Developing Interoperable Geographic Data Model for the Mitigation Phase of Disaster Management

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Keywords: Geographic Information Systems, Mitigation Phase of Disaster Management, Geographic Data Model, Data Requirement Analysis, Interoperability.

SUMMARY

Manmade and natural disasters have been increasing day by day and cause great human and properties losses. Hazard is a dangerous fact or activity that can leads to loss of life, health effects, social and economic losses. Vulnerability is a feature of a society that makes it susceptible to the destructive outcomes of the hazardous event. The interaction of hazard and vulnerability creates the risk of disaster. Mitigation stage refers to activities such as determination of disaster hazard and risk and avoidance of damages, prevention of its effects or minimization, taking measures to compensate inevitable losses. It is an intricate issue in the whole sequence of emergency management requiring full and quick collaboration between diverse actors in diverse sectors. Geographic Information Systems (GIS) will facilitate to diminish of calamitous results of disasters and protect lives and properties with dynamic use in mitigation phase of disaster management. For effective management of disasters as a priority, data requirement analysis were accomplished for mitigation phase of disaster management after determining disaster types such as earthquake, flooding, landslide, forest and urban fire. Developing an interoperable geographic data model is a new approach for Turkey that enables using the data corporately and successfully. This model is object-oriented model and based on ISO/TC 211 Geographic Information standards. The model is fully described with Unified Modeling Language (UML) class diagram and converted to Geographic Markup Language (GML) of OGC. The model compliant with Turkey National GIS specifications can be starting point for geographic data providers in Turkey to determine disaster risk that has significance because of the increasing of natural or man-made disasters. When data sets are produced with these standards, risk map will be produced effectively and data sharing will be possible between different actors.

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1. INTRODUCTION

Many people in different parts of the world are faced with different types of disasters. These disasters affect the capacity of working and cause significant loss of life and property. The actions taken to counteract these disasters are performed systematically (Kadıoglu, 2011). Disaster management is to perform preparedness, response, mitigation, and recovery activities in a sequence to save humans, diminish assets damages on manmade and natural disasters. Accomplishment in disaster management depends on effectively realization of activities that are carried out in the disaster cycle. These activities are done before and after the disaster occurred. Damage mitigation includes studies towards necessary technical, administrative and social measures in order to be protected from the adverse effects of the disaster beginning disaster response period until the next disaster (Guler, 2008).

Disaster hazard is a dangerous phenomenon or a substance that causes social, economic, and environmental disruptions, loss of life, injuries, asset damages and loss of facilities (UN/ISDR, 2009). Vulnerability is a second component of a disaster that is poses the disaster risk, the characteristics or the conditions of a society, system or assets that cause the damaging effects of a hazard (UN/ISDR, 2009). In order to understand the disasters it is necessary to determine the hazard and different vulnerability levels of different groups of society in the face of the disasters (Blaikie et al., 2004). Disaster risk appears as a function of hazard and vulnerability concept mentioned above. After determining disaster risk, disaster mitigation activities will facilitate the coordination of all disaster management activities by using Geographic Information Systems (GIS). Geographic Information Systems have a vital function in thriving disaster management. In view of intricate character of disaster, Geographic Information Systems can deal with base different geographic and real time data sets. Disaster management needs to be used geographic data sets collaboratively (Aydinoglu and Bilgin, 2015). For this purpose, in this study, geographic data needed in the scope of determining hazard, vulnerability and risk were determined and geographic data model was developed with geographic information technologies for mitigation phase of disaster management.

Geographic data model for disaster risk management is based on the relevant standards of ISO TC/211 such as ISO 19103 conceptual schema language (ISO/TC 211, 2005a), ISO 19109 implementation scheme rules (ISO TC/211, 2005b) to design feature types, relationships, geometry, and other properties (Golodoniuc and Cox, 2010) and it is also an object oriented geographic data model which was designed according to the requirements of the risk analysis of landslide, flood, fire/urban fire and traffic accident. To develop the model, data needed for risk management of the most devastating disasters in Turkey such as landslide, flood, fire/urban fire, and earthquake was determined by academic literature survey. The data and the relationships between them were modeled using UML.

2. MULTI HAZARD DISASTER RISK

Disasters are unusual natural or events causing human and assets loss and damage to biotic and abiotic environment (Sahin and Sipahioglu, 2002). Two factors play an important role in the emergence of disasters. First of these factors is the presence of the hazard that can lead to disaster (human or natural origin) and the second is the presence of people that can be vulnerable in the face of this disaster. Hazard is physical events or phenomenon that has damage potential for environment and assets (AFAD, 2012). Some hazards are originating from technological factors. A large part of this hazard arises due to an accident.

