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APPLICATION OF SERVICE ORIENTED GEOGRAPHIC INFORMATION SYSTEM IN RISK ANALYSIS

Abstract: Natural disasters and crises cause fatalities and considerable economic losses worldwide every year. Crisis management operations require a clear understanding of exposure and vulnerability of both physical assets and populations. In this paper, identification, classification and mapping of forest fire risk is completed with an aim of reducing the ratio and ecological damage caused by the fire. Suggested model is based on the combination of Service Oriented Geographical Information System and Multi-Criteria Decision Analysis using Analytic Hierarchy Process and Weighted Linear Combination for mapping and assessment of forest fire risk in the area of Municipality Nevesinje, Bosnia and Herzegovina. The process was developed with an aid of 8 criteria grouped in four clusters. The weights are determined using AHP. Final map of forest fire risk is classified in 5 categories, from very low to very high risk.

Key words: decision-making, disaster management¸ risk, SDSS, GIS, AHP, forest fire risk map

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1. BASIC CONCEPTS

Hazard is a potentially damaging physical event, phenomena and/or human activity, which may cause loss of life or injury, property damage, social and economic disruption, or environmental degradation. Hazards can have different origins: natural (geological, hydrometeorological and biological) and/or inducted by human processes (environmental degradation and technological hazards).

Vulnerability is susceptibility to suffer loss or a set of conditions and processes resulting from physical, social, economic and environmental factors, which increase the susceptibility of a community, an individual, an economy or a structure to the imapct of hazards.

[1] define disaster as “A serious disruption of the functioning of a community or a society involving widespread human, material, or environmental losses and impacts which exceeds the ability of the affected community to cope using only its own resources.” Disaster is function of the risk. It results from the combination of hazards, conditions of vulnerability, and insufficient capacity or measures to reduce the potential negative consequences of risk.

Risk is defined as „the combination of the probability of an event and its negative consequences“ [1]. The term disaster risk therefore refers to the potential (not actual and realised) disaster losses, in lives, health status, livelihoods, assets and services, which could occur in a particular community or society over some specified future time period resulting from interactions between natural- or human-induced hazards and vulnerable conditions. Disaster risk is the product of the possible damage caused by a hazard due to the vulnerability within a community and is expressed by the notation:

$$\text{Risk} = \text{Hazards} \times \text{Vulnerability} \quad (1)$$

One important consequence of the definition (1) is that a high probability hazard with small consequences has the same risk as a low probability hazard with large consequences.

2. DISASTER RISK MANAGEMENT

Integrated disaster management is an iterative process of decision making regarding prevention of, response to, and recovery from, a disaster. It involvs complex intersections within and between the natural environment, represented by natural system, human populationa, human activity systems that frame actions, reactions and perceptions, and built environment (human made system). Integrated disaster management includes measures for before (prevention, preparedness, risk transfer), during (humanitarian aid, rehabilitation of basic infrastructure, damage assessment) and after disasters (disaster response and reconection) Figure 1.

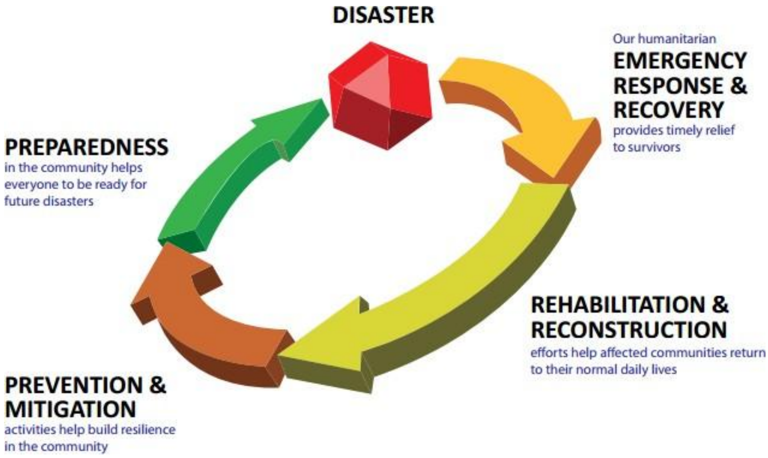

Figure 1 – Integrate disaster risk management cycle [2]

Disaster risk reduction (DRR) is development and application of policies, strategies and practices to reduce vulnerabilities and disaster risks throughout systematic efforts to analyse and manage the causal factors of disasters. DRR strategies include, primarily, vulnerability and risk assessment, as well as a number of institutional capacities and operational abilities. Disaster risk management (DRM) is the systematic process of using administrative directives, organisations, and operational skills and capacities to implement strategies, polices and improved coping capacities in order to lessen the adverse impacts of hazards and their possibility of disaster. DRM is more focused on the practical implementation of initiatives to achieve DRR goles [3] i.e. disaster risk reduction concerns activities more focused on a strategic level of management, whereas disaster risk management is the tactical and operational implementation of disaster risk reduction. The components of the DRM are mitigation, preparedness, response and recovery [4].

Mitigation is long-term planning and it involves identifying the vulnerability of every part of the territory to particular types of hazards, and identificatio of steps that should be taken to minimize the risks. Disaster mitigation measures are those that eliminate or reduce the impacts and risks of hazards through proactive measures taken before an emergency or disaster occurs (hazard mapping, implementing and enforcing building codes, floodplan mapping).

Preparedness for disasters is intended to avoid or reduce loss of life and damage to property if an extreme natural event occurs. Preparedness includes such activities as formulating, testing, and exercising disaster plans; providing training for disaster responders and the general public.

