Development of an Urban Disaster Management System Based On a Geographical Information System

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ABSTRACT

We designed a disaster management system (DMS) for Samsun AFAD which is Provincial Disaster and Emergency Directorate of Samsun City, Turkey, to be used before and after a disaster such as earthquake or flood. Using this software, before and after a disaster, data belonging to buildings and inhabitants can be collected, mapped and analyzed statistically ensuring necessary resources to be determined and utilized efficiently. Designed system is basically a server-client application that server and client are independent of each other and interact through internet. Based on a geographical information system (GIS), software is developed appropriately for service oriented architecture. On the client side, there is a web interface and a mobile application provided for user. Through browser, the web portal provided by system can be reached from computers within directorate and mobile devices used in field work through internet/intranet.

1. INTRODUCTION

Upon request from Samsun AFAD (http://www.afetacilsamsun.gov.tr), a project for developing a DMS started a couple of years ago by PROLINE Integrated Intelligence Corporation (http://www.pro-line.com.tr). This system aimed migrating tasks being done by AFAD on document to a computer environment. Thus many tasks that requires long time to accomplish now can be done automatically and faster. The designed DMS offers a GIS approach helping officers to analyze and collect data, coordinate task force and prepare for a disaster situation with a comprehensive view.

General overview of DMS is shown in figure 1. There are nine different modules of DMS to handle various tasks to be utilized by user. DMS software has a map based interface offering conventional map functions and layer selection such as buildings, administrative borders, rivers on a selected base map. Base maps can be transferred from other institutions or from map servers of Google (https://www. maps.google.com), ESRI (http://www.esri.com), Bing (https://www.bing.com/maps). Building inventory module (BIM), keeps record of structural information of buildings and inhabitants working dynamically with the services provided by general directorate of civil registration and nationality and general directorate of land registry and cadastre (GDLRC). While damage assessment module (DAM) is used to assess affected area and damaged buildings after disaster, geological survey module (GSM) is used to determine area and buildings that are under risk of a disaster. Institution inventory module (IIM) is used to update, report and submit GIS based data of institution's resources. Right

ownership module (ROM) is designed to organize processes of right owners affected from disaster. Temporary shelter area module (TSAM) is designed to handle map based data of shelters and inhabitants. Land selection area module (LSAM) is used to submit data of new housing zones and buildings for right owners. Lastly, administrator module is used to manage user accounts and reference type and values used in other modules.

For officers working in the field, a mobile application is designed to work dynamically together with DMS. This application uses and process local data and store it back to local while synchronizing with system through a check-in and check-out mechanism over internet. In case internet is not accessible, collected data can be submitted offline to the mobile device. Submitted data of buildings, inhabitants and damage assessment can be visualized on a map. User can see him/herself on the map being investigated if there is internet connection. Application also allows to take and store photos of inspected buildings.
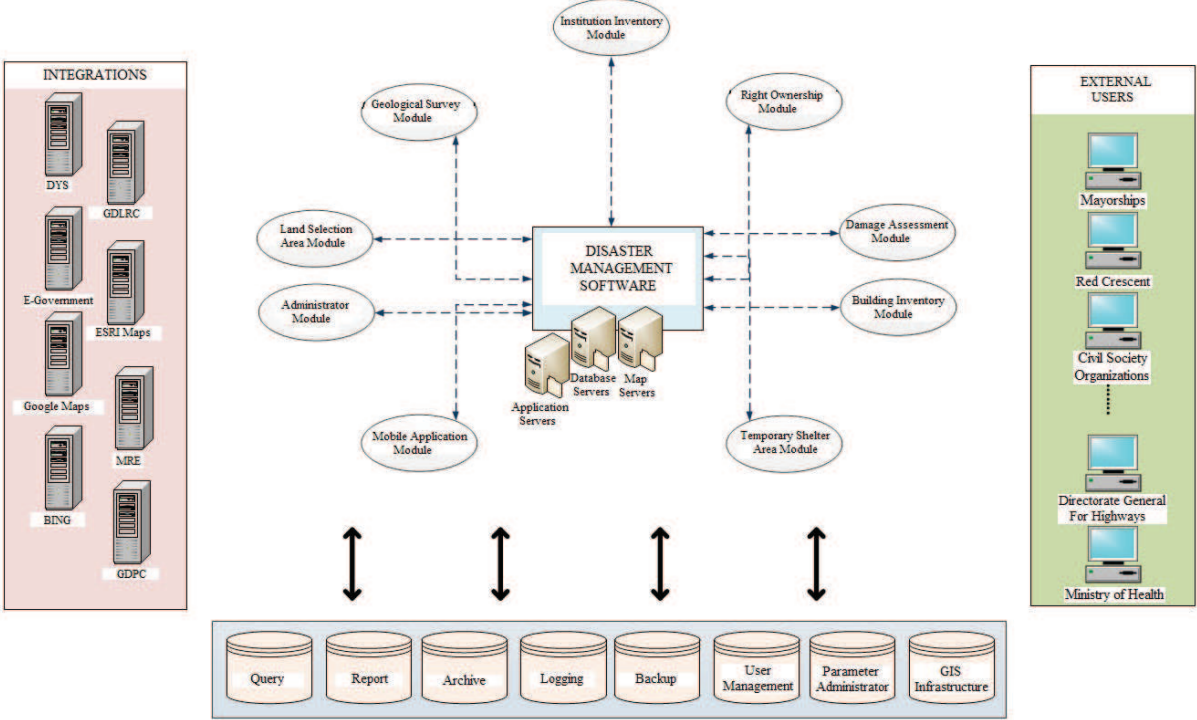

