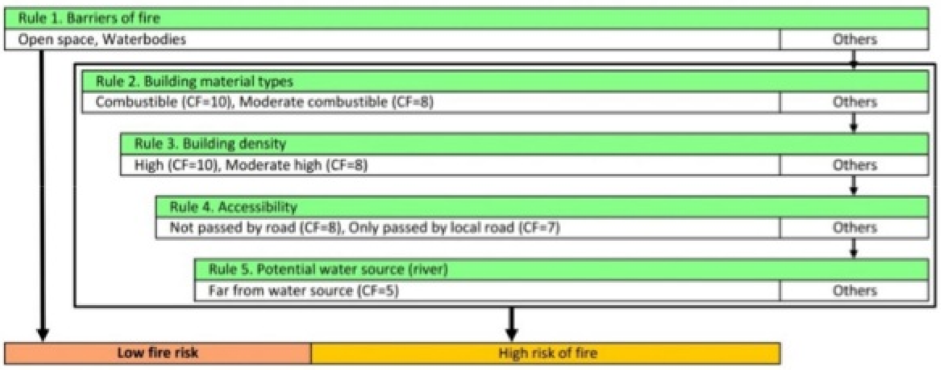



**Table 2**: Certainty Factor for Urban Fire Risk (Source: Authors, 2016)

| Factor | Categories | CF* |
|---|---|---|
| Building material types | Combustible | 10 |
| | Moderate combustible | 8 |
| Building density | High, >75% | 10 |
| | Moderate high, 50-70% | 8 |
| Accessibility | Not passed by road | 8 |
| | Only passed by local road | 7 |
| Potential water source (river) | Far, >942 m | 5 |

**Certainty Factor*

**Figure 9**: Landuse Map, CBD of Mandonga, 2015 (Source: Authors, 2016)

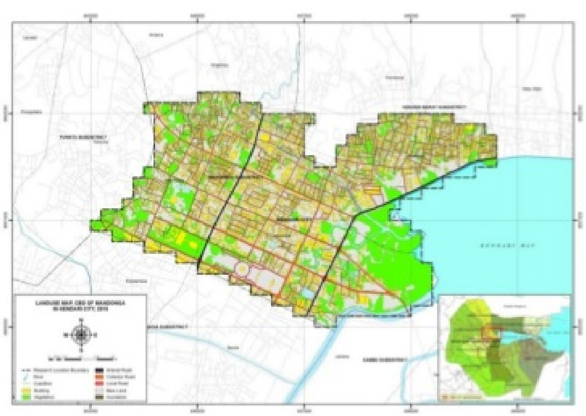
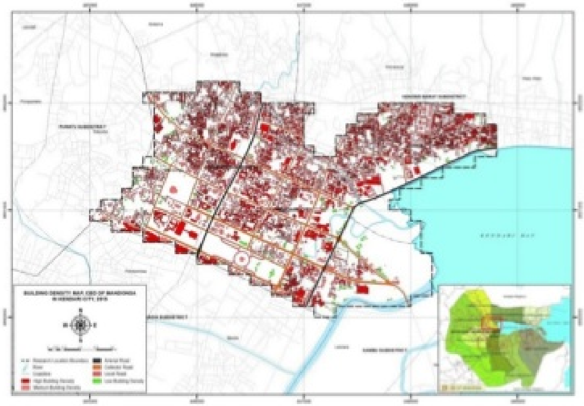


**Figure 10**: Building Material Types Map, CBD of Mandonga, 2015 (Source: Authors, 2016)

**Figure 11**: Building Density Map, CBD of Mandonga, 2015 (Source: Authors, 2016)



### 3.3. Fire Station Allocation (Applied in CBD of Mandonga, Kendari City)

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 (<1 Km), and categorized as unused area. In addition to supporting factors, the analysis was also conducted to several inhibiting factors in fire station allocation, 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.