Disaster response activities include emergency sheltering, search and rescue, care of injured, for fighting damage assessment, and other emergency measures. The response phase of the integrated disaster management involves the implementation of the measures developed during the mitigation and preparedness phases.

Disaster recovery (DR) involves a set of policies, tools and procedures to enable the recovery or continuation of vital technology infrastructure and systems following a natural or human-induced disaster.

3. DECISION MAKING PROCESS

In disaster situations, ineffective decisions can lead to great losses (infrastructure destruction, human losses, etc.). Decision analysis is a formal method of identifying, representing and assessing various alternatives to determine the best cours of action. The main protagonists in the decision analysis process are: a decision-maker (person charged with finding solution for decision-making problem), a decision analyst (gives advices and clarification to the decision maker in order to aid the in finding the best decision alternatives) and a stakeholder. Decision-making is an important task in disaster management because it appears in all management activities before, during and after a catastrophic event. Therefore, decision-making represents an activity that aims to reduce the aftermath of a disaster. Decision-making process presents a big challenge for disaster stakeholders and can be devided into following steps: Define the problem, determine requirements, establish objectives, identify alternatives, define criteria (that should be: able to discriminate among the alternatives and support the comparasion of the performance of the alternatives, include all important aspects of the objectives, operational and concise, non-redudant with each criteria its own sifle concept, few in number, measurable, so that the alternatives can be expressed on either a quantitative or qualitative measurement scale), select a decision making tool, evaluate alternatives against criteria and validate solutions against the problem statement.

4. DECISION SUPPORT SYSTEM

Decision Support Systems (DSS) are computer-based tools designed to support management decisions. DSS incorporate modeling or analysis tools along with database managemet systems and user interface which provide access and allows decision makers to combine personal judgment with computer output, in a user-machine interface, to produce meaningful information for support in a decision-making process. Such systems are capable of assisting in solution of all problems (structured, semistructured, and unstructured) using all information available on request [4]. A DSS can be designed as: very specific to a particular decision or component of particular decision (e.g., a watershed nutrient loading model built for a specific watershed), a framework that allowa a particular type of application to be modeled (e.g. watershed management) and generic framework for modeling any type of decision [5]. According to the way in which decision-making is supported there are two types of DSS: Information-Based DSS and Model-Based DSS. For information-based DSSs, decision-making is supported indirectly by providing access to information that is relevant to the decision at hand. Although numerical analysis tools might be involved, the decision component is qualitative. For model-based DSSs, a further step is taken in order to quantitatively support decision making. Basic construction includes building a model structure, specifying the model, and processing the model.

4.1. General structure of DSS

The general components of DSS system are: data component (Data Warehouse, Tools for extracting and filtrating data, query tools), model component (model base for analysis and decision making, tools for analysis and decision-making model building and toold for executing analysing and decision making models) and component for data presentation (Charts, GIS, Virtuar reality). The data component facilitates the merger of data from different sources without explicit instructions from the user how to accomplish this task. Model component of DSS keeps track of all of the possible models (statistical models, sensitiv analysisi models, optimization analysis models,) that might be run during the analysis as well as controls for running the models.

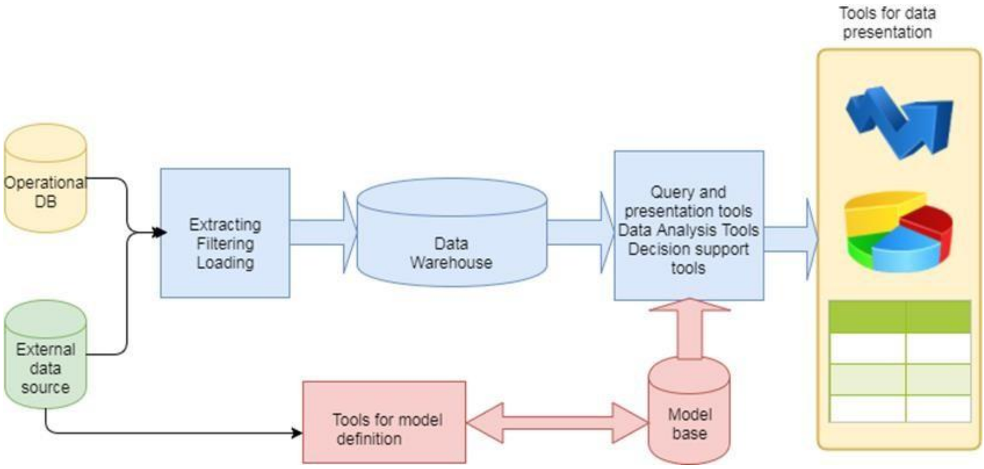

Figure 2 – Basic structure of DSS

An operational database contains data about the state of organisation or enterprise in specific time. External database contain data outside the organisation operating system. From external database only data which are significant for decision making are collected. Data generated by algorithms (mean, linear programming) are stored in Model database.

The goal of the DSS is to bring together appropriate business intelligence and models to help that individual to consider a problem or opportunity from more perspectives with better information [7].

Business is collection of activities carried out for whatever purpose while intelligence is defined as "the ability to apprehend the interrelationships of presented facts in such a way as to guide action towards a desired goal." [8] The goal of business intelligence (BI) is to provide managers with information about the business in time to allow them to make decisions that can solve problems or take advantage of opportunities. The BI is the proccess and the systems that create those process is called DSS. In term of DSS, BI describe the emerging practice of transforming raw data from an organization's disparate operational data into a common data warehouse that could be used for discovering and reporting information.