Figure 1: System overview of Disaster Management System

2. SYSTEM ARCHITECTURE

Right and fast decision making holds critical importance during the disaster. Success of decisions heavily depend on up-to-date data. While required data can be collected prior to disaster, during the preparation period, up-to-date data should be collected by establishing an integration to the authorized institutions which provides these data. Regarding that, system is composed of application substructures that is responsible of three main tasks: firstly, producing data and using these data inside AFAD, secondly retrieving data produced by external institutions by integrating AFAD with them and lastly providing data produced by AFAD to other institutions. Resulting from studies conducted with AFAD project team, the

general architecture of system is designed to be as shown in figure 1. According to this architecture, DMS is composed of four main blocks as follows: Samsun AFAD system modules, external system integrations, system infrastructure and external user applications.

Server is designed to have a three tier structure which is composed of service, task and data tiers [1]. This type of structure offers a modular structure whereas tiers are independent from each other that ensures in case of a modification in a tier, remaining tiers are not affected. Service layer contains web portal and web services with which client establish direct communication. Web portal provides necessary environment for user processes to be done through internet. Each process executed by user and requests from system are performed through the portal. Task layer contains every process requiring intelligence. Data and task layers work together with client-server principle such that data tier responds any kind of query coming from task tier. In designed disaster management system, there are application server, database server and map sever as shown in figure 1. For database management PostgreSQL (together with PostGIS extension) [2] is preferred due to having no cost since it is an open source database. Geospatial data is processed by Geoserver in OGE standards [3] which is also an open source without any cost.

3. SYSTEM MODULES

Considering essential functions required to be in a DMS , eight different modules was designed. System is reached via designed user screen. Staff of institution can enter to the system and be online by using a predefined user name and password.

3.1 Map Interface

Interface is designed for managing data on map using various map functions. Besides basic map functions such as zooming out and in, moving map, measuring distance and area, user interface contains buttons also for advanced applications like layer management, uploading shape files, submitting, erasing and modifying information. Layer management function offers the possibility of viewing map with various layers together or separately. For example address layer shows address and building information of inhabited areas. Information is stored separately using modules such as geological survey module, temporary shelter area module which are on other layers. Administrative layer shows borders in district and county level. While data produced by AFAD itself is shown on a layer, map module can show data obtained from other government institutions such as mineral research and exploration (MRE) institute providing geological, earthquake, fault and landslide maps. Layers described can be shown on base maps of Google, Bing or high resolution maps such as aerial or satellite images obtained from other institutions depending on the choice of user.

Map module allows user to delete, update or make geometrical changes on objects such as buildings which are previously created. In order to that corresponding layer e.g. building layer has to be selected. Moreover using map module, a shape file (.shp) of any designed object can be imported to the related layer.