**Figure 12**: System Chart for Fire Station Allocation (Source: Authors, 2016)

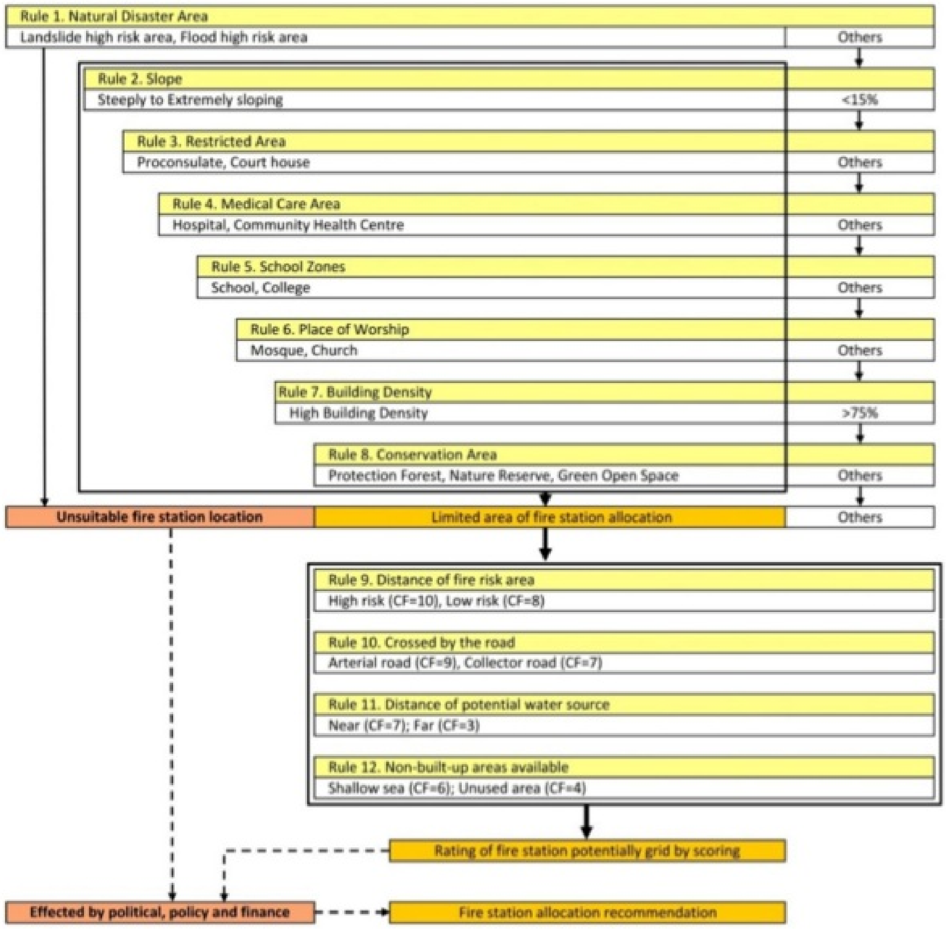



**Table 3**: Certainty Factor for Fire Station Allocation (Source: Authors, 2016)

| Factor | Categories | CF* |
|---|---|---|
| Distance of fire risk area | Near, <3000 m | 10 |
| | Far, >3000 m | 8 |
| Crossed by the road | Arterial road | 9 |
| | Collector road | 7 |
| Distance of potential water source | Near, <1000 m | 7 |
| | Far, >1000 m | 3 |
| Non-built-up areas available | Shallow sea, <3 m | 6 |
| | Unused area | 4 |