Data Warehouse (DW) is the foundation of all DSS processing. DW doesn't represent the copy of operational database but it contain aggregated and restructure data in such way to support effective query execution. The job of the DSS analyst in the DW environment is immeasurable easier because there is a single integrated source of data to drow from, the granular data in the DW is easily accessible and DW forms a foundation for reusability and reconciliation of data. A data warehouse is a subject-oriented, integrated, nonvolatile, and time-variant collection of data in support of management's decisions [7]. The integration is the most important caracteristics of data warehouse. DW represents a centralized database which contains information about all organizational parts of the company in a standardized format. All data about one entity are stored at one place. Data is fed from multiple, disparate sources into the data warehouse. The data integration is always a complex and tedious task which can be automaticly done by ETL software. Extract, Transform, and Load (ETL) is a process in data warehousing that involves extracting data from outside sources, transforming it to fit business needs, and ultimately loading it into the data warehouse. The application data is integrated as it passes into DW.

The data warehouse is oriented to the major subject areas of the corporation that have been defined in the high-level corporate data model. Each major subject area is physically implemented as a series of related tables in the data warehouse

Time variancy implies that every unit of data in the data warehouse is accurate as of some moment in time. Time variance implies that every unit of data in the data warehouse is accurate as of some moment in time. Non Volatile means that, once entered into the warehouse, data should not change or delete. More often data are just added to DW.

The data mart is a subset of the data warehouse and is shaped by end-user requirements into a form specifically suited to the needs of the department. Data mart can be defined as Data Warehouse with only one topic.

Data mining is the analysis of (often large) observational data sets to find unsuspected relationships and caracteristics, dependencies, tendencies and summarize the data in novel ways that are both understandable and useful to the data owner [9]. Data mining: analysis operational data, reveals problems or opportunities, hidden in data relations, forming computer models based on these discoveries, and use those models for prediction. Data mining algorithms are based on: statistical methodes (factor, cluster, taxonomy and component analysis), artificial intelligence and neural networks (ANN, CNN, SVM, decision tree), inductive reasoning and prediction logics [9].

Important characteristics of DSS for integrated disaster management include accessibility, flexibility, facilitation, learning, interaction, and ease of use. Decision support systems often do not account for or handle spatial aspects of decision making, and thus extension of the concept of DSS to SDSS has been necessary.

5. SPATIAL DECISION SUPPORT SYSTEM

It is estimated that 80% of data used by managers and decision makers is related geographically [10]. In order to handle different temporal and spatial scales, the majority of DSSs include GIS (Geographic Information System) tools. These specific DSSs are often referred to as Spatial Decision Support Systems (SDSSs) [11]. Spatial data referred to a location on the Earth's and include facts, results of observation, original remote-sensing images all of which are gathered and communicated to the decision maker. At subsequent stage of the decision –making process the original data are interpreted and analyzed to produce information useful to decision makers. The decision situation determines the need and the nature of the information required. Spatial Decision Support System is an interactive computer based system designed to support a user or group of users in achieving a higher effectiveness of decision making [10]. SDSS are explicitly designed to provide the user with a decision-making environment that enables the analysis of geographical and non spatial information to be carried out in the flexible manner. Therefore, SDSS are an extension of DSS concept, with spatial data used for the analysis of decision. Along with generic caracteristics of DSS have four distinguishing capabilities and functions of an SDSS: (1) provide mechanisms for the input of spatial data, (2) allow representation of the spatial relations and structures, (3) include the analytical techniques of spatial analysis, and (4) provide output in a variety of spatial forms, including maps [11]. SDSS aims to improve the effectiveness of decision making by incorporating decision-maker judgments and computer-based programs within the decisionmaking process. The development of SDSS has entailed integrating analytical/decision model with GIS to produce system capable to solving spatial problem.

5.1. SDSS components

SDSS have evolved from DSS and GIS. The database component of DSS deals with nonspatial data collection, management and analysis while GIS porvides spatial and non spatial data collection, storage, management and cartographic display functionalities. The basic structure shown on Figure 2. is in line with SDSS. Spatial data (including geometry, attribute and topology) are stored in operational and external database (which can be accessed trought WMS, WFS and WCS) and DW. GIS tools for the manipulation, storage, management, analysis and visualization of geospatial data are incorporated in such system.

6. GEOGRAPHIC INFORMATION SYSTEM

The GIS subsystem is on of key components of SDSS. A geographic information system (GIS) is a computer system for capturing, storing, querying, analyzing, and displaying geospatial data [12]. Geographical objects are described by two types of data: locational data, which relate the objects to their location in geographical space, and attribute data, which describe other properties of the objects apart from their locations. The world consist of sets of discreate objects, their associated attributes and relationship between objects, if entites are fully definable (e.g. parceles, roads, objects) vector data model was used. For entities that are incompleat, inexact and incompleatly definable (e.g. soil types, vegetation types, elevation) the data model of the world should represent the world as being made up of raster model [12]. GIS database use data model so that geographical data can be stored, manipulated and analyzed. For exact data models, the database contains a set of objects, attributes, relationship between objects and set of rules dafining how they behave (topological realtionship). Both the discrete object and the field models can be implemented by means of the raster and vector data structure.

Data in raster format are stored in a twodimensional matrix of uniform grid cells (pixels). Each cell is supposedly homogeneous, in that the map is incapable of providing information at any resolution finer than the individual cell. Data in vector format are entities represented by strings of coordinates. A point is one coordinate; that is, points on a map are stored in the computer with their "exact" (to the precision of the original map and the storage capacity of the computer) coordinates. Points can be connected to form lines (straight or described by some other parametric function) or chains. A polygon is represented as a set of coordinates at its corners. For example, a point that represents a village or town may have a database entry for its name, size, services, and so on. A line that represents a road may have a database entry for its route number, traffic capacity, emergency route, and so on. A polygon that represents an administrative unit may have a database entry for the various socio economic, environmental, and population characteristics. In the vector representation, the various geographical objects have a definite spatial relation called topology. The topology defines spatial relationships between objects (points, lines, and polygons). It allows a GIS to perform spatial analysis functions on geographical data.