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3.2 Building Inventory Module

Creating and managing building inventory of Samsun City are the primary tasks to be handled to make AFAD perform effectively in case of disasters and emergency situations. Regarding that building inventory module enables forming database of all buildings in Samsun via internet. Utilizing this module, users can add building to the layer defined as building layer. For example, a building appearing on a base map, can be created using geometric tools as an geometrical object and then added to related building layer. Afterwards, data corresponding to defined building which is composed of attributes such as structure type, construction year, number of flats, type of usage, load bearing system, type of roof and its material, can be submitted via a form. Users can add, erase and update flats as independent sections of this building and data of individuals living in this building. Independent section data is composed of story, type of usage, door number, electricity and water installation numbers and structure of flat. Besides, scanned official documents belonging to building and flats can be added, erased and displayed.

Through the services provided by directorate of civil registration and nationality and general directorate of land registry and cadastre, data regarding parcel of land and its shareholders can be reached by selecting related layer from the layer control menu mentioned in map module. After clicking on interested building, data of shareholders and their identity numbers are displayed. Utilizing these identity number, users of DMS can reach data of individuals through services provided by "general directorate of population and citizenship (GDPC)". Using search building function, users can make queries with corresponding attributes of related building. For example, by entering county, district and structure type such as concrete, concrete buildings in interested region are listed and shown on the map. By clicking on a building in the list, selected building is shown on the map with a different color. Another search method is selecting area with the mouse and then perform search within this area according selected criteria. A building in the search result list can be shown on map, edited, erased and related files can be added to it by using corresponding buttons resided at rightmost of each result. One another search can be done through GDPC services. Submitting following attributes: county, district, roads of district and building connected to a selected road, data of independent sections can be listed.

3.3 Damage Assessment Module

Utilizing damage assessment module, users can define a disaster effect area such as a county, district or an area drawn by user manually. Data about disaster such as disaster type, disaster date, damage assessment date, number of dead, injured and saved people, economic damage are submitted by user. A second type of data called "effects on daily life (EDL)" is entered from another tab where EDL situation, serial number of verdict, verdict date is submitted. From this point, damage assessment for each independent sections of buildings resided in disaster area is recorded under types of load bearing system damage, partition wall damage, roof damage, stairs damage where related damage can be defined as severe, moderate or low damage. Users can update damage info, add file and petition applied for damage to the system. Users can query in defined disaster effect area according to determined criteria such as disaster type and date. Another type of query can be done in disaster effect area to list buildings according to condition of damage such as collapsed, severe, moderate and low damage. Independent sections of buildings also can be searched using the criteria which are

entered during assessment. Petitions applied for independent sections can be searched based on petition number or identity number of applicant. Another helpful function is that users can thematize by coloring according to damage status and water level in case of flood. Lastly, users can get various types of report regarding the related data of damage assessment as a pdf file.

3.4 Geological Survey Module

With the Geological Survey Module (GSM) which is used prepare a report for a possible disaster for any region in the expected disaster area, while areas that is supposed to be affected by disaster can be determined, right ownership and precautions to avoid disaster can be submitted and displayed. By determining the region that needs geological survey, a GSM layer can be added onto map. Users can register "regions under effect of disaster (RUED)" to the system by drawing it in the GSM layer. Buildings which resides in RUED are automatically signed as "transfer". Users can determine the condition of buildings in GSM layer by identifying its status of damage, type of action such as transfer, precaution, checking required or temporary transfer.

In case GSM is not required, users can prepare a technical report for an area which is determined by manually by drawing. Other attributes are disaster type, survey date. By using the dedicated button, all GSM data entered to the system can be reached from a drop down list. After selecting a GSM, information, EDL, "disaster avoiding precaution (DAP)" tabs appear. While submitted data for GSM area is shown information tab, EDL shows decision whether area is affected or not. DAP contains actions selected by user to avoid disaster. Like in other modules, using submitted data GSM can be searched with a dedicated button. Search results are shown in GSM and three buttons next to each result to edit, show on map and add file respectively. Other data submitted by user such as buildings, RUED and technical reports can be searched for certain criteria. Lastly, users can get various types of report from GSM in pdf file format.