**Certainty Factor*

**Figure 13**: Road Hierarchy Map, CBD of Mandonga, 2015 (Source: Authors, 2016)

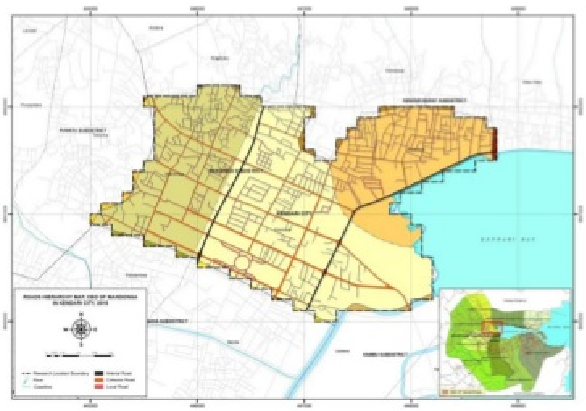


**Figure 14**: Potentially Water Source Map, CBD of Mandonga (Source: Authors, 2016)

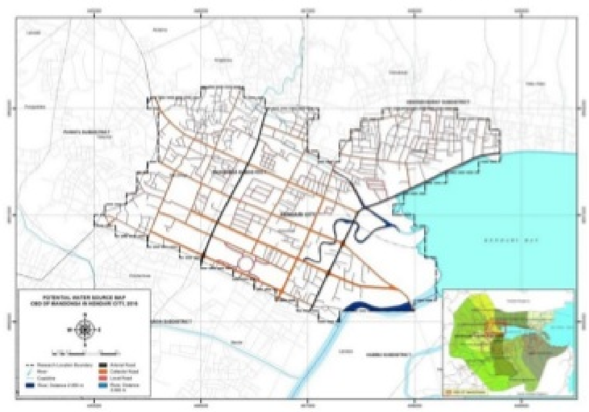
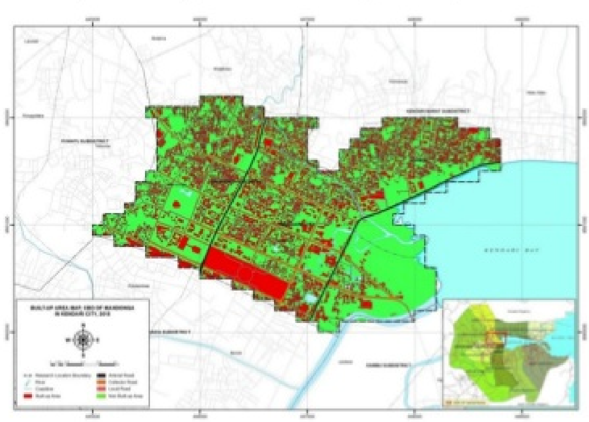


**Figure 15**: Built-up Area Map, CBD of Mandonga, 2015 (Source: Authors, 2016)



## 4. RESULT AND DISCUSSION

### 4.1. Urban Fire Risk

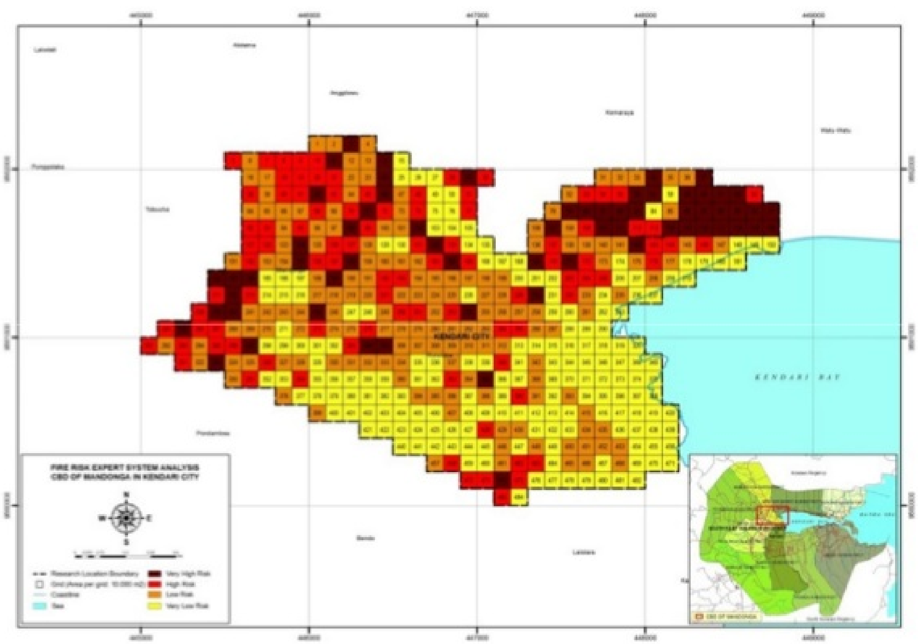
The fire risk in CBD Mandonga, Kendari City, was rated by expert system approach by using GIS Grid shows the risk degree which was then classified into four classes, i.e. (1) Very High Risk, amounting to 64 grids or 13,22%, (2) High Risk, amounting to 93 grids or 19,21%, (3) Low Risk, amounting to 153 grids or 31,61%, (4) Very Low Risk, 174 grids or 35,95%.