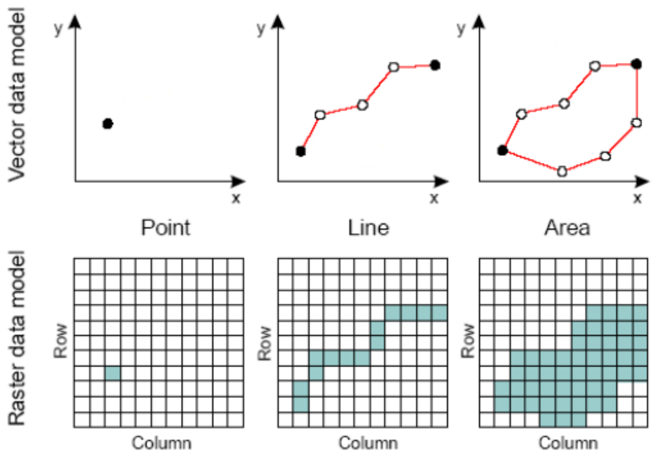

Figure 3 – Raster and Vector data model

One of the main strengths of GIS is the ability to store large amounts of non spatial information that are either directly or indirectly related to spatial features. Pieces of information directly related to spatial features are called attributes. A wide variety of characteristics of any vector feature can be recorded in the attribute table of the vector feature class. The ESRI shapefile format (which is made up of anywhere from three to seven files) is an example, with the attribute data being stored in a .dbf (dBase format) and the primitive geometry data stored in the .shp file.

Object-relational databases technology, such as ESRI's Geodatabase, provides an evolutionary approach to the use of objects in databases by building on established relational database research results. The relational database method stores data in a tabla. An advantage is that these methods are based on standard technologies, allowing easy transfer and ease in using technologies such as the Structured Query Language (SQL). Object-oriented data model allows complex data type. Both object-oriented databases and object-relational databases, collectively known as object databases, provide inherent support for object features, such as object identity, classes, inheritance hierarchies, and associations between classes using object references. An object is an abstract concept, generally representing an entity of interest in the enterprise to be modeled by a database application. An object has state and behavior. The state of an object describes the descriptive properties of the object (such as an identifier, a name, and an address). The behavior of an object is the set of methods that are used to create, access, and manipulate the object. Objects having the same state and behavior are described by a class. A class essentially defines the type of the object where each object is viewed as an instance of the class.

7. SERVICE ORIENTED GIS

The traditional GIS applications conventionally used to access and analyze local data do not have the ability to interact with online data sources and with other spatial analysis applications [13]. The nature of the geographical applications, especially in the case of disasters management, requires seamless integration and sharing of spatial data from a variety of providers. Interoperability of services across organizations and providers is a main goal for GIS. According to OGC interoperability is defined as capability to communicate, execute programs, or transfer data among various functional units in the manner that requires the user to have little or no knowledge of the unique caracteristics of those units i.e. interoperability enables the integration of data between organizations resulting in generation and sharing of information and reduce redundancy [14].

Distributed GIS builted around the principles of Service Oriented Architecture is being used to share crucial informations across organizational boundaries via the Internet and emergence of Web services. SOA is an architectural style for building software applications that use services available in a networke such as Web. SOA concept has three components: service provider, service registry and service requester and three operations: publish, find and bind. A SOA relates the roles of three components with three operations to maintain automated discovery and use o services. In contrast of standard GIS applications where normally only a small percentage of the functions in the software are used, application based on SOA provide with just the functionality they needed. Another prominent intention of the design of a SOA is data used for given processing activity are not stored locally, but rather decentralized close to the source of production. The key component in the SOA is services. A service is well defined set of actions. It is a self contained, stateless and does not depend on the state of other services. The implementation of SOA in the web enviroment is called web services. The concept of Web services is based on SOA paradigme where a complete application can be constructed from various services which provide different functionality. In order to create SOA architecture for the GIS services it is necessary to create web services correspondences of each GIS services. GIS services can be grouped into three categories [15]: GIS data services are tightly coupled with specific data sets and offer access to customized portions of that data. Web Feature Service (WFS), Web Feature Service-Transactional (WFS-T), Web Mapping Service (WMS) and Web Coverage Service (WCS) can be considered in this group. WMS produces maps as two-dimensional visual portrayals of geospatial data. WCS provides access to un-rendered geospatial information (raster data). WFS provides geospatial feature data (vector data) encoded in Geography Markup Language (GML) whereas WFS-T enables editing feature coordinate geometry (i.e position and shape) and related descriptive information (i.e. attribute values), as well. Processing Services provide operations for processing or transforming data in a manner determined by user-specific parameters. They provide generic processing functions such as projection and coordinate conversion, rasterization and vectorization. Coverage Portrayal Service (CPS), Coordinate Transformation Service (CTS), and even WMS can be considered in this group.

Registry or Catalog Service allows users and applications to classify, register, describe, search, maintain, and access information about Web Services. Web Registry Service (WRS) and Catalog Service for the Web (CS-W) are considered in this group [16].