Multiple hazard situations are consisting of the initiation of a hazard and other events and the result of the consecutive occurrence of hazards. According to Komendantova et al (2013); multiple hazards, is parallel series of events arising from diverse backgrounds. For example, a storm can be seen with the earthquake. In consecutive events; first event initiates following series of events. For example earthquakes trigger landslides and tsunamis. Determination and mapping of multiple hazards provide many benefits in response phases of disasters. However, vulnerable situations should be determined against multiple hazards. Vulnerability can be evaluated on several dimensions such as physical, economic, environmental, and social and so on. To determine vulnerability factors against hazard has an important place in risk analysis studies. “Vulnerability is the characteristics of any person or group that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard” (Blaikie et al., 2004: 11). Also “vulnerability is a function of the characteristics of the risk element, i.e. the way the element is exposed to the specific hazard and the magnitude of the exposure” (Schmidt et al., 2011:1172). Human vulnerability consists of exposure, resistance and resilience. Exposure is a product of natural environment, surrounding building characteristics and physical location. Resistance reflects the physiological, physical, health, economic and the health care systems (Pelling, 2003).

Disaster risk means: “The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period” (UNISDR, 2009: 9). Risk also can be stated; risk equal to potential losses (potential losses= risk prediction x sensitivity (AFAD, 2012). A single risk assessment process only considers the risk situation that may arise due to danger; multiple risk process considers the risk situations that may arise from multi hazards. When different hazard events trigger each other disaster hazard may be precursors or initiator of the other. According to FEMA (2007:445), triggering events is the result event of initiating event observed directly or indirectly. For example flash floods affect the electrical system of an area as a result of power cuts, fires and explosions can be seen due to an earthquake that tore natural gas pipelines. Forest fires can expose the mudflow. Tornadoes can cause the destruction of power lines.

To manage multiple hazards, multi hazard and vulnerability situations can be analyzed and the factors that demonstrate hazard and vulnerability status must be examined in detail (Tastan and Aydinoglu, 2015). As seen on Figure 1 multi risk assessment is a complex process. It begins with a step of identifying hazards simultaneously independent of each other and the step of identifying the sources of each trigger or fluctuation danger**.** Next, vulnerability analysis is made for assets, people, buildings and environment exposed to hazards. Risk assessment in terms of loss of life, economic losses, and environmental degradation is performed for single hazard and triggered hazards. Finally multi risk situations are ranked and integrated in a single risk index (Marzocchi et al., 2012: 557)