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 fire fighting.

**Table 4**: Degree of Urban Fire Risk, CBD of Mandonga (Source: Authors, 2016)

| No. | Grid | Classification |
|---|---|---|
| 1. | 3, 11, 14, 24, 29, 34, 37, 42, 46, 56, 57, 59, 60, 61, 62, 71, 79, 80, 81, 82, 83, 86, 87, 88, 89, 90, 91, 98, 102, 107, 110, 111, 114, 115, 116, 117, 118, 119, 120, 124, 132, 142, 155, 158, 164, 169, 171, 182, 183, 184, 189, 212, 230, 239, 240, 245, 254, 265, 297, 304, 305, 323, 365, 474 | Very High Risk |
| 2. | 5, 7, 8, 9, 10, 8, 19, 20, 21, 28, 30, 38, 40, 41, 43, 45, 48, 51, 53, 54, 55, 63, 68, 70, 72, 74, 77, 92, 93, 95, 99, 109, 112, 113, 121, 122, 126, 127, 131, 133, 137, 143, 144, 146, 152, 156, 157, 163, 165, 170, 172, 176, 192, 193, 203, 204, 205, 211, 213, 221, 229, 232, 238, 250, 251, 253, 264, 266, 267, 273, 276, 284, 285, 291, 293, 295, 296, 303, 321, 326, 340, 351, 354, 363, 390, 428, 458, 462, 463, 472, 473, 475, 483 | High Risk |
| 3. | 1, 2, 4, 6, 12, 13, 16, 17, 22, 23, 31, 32, 33, 35, 36, 39, 44, 47, 52, 64, 65, 66, 67, 69, 73, 78, 85, 94, 96, 97, 100, 101, 106, 108, 123, 125, 128, 136, 138, 139, 140, 141, 145, 147, 151, 153, 154, 159, 160, 161, 162, 173, 175, 177, 188, 190, 191, 194, 195, 196, 197, 198, 199, 208, 217, 218, 219, 220, 222, 223, 224, 225, 227, 228, 233, 235, 241, 242, 243, 244, 246, 249, 252, 255, 256, 257, 258, 261, 268, 269, 270, 272, 274, 275,277, 278, 279, 280, 281, 282, 283, 286, 287, 292, 294, 306, 307, 308, 309, 310, 311, 312, 322, 324, 325, 327, 328, 330, 331, 332, 333, 334, 337, 342, 350, 360, 364, 368, 376, 384, 385, 386, 388, 391, 393, 399, 407, 415, 429, 430, 434, 435, 446, 448, 450, 451, 452, 453, 457, 461, 465, 466, 468 | Low Risk |
| 4. | 15, 25, 26, 27, 49, 50, 58, 75, 76, 84, 103, 104, 105, 129, 130, 134, 135, 148, 149, 150, 166, 167, 168, 174, 178, 179, 180, 181, 185, 186, 187, 200, 201, 202, 206, 207, 209, 210, 214, 215, 216, 226, 231, 234, 236, 237, 247, 248, 259, 260, 262, 263, 271, 288, 289, 290, 298, 299, 300, 301, 302, 313, 314, 315, 316, 317, 318, 319, 320, 329, 335, 336, 338, 339, 341, 343, 344, 345, 346, 347, 348, 349, 352, 353, 355, 356, 357, 358, 359, 361, 362, 366, 367, 369, 370, 371, 372, 373, 374, 375, 377, 378, 379, 380, 381, 382, 383, 387, 389, 392, 394, 395, 396, 397, 398, 400, 401, 402, 403, 404, 405, 406, 408, 409, 410, 411, 412, 413, 414, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 431, 432, 433, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 447, 449, 454, 455, 456, 459, 460, 464, 467, 469, 470, 471, 476, 477, 478, 479, 480, 481, 482, 484 | Very Low Risk |

**Figure 16**: Urban Fire Risk Map, CBD of Mandonga (Source: Authors, 2016)



### 4.2. Fire Station Allocation

The analysis of fire station location based on expert system approach by using GIS Grid resulted five chosen locations, i.e. (1) Suitable I, in Grid no. 149, (2) Suitable II, consists of Grid no. 368 and 391, (3) Suitable III, consists of Grid no. 148 and 150. Out of these 5 Grids, the others are unsuitable areas to set the location of the fire station.