8. SOURCE OF SPATIAL DATA

Major data source of spatial data are: Remote sensing data, aerial photographs, GNNS measurement, other point measurement, digitizing and scanning paper maps. Those data source can be categorized as: official government data (land parcels, objects, ownerships, pipelines, roads) , commertial (areal images, DEM, satellite images (WorldView, Quicbird, Rapideye...)) and open data. The provision of data in freely available and reusable formats and under the provision of open licenses (without any restriction both in terms of access and fee) is called open data. The free, full and open data policy adopted for Copernicus, Landsat and Terra programs has granted access to the Sentinel 1-2, Landsat 4-8, MODIS, MERSI, ASTER data products providing global coverage of high, medium and low spatial resolution, optical and radar, images and digital elevation model. Volunteered geographic information (VGI) is the harnessing of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals. Some examples of this phenomenon are WikiMapia, OpenStreerMap (OSM) and Yandex. The aim of OSM is to create and provide free geographic data in vector format [17]. In addition, the Humanitarian OpenStreetMap Team (HOT) applies the principles of open source and open data sharing for humanitarian response and economic development by providing free, up-to-date maps that are a critical resource when relief organizations are responding to disasters or political crises [17]. Over the years, OSM, Sentinel 1-2, and Landsat image have turned out to be a serious geodata alternative for different applications and was used in a wide range of geographic information systems (GIS) and applications especially in disaster management.

9. MULTI-CRITERIA DECISION ANALYSIS (MCDA)

One instrument that permits the development of a DSS is MCDA [5]. It is capable of taking into consideration all of the variables present in the decision process. Multi-criteria decision analysis (MCDA) is discipline that encompasses mathematics, management, informatics, psychology, social science, economics and it includes a large class of methods for the evaluation and ranking or selection of different alternatives that considers all the aspects of a decision problem involving many actors [18]. MCDA permits the combination of quantitative and qualitative inputs like risks, costs, benefits, and stakeholder views while MCDA algorithms are designed to synthesize a wide variety of information and raise awareness of the tradeoffs that must be made between competing projects objectives. MCDA techinques can be categorised as: Multi-objectiv Decision Analysis (MODA) and Multi-Attribute Decision Analysis (MADA) [5] (Figure 4). Main difference between MADA and MODA are presented in Table 1.

Table 1 – Difference between MADA and MODA [5]

MADA	MODA
„discrete environment“ in which the decisions are selected from a finite number of possible alternatives	„continuous environment“ in which a linear function is created and optimized for reaching the proposed objectives
considers the ‘‘attributes’’ that are measurable values, expressed as a nominal scale, ordinal scale, or comparison scale	considers ‘‘objectives’’ that represent the improving level of the attributes, in this case maximizing or minimizing the functions that are concerned with the attributes (minimizing costs or maximizing earnings)

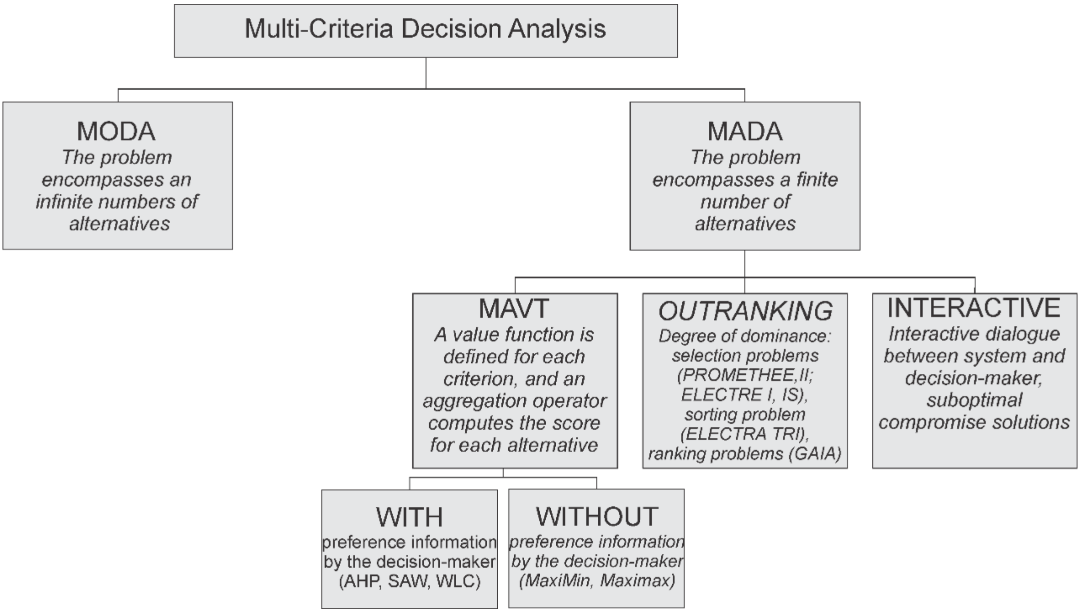

Figure 4 – A classification of MCDA problems and methods

9.1. Multiple attribute utility/value theory (MAVT)

Multiple attribute utility/value theory (MAVT) constructs a utility/value function for each criterion. The value functions (sometimes also called ‘‘utility’’ functions) convert the attribute values into a common scale, and then these numerical values are aggregated into the final score [5]. Many methods exist to define the value function. The next step consists of the aggregation of this normalized data into a single numerical output, the score of the alternative, or of an intermediate level node of the decision tree, if a hierarchical structure is defined. To this purpose, an Aggregation Operator needs to be defined, that is a multi-dimensional function that satisfies a set of rationality axioms.