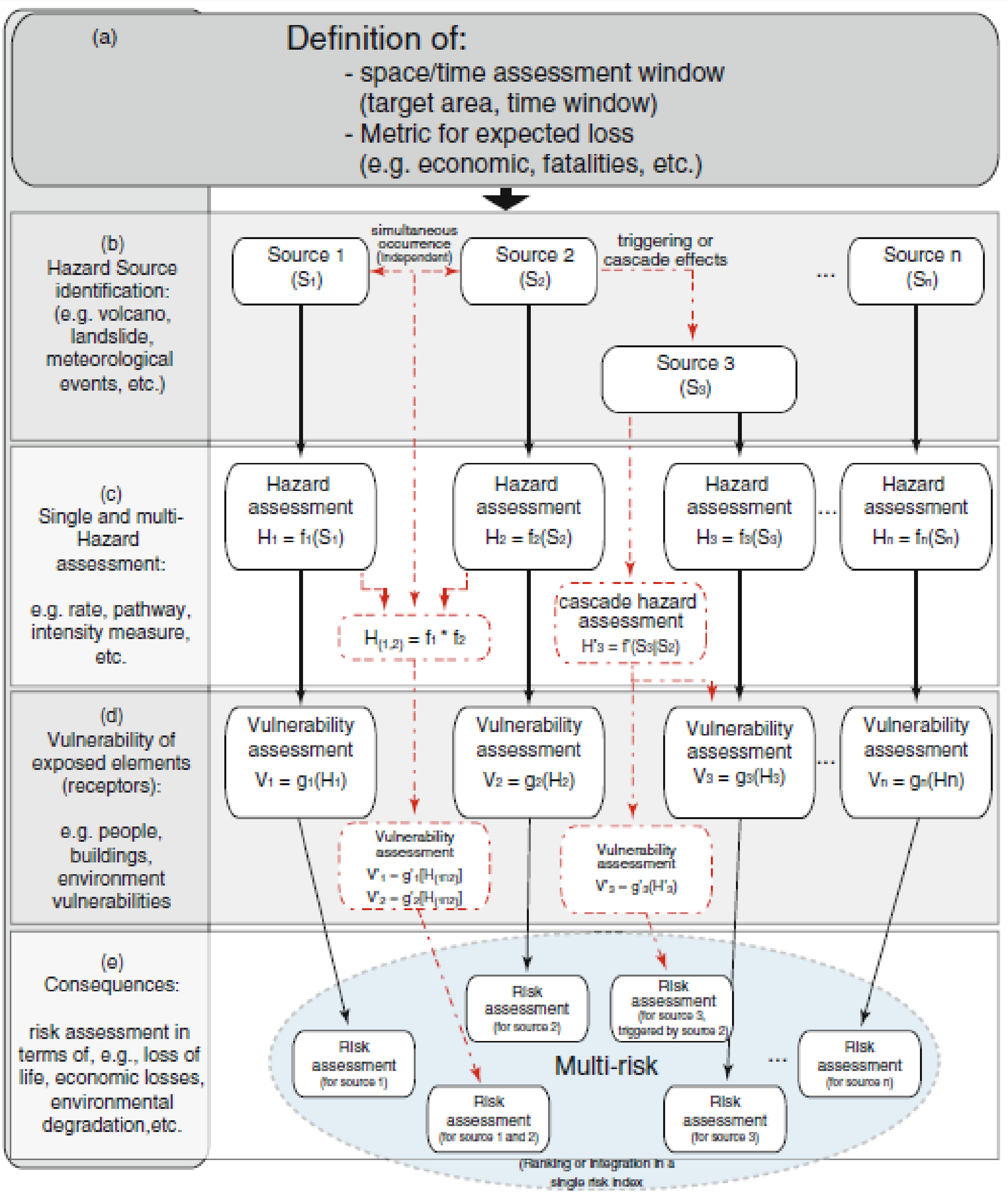

Figure 1. Schematic explanation of Multi risk assessment stages (Marzocchi et al., 2012:557)

Multi hazard risk analyses have a lot of challenges. Qualitive, semiquantitive, or quantitive approaches are used to assess the multi hazard situation (Kappes et al., 2012). Risk assessment methods can be varied according to the data and research area. Mapping multi hazard and performing multi hazard analysis are used for risk determination at mitigation phase of disaster management and this analysis supports planning disaster preparedness (URL 2).

3. DEVELOPING OF INTEROPERABLE GEOGRAPHIC DATA MODEL

Geographic data model for disaster risk management is compatible with the standards of ISO TC/211 Geographic Information Committee and Turkish National Geographic Information System (TUCBS). The model indicates required data contents for the risk management of destructive disasters in Turkey such as flood, fire/urban fire, earthquake, and traffic accident.

TUCBS aims to establish the GIS infrastructure appropriate to INSPIRE directive and user needs at the national level and to provide geographic information to the public institutions and all users over TUCBS infrastructure. It is expected TUCBS portal collects and manages geographic data sets produced depending on open geographic data exchange format in the quality to meet the needs of all users (URL 1).

TUCBS data models include UML applications schemas and feature catalogs for data themes such as Address (AD), Building (BI), Cadastre and Land Registry (TK), Administrative Unit (IB), Transportation (UL), Hydrography (HI), Land Cover/Use (AO), Orthophoto (OR), Topography (TO), and Geodesy (JD) (GDGIS, 2012 a). Besides, Urban GIS data model supporting urban management includes data models for data themes such as Vegetation (BO), Public Services (KH), Urban Furniture(KM), and Water mass (SK) (GDGIS, 2012b). Data themes mentioned above were used as base models to generate geographic data model of disaster risk management.

When developing the model, the required data for risk management were determined by the academic literature work. Because disaster risk consists of hazard and vulnerability, data needs for hazard, vulnerability, and risk of destructive disasters were analyzed. Then these data and the relationships between them were modeled using UML.

3.1. Geographic Data Model for Hazard Analysis

For landslide hazard analysis; aspect, slope, and elevation feature types from TUCBS TO, river feature type from TUCBS HI, land cover data class from TUCBS AO, road class from TUCBS UL, lithology and meteorology feature types from other data theme should be used.