**Table 5**: Chosen Grid for Suitable Fire Station Allocation (Source: Authors, 2016)

| No. | Grid | Classification |
|---|---|---|
| 1. | 149 | Suitable I |
| 2. | 368, 391 | Suitable II |
| 3. | 148 | Suitable III |
| 4. | 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484 | Unsuitable |

**Figure 17**: Urban Station Allocation Map, CBD of Mandonga (Source: Authors, 2016)

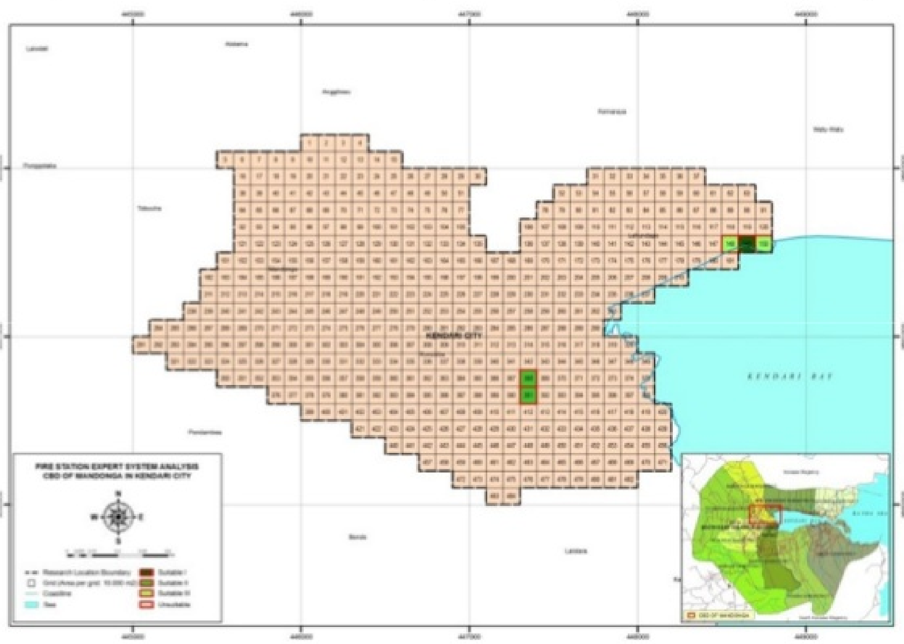
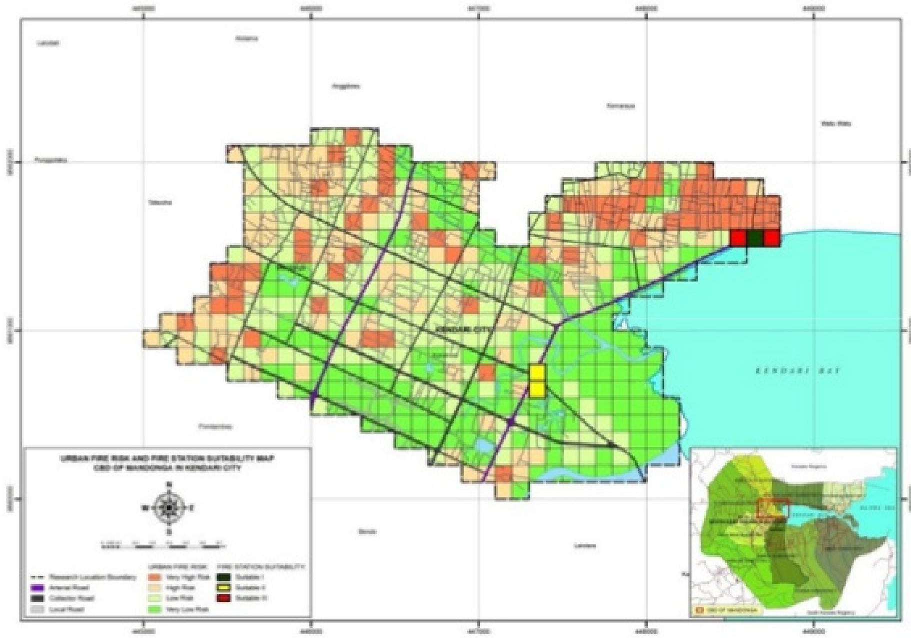