10. APPLICATION OF SERVICE ORIENTED GIS IN FOREST FIRE RISK ASSESSMENT

Forest fires are considered to be natural disasters. The causes of fire are most often directly related to human activities, such as negligence, carelessness, accident or arson on the forest areas. Recent research of JRC Technical Reports shows that, due to climate change increasing air temperature and decreasing of humidity, could double the area affected by forest fires in Europe [19]. This fact rises concern and initiates serious analysis of this fenomen and preventive modeling of forest fire risk. The production of forest fire risk map was divided into following steps:

Definition of the problem: Bosnia and Herzegovina is a country with a high risk of forest fires. Acording to European Forest Fire Information System’s report, Bosnia and Herzegovina is on high four places, right behind Algeria, Spain and Portugal according to areas which were burned by fire [19]. The aim is production of forest fire risk map. Forest fire risk zones are locations where a fire is highly likely to start, and from where it can easily spread to neighborhood area. Identification of those zones helps us to discover areas with increased risk of forest fire occurrence and its development, which is the base for emergency intervention planning. This creates favorable conditions for minimizing the number of fires and to remove conditions for their formation. Modern tools and technologies in combination with traditional knowledge could have great importance in prevention and forest fire control.

Identification of alternatives: According to suitability for forest fire the five alternatives are defined: very low, low, moderate, high and very high suitability for forest fire ignition.

Identification of criteria: Therefore, in order to reach the right conclusions, causative factors for spreading of fire and the possibility of their extinguishing, was defined based on knowladge database, expert opinion and data mining. The 8 criteria grouped in 4 clusters which are vital for starting of fire and forest fire risk assessment in Municipality Nevesinje are shown in Table 2.

Table 2 – Criteria description

Cluster	Criteria	Description criteria
K1 Land use	C1	*Vegetation*. The Vegetation is crucial for the fire spreading because it represents the total fuel available for the fire [20].
K2 Topography	C2	*Aspect.* Generally, in the north hemisphere, south and southeast aspects are the most suitable for both, ignition and spreading of fire [21], they receive more direct sunlight and because of that they have a higher temperature and a minor humidity.
	C3	*Slope*. Slope affects speed and capability of firefighter and equipment movement and there for speed of fire extinguishing. Increasing of the slope for 10% can double the rate of the fire spreading.
	C4	*Elevation.* Elevation is associated with wind behaviour and fire spreading it's affects a structure of vegetation, total fuel available for fire, air humidity and temperature.
K3 Climate	C5	*Mean annual air temperature*. Air temperature is one of the most important climate factors. Fires can occur at any temperature, but their number depends on increasing of the temperature [22].
	C6	*Mean annual precipitation.* Precipitation is an important factor which influences suitability for ignition and fire spreading.
K4 Socioeconomic	C7	*Distance from roads.* The roads are a significant factor because their presence means human activities, therefore the forest near roads have a higher risk of forest fires.

	C8	*Distance from settlements*. It was found that the man is the main cause of the fire, so it was logical that with increasing of distance from human's residence the number of fires would decrease.

Define decision making tool: Weighted Linear Combination is one of widely used Multi Criteria Decision Analysis method for analysing land suitability. One of the weaknesses of WLC is in establishing the weights effectively and in realistic fashion without user bias. To address this shortcoming, another multiattribute technique that has often been used in spatial decision- making processes and SDSS applications is the Analytical Hierarchy Process (AHP).

AHP is a very popular method, originally developed by Saaty [23]. It is flexible because it provide that for complex problems with large number of criteria and alternatives it is relativy easy to finde relation between factors, recognizes their explicit or relative influence and importance in real terms and determines the dominance of one factor relative to the other. Methodologically speaking, the AHP is a multi criteria technique based on the interpretation of a complex problem in the hierarchy structure. The decision hierarchy is structured from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).

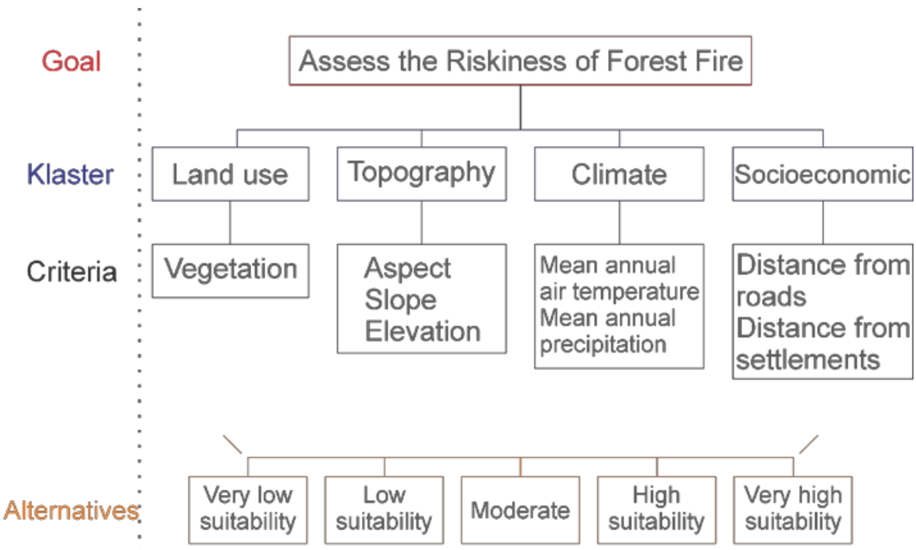

Figure 5 – Hierarchy structure of the forest fire risk prediction

AHP first requires construction of pairwise comparison matrices and calculation of their weight with regard to goal. The goal is at the top of the hierarchy and it is not comparable. At the first level, n criteria were compared in pairs and with respect to a pattern element at a higher level. If an element A is n times preferred over B, then B is preferred 1/n over A [23]. The comparison of two elements of the hierarchy, at the same level, is performed using Saaty's fundamental scale with 9 levels of relative importance [23].