For flood hazard analysis; as seen on Figure 2, aspect (*Baki*) and slope (*Egim*) feature types obtained from elevation feature type (*YukseklikGrid*) of TUCBS TO, land use (*AraziKullanimi*) featuretype from TUCBS AO, drainage basin(*DrenajHavzasi*) featuretype from TUCBS HI, soil groups and meteorological feature types from other base themes (*TemelCografiNesneler*), and flood events data sets (*GecmisVaka*) should be used to produce flood hazard feature type (*SelTehlike*). All attributes, values, and relationships were defined with ISO/TC211 encoding rules as defined in the schema.

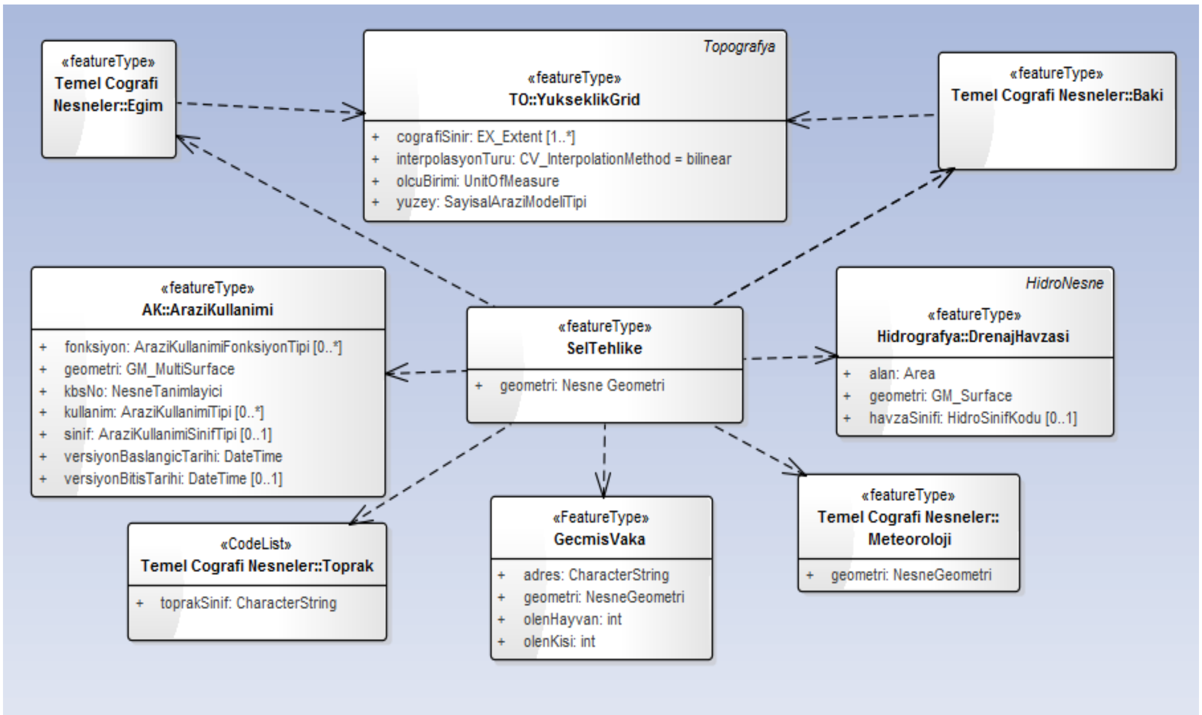

Figure 2.UML Application Schema for the activity of flood hazard analysis

For forest fire hazard analysis (*OrmanYanginiTehlike*); as seen on Figure 3, aspect (*Baki*), slope (*Egim*), and elevation (*YukseklikGrid*) feature types from TUCBS TO, land use feature type (*AraziKullanimi*) from KBS AK, road feature type from TUCBS UL, district (*Mahalle*) feature type from TUCBS ID, vegetation feature type from TUCBS BO, meteorological and inventory feature types from base themes (*TemelCografiNesneler*), and fire events data set (*GecmisVaka*) should be used to produce flood hazard feature type (*OrmanYanginiTehlike*) with defined content on the schema.