**Figure 18**: Urban Fire Risk and Fire Station Suitability Map, CBD of Mandonga (Source: Authors, 2016)




## 5. CONCLUSION

The research result studied in Central Business District (CBD) Mandonga, 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 area which consist of water body, open space and vegetation, (2) The fire station allocation 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.

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## 7. REFERENCES

Badri *et al*., (1998). Theory and Methodology. A Multi-Objective Model for Locating Fire Stations. European Journal of Operational Research 110(2):243-260. Faculty of Business and Economics, UAE University, United Arab Emirates

Central Agency on Statistics, Southeast Sulawesi Province (2015). Kendari City in Figures, 2015. BPS Catalog 1102001.7471, Kendari

Chainey, S., & Ratcliffe, J. (2005). GIS and crime mapping. West Sussex. John Wiley & Sons, England

ESRI (2012). GIS for the Fire Service. An Esri White Paper. Environment Systems Research Institute. Redlands, USA

Fire Department Kendari City (2015). History of Fires on 2009-2014, Kendari City, Kendari

Gai *et al* (2011). GIS-based Forest Fire Risk Assessment and Mapping. Fourth International Joint Conference on Computational Sciences and Optimization, 978-0-7695-4335-2. Department of engineering Physics, Institute of Public Safety Research, Tsinghua University Beijing, China

Guettouche MS *et al* (2011), A Fire Risk Modelling and Spatialization by GIS: Application on the Forest of Bouzareah Clump, Algiers (Algeria). Journal of Geographic Information System, 2011, 3, 254-265. Sciences and Technology University of Houari Boumediene, Algiers, Algeria

Himoto, K., & Tanaka, T. (2012). A Model for The Fire-Fighting Activity of Local Residents in Urban Fires. Fire Safety Journal 54 (2012) 154–166. Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, Kyoto, Japan

Ikram, A., & Qamar, U. (2014). Developing an expert system based on association rules and predicate logic for earthquake prediction. Knowledge-Based Systems Journal 75 (2015) 87–103. Computer Engineering Department, College of Electrical and Mechanical Engineering, National University of Sciences and Technology (NUST), Islamabad, Pakistan

Kim, TJ *et al* (1990). Expert Systems: Applications to Urban Planning. Springer-Verlag. Department of Urban and Regional Planning, University of Illinois, Champaign, USA

Mantra, I.B.G.W (2005). Study of Fire Preventive on Housing. A Base Study in Sarijadi Residence Bandung. Journal of Natah Settlement Volume 3 No. 1. Housing Laboratory of Architecture Department, Technic Faculty, Udayana University, Denpasar

Ministry of Public Work and People Housing (2015). The Sixth Asia-Pacific Urban Forum Conference, Jakarta

Murray, T.A (2013). Optimising the spatial location of urban fire stations. Fire Safety Journal. Volume 62, Part A, Pages 64–71. GeoDa Center for Geospatial Analysis and Computation, School of Geographical Sciences and Urban Planning, Arizona State University, USA

NFPA 1710 (2001). Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments. National Fire Protection Association, USA

Toki *et al* (2011). Protection of Cultural Heritage from Post-Earthquake Fire. Journal of Disaster Research, 6(1): 4-10. Research Center for Disaster Mitigation of Urban Cultural Heritage, Ritsumeikan University, Kitaku, Kyoto, Japan

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