Observing the defined goal, for each pair of the criteria, the importance of one over the other are entered in the matrix of comparison. In this way, the amounts of cells along the matrix diagonal is 1. Based on comparison matrix the weight of the weigh priorities in the level immediately below was calculated. Then for each element in the level below weighed values are added in order to obtain its overall or global priority. In a completely consistent evaluation, the pairwise comparison matrix A, containing the comparison results, would be identical to the matrix X:

$$X = \begin{bmatrix} \frac{w_1}{w_1} & \cdots & \frac{w_1}{w_n} \\ \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \cdots & \frac{w_n}{w_1} \end{bmatrix} \quad (2)$$

where wi denotes the relative weighted coefficient of the element i. The weight vector wi can be calculated by solving the following system of homogeneous linear equations:

$$A \cdot w = n \cdot w \text{ or} \quad (3)$$

$$(A - n \cdot I) \cdot w = 0 \quad (4)$$

where n is the eigenvalue of the comparison matrix A. The weight of criteria, based on defined comparasion matrix, were claculated in QGIS by using Easy AHP plugin. Comparison matrix at the cluster and criteria levels are shown in Table 3. and Table 4.

Table 3 – Comparison matrix and weights to clasters

Cluster	K1	K2	K3	K4	w_i
Land use (K1)	1	3	4	2	0,450
Topography (K2)	1/3	1	2	1/3	0,142
Climate (K3)	1/4	1/2	1	1/4	0,087
Socioeconomic (K4)	1/2	3	4	1	0,321
λ_{max}=4,108 CI= 0,036 CR= 0,040					

Table 4 – Comparison matrix and weights to criteria

Criteria		C2	C3	C4	w_i
Aspect (C2)		1	3	4	0,623
Slope (C3)		1/3	1	2	0,239
Elevation (C4)		1/4	1/2	1	0,138
λ_{max}=3,026 CI= 0,013 CR= 0,022					

Criteria	C5	C6	w_i
Mean annual air temperature (1981-2010) (C5)	1	3	0,750

Mean annual precipitation (1981-2010) (C6)	1/3	1	0,250

Criteria	C7	C8	w_i
Distance from roads (C7)	1	3	0,750
Distance of settlements (C8)	1/3	1	0,250

Weighted Linaear Combination

The final Forest fire risk map was calculated by the Weighted Linaear Combination. Application of weighted linear combination (WLC) requires that all data sets are standardized (reclassified) [24] in units that are comparable (same numerical scale). There are a large number of approaches that can be used in order to make map attribute layers comparable, and some of them are described in Malczewski [10]. In accordance with the practice, the experts' experience and literature, the suitability of criteria, in this study, was performed using linear standardization on a score from 1 to 5, where 5 is the highest risk and 1 is lowest risk value of alternatives (a cell) for the ignition of the fire. Standardized criteria, with a defined class values are shown in Table 5.

Table 5 – Standardization criteria

Criteria	Intensity of importance				
	1	2	3	4	5
	very low	low	moderate	high	very high
C1*	(512)	(112,332,333)	(211,242,243)	(222,231,321,324)	(311,312,313)
C2	N	NE, NW	E, W	Flat, SE	S, SW
C3	0-5º	5-15º	15-25º	25-35º	>35º
C4	>800 m	600-800 m	400-600 m	200-400 m	0-200 m
C5	< 10 Cº	10-15 Cº	15-20 Cº	20-25 Cº	>25 Cº
C6	>1750 mm	1500-1750 mm	1250-1500 mm	1000-1250 mm	< 1000 mm
C7	>1200 m	900-1200 m	600-900 m	300-600 m	0-300 m
C8	>2000 m	1500-2000 m	1000-1500 m	500-1000 m	0-500 m

The preparation of criteria layers and final forest fire risk map generation was preformed in open source software QGIS. The information of defined criteria are obtained from different sources. Corine Land Cover map was used as source of vegetation layer. Digital elevation model, obtained from USGS, was used as a source for topography cluster. Based on the DEM and Terrain analysis tool in the QGIS slop (Slop function) and aspect layer (Aspect function) was created. OpenStreetMap database is used for obtaining information about settlements and roads. The zones defined in Table 5. are created by using Buffer tool. After that vector layers are rasterized and reclassify in the scale from 1 to 5.