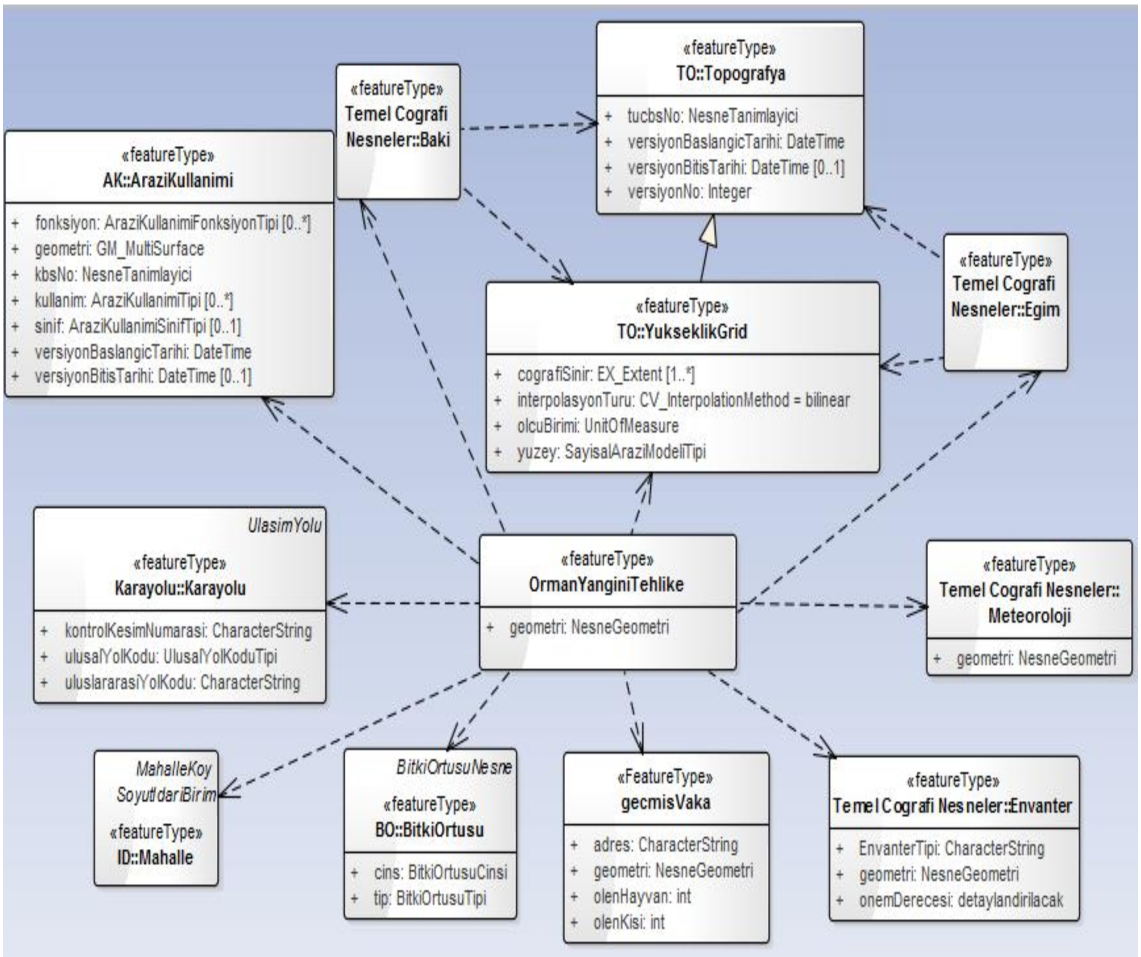

Figure 3.UML Application Schema for the activity of forest fire hazard analysis

For urban fire hazard analysis; building feature type from TUCBS BI, land use feature type from TUCBS AO, topography featuretype from TUCBS TO, meteorology from other base themes, water system and hydrant from KBS SK/KM, and energy network feature types from KBS KH should be used.

For earthquake hazard analysis; elevation and slope feature types from TUCBS TO, soil and lithology, and fault feature types from other base themes, surface water feature type from TUCBS HI should be used.

3.2. Geographic Data Model for Vulnerability Analysis

For vulnerability analysis of all disaster types; buildings, infrastructures, and transportation feature types were accepted as vulnerable elements. Data contents were defined also for environmental, economic and social vulnerability.

For fire vulnerability analysis as example; infrastructure (*Altyapi*), transportation (*Ulasim*), and fire building (*YanginZararBina*) feature types are required. Infrastructure includes telecommunication network (*TelekomunikasyonAgi*), energy pipeline (*EnergyNakilHatti*), sewer pipeline (*KanalizasyonBorusu*), and pipeline (*BoruHatti*). Transportation includes road (*Karayolu*), railroad (*Demiryolu*), seaway (*DenizyoluHatti*), and air lines (*UcusHatti*). Besides, data content was defined to determine social (SosyalZarargorebilirlik), economic (EkonomikZarargorebilirlik), and environmental (*CevreselZarargorebilirlik*) vulnerability as shown on the UML diagram of Figure 4.