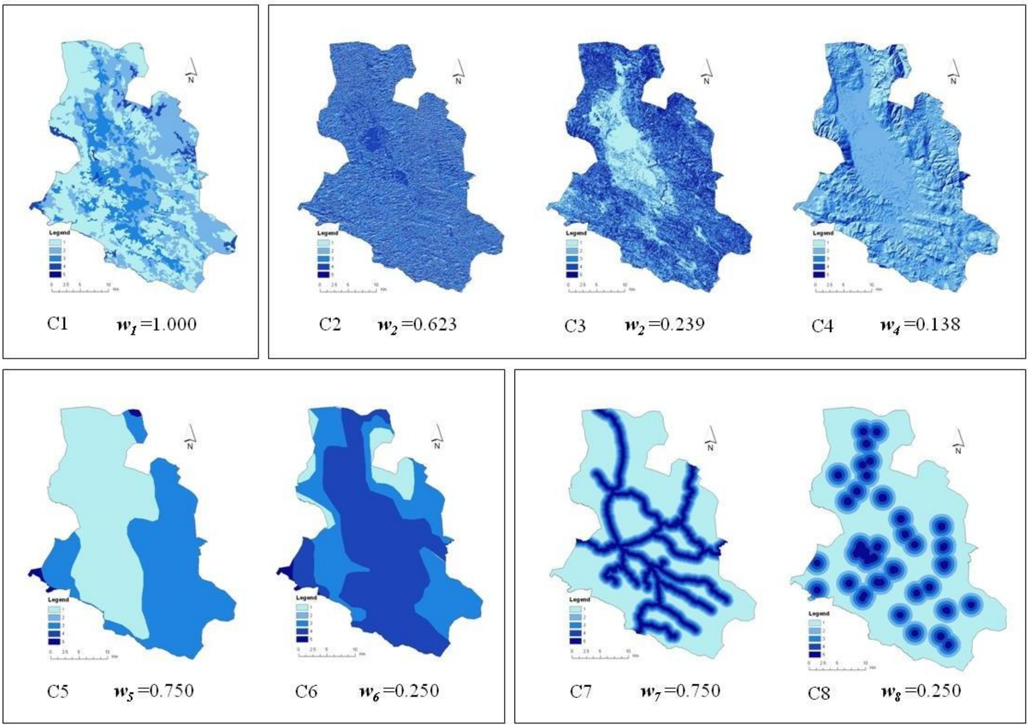

Figure 6 – Standardized criteria

As a result of multiplying weight criteria obtained as a result of AHP, with a cell's score of each criterion by appling Weighted Linear Combination (WLC), that is integrated into Easy AHP tool, according to the formula (5) the final forest fire risk map is generated.

$$S=\Sigma \, wi \, xi, \tag{5}$$

where S is the fire hazard rating, wi is normalized weight of factor i, and xi is the criterion score of factor i.

Based on defined criterias and clusters, final map is represented in the same score as criteria from 1 to 5 (Figure 7). Larger values of cells score are characterized for location with high risk of fire ignition. On Figure 7 areas that are the most critical when it comes to the spread of fire are represented with dark colors.

Analyzing the results, the total area of the most endangered area (value of cell 5) of forest fire in Nevesinje municipality is 121.4 km2, which is about 13.2% of its territory. Mainly, those areas are the parts of the municipality which are located near settlements on steep slopes and that are mostly covered by pastures and conifer forests.

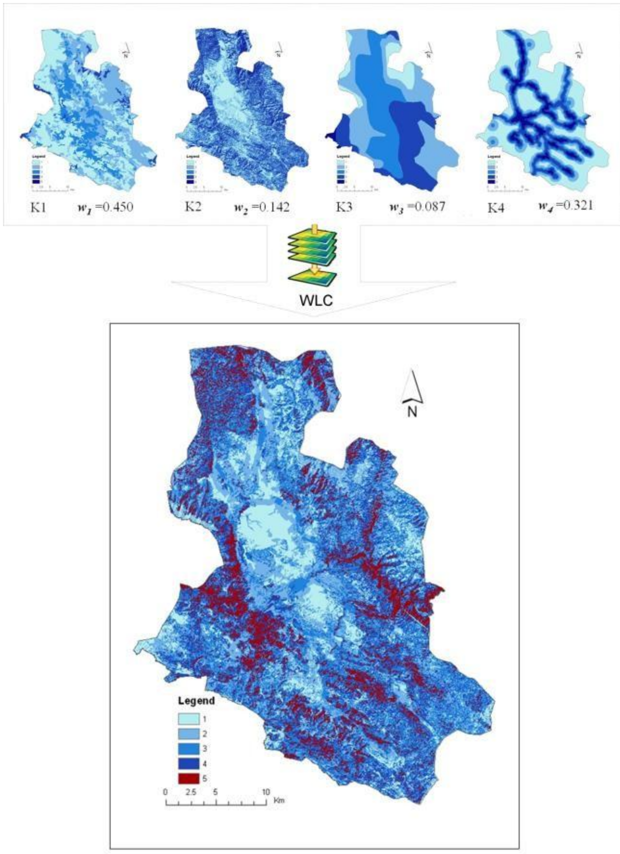

Figure 7 – Aggregation of forest fire risk map, municipality of Nevesinje

Validation of proposed method was performed by establishing spatial relationship between historical data and forest fire map. The Landsat 8 data was used for burned area extraction.

11. CONCLUSION

The measurement and assessment of the evolving risk environment is the base for the creation of comprehensive, proactive instriments that enable the prioritization of risk reduction investments. Hazard mapps is one of most used measure that provide information needed for respons and recovery from disasters. Disaster managemet and hazard mapping requires seamless integration and sharing of spatial data from a variety of providers. Therefor, Spatial Decission Support System which integrates Service Orientrd GIS and decision analysis tools (several MCDA methods) is needed to support decision maker. In this case, combination of SO GIS and AHP MCDA method is used to determine forest fire risk zone in the municipality Nevesinje.

Prediction of forest fires was carried out on 8 criteria grouped in four clusters (land use, topography, climate and socio-economic). The AHP multicriteria method is used to calculate a correspondent weight of criteria. Comparisons matrix are based on the experience of experts, literature and current practice. The final risk map is obtained in the WLC methods. Approximately 13.2% of the municipality Nevesinje area belongs to the zone of very high, 29.3% of the zone of high, 31.1% moderate zone, 21.3% of the low zone and 5.1% zone of very low risk of fire. For validation spatial relationship between forest fire risk map and historical data was performed.

12. QUESTIONS

1. What are the main components of Disaster Risk Management?
2. What are a basic phase of Decision Making Process?
3. What is DSS and why we need it?
4. What is the major difference between DSS and SDSS?
5. Which data models use GIS for computer representation of real world?
6. What are the major advantages of SO GIS comparing to traditional GIS?
7. What is basic principles of Analitic Hierarchy Process?
8. Why we need risk map?

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