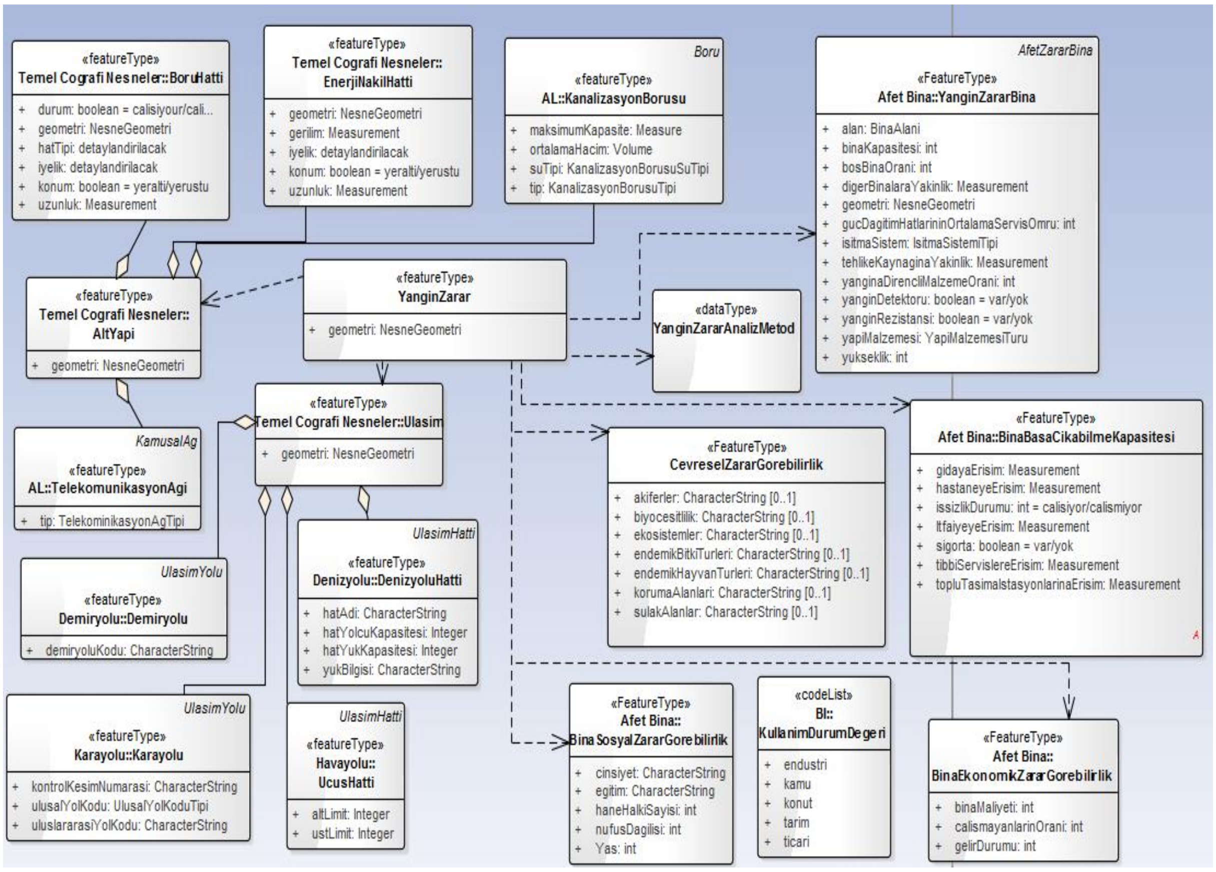

Figure 4.UML Application Schema for the activity of fire vulnerability analysis

4. CONCLUSION

In this study hazard and vulnerability data requirement was determined to look for a holistic approach to disaster risks that is for the most devastating disaster types in Turkey. Data requirements are based on general assumptions in the literature. To support Disaster-Emergency Management Systems, geographic data model for risk management was developed according to the data requirement analysis. Disaster-Emergency situation requires the use of sophisticated technology to support the interoperability of geographic data sets. In this regard ISO / TC 211 standards are accepted as an authority. Considering the complex nature of disaster risk management, this model can be used as base data exchange model to produce hazard and vulnerability maps that determine risk map. Open data model is compatible with national geographic data standards of Turkey to support data interoperability between actors.

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BIOGRAPHICAL NOTES

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