3.5 Institution Inventory Module

As a preparation before a possible disaster, to submit, update, query and report GIS based data of the sources recorded in the inventory of institutions to utilize during or after the disaster, Institution Inventory Module was designed. Users can submit the inventory data by selecting the building of interested institution by entering data classified in four tabs such as structure, institution, staff and equipment. Some of attributes of structure data are type of institution (e.g. government, private, foundation or civil society organization), soil investigation, insurance, used and stored dangerous materials, ventilation, fire alarm, heating method, assembly area. Institution data includes type of institution (e. g. training facility, health facility, shopping center or religious facility), name, indoor and outdoor space capacities, number of staff. On the other hand, type and number of attributes depend on the type of institution. For example if the building is a health facility, some of the attributes are particular to a hospital such as bed capacity, dialysis unit, operating room, decompression chamber, burn unit and emergency bed capacity. In the staff tab, users can add staff data regarding department, field of study. Equipments belonging to institution can be submitted from equipment tab. Staff or a responsible person can be assigned to the added equipment. Using submitted data in the module, institutions can be searched according to the attributes defined.

Search results are displayed as a list where show map and edit buttons appear for each result. The same style search is also applicable for staff and equipment search.

3.6 Right Ownership Module

In this module firstly users should select that right ownership procedures are initiated due to GSM report or disaster. After entering dates of announcement published by government, list of victim of disaster appears on the screen. Using dedicated buttons, users can select from people appearing in the list to the right ownership list. In right ownership procedures, contract and debt of each person listed in right ownership list can be displayed and edited. Using right ownership query with identity number, users can display right ownership data belonging to individuals. Besides from reporting tab, users can get reports in list format regarding victims of disaster, contracts, debts and disclaimers for a location specified as disaster area or GSM report.

3.7 Temporary Shelter Area Module

Using Temporary Shelter Area Module (TSAM), users can determine temporary shelter area (TSA) by drawing manually to place containers or tents for victims of disaster. Data of determined area can be submitted through a dedicated tab. Determined TSA can be updated and predefined objects such as block, parcel, shelter and facility area can be drawn inside it. Users can place identified victims of disasters to the shelters drawn by using a dedicated function. Using data submitted to define TSA, searching among defined TSAs can be done. As individuals living in TSA can be listed, individuals can be queried with their identity number.

3.8 Land Selection Area Module

Using Land Selection Area Module (LSAM), users can determine appropriate area and draw it on the map and then for the defined area users should submit and record data such as source (e.g. GSM report or disaster), location, county, district to where new settlement will be placed, number of right owners. User can define blocks and parcels inside the designated area by drawing manually. For defined blocks, a number and its usage purpose should be entered to appearing form. Blocks can be divided into parcels giving numbers to them. Using add building function of module, buildings can be drawn into parcels by filling up a form containing building data such as structure type, construction year etc. as done in other modules for adding building to the system. However not to confuse with other existing buildings, drawn buildings should be classified as disaster building as usage status. Into the drawn building, users can define independent sections where using add right owner function, right owner can be placed from the list of right owners. Among defined areas, searching can be done depending on criteria such as county, district, disaster effect area and GSM.

3.9 Administrator Module

Users manage the system using this module. By selecting a reference type such as building damage status, user can edit assigned value to status such as low damage to 2 instead of 1. Under the reference type of disaster, new disaster types such as nuclear leakage can be

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defined and a value representing its effect can be assigned. Using user management function, new users can be added to the system and authorizations belonging to these users can be determined with defined profiles. Damage status graphics function produces graphics according to damage status of independent sections in a selected disaster area. By clicking on the graphics, a pie chart according to usage type of sections is displayed. A specialized function, flood situation graphics is designed generating pie charts showing water levels for each type of usage of sections. Statistics of damage assessment is shown in a separate display where for selected disaster area, users can see inspected buildings and staff who made that inspection. Pie charts arranged by data entrance date or staff attributes are also shown.

3.10 Mobile Application Module

Mobile application offers interface for various data submission. Firstly users determine their working field based on district information through the dedicated button. If there is internet connection, users can utilize base maps such as Google maps, aerial photos etc. There are also base maps formed to work offline. Using a dedicated button, users can download building data of interested area to their tablet and then staff responsible for this task is selected. As existing buildings can be updated, they can also be deleted or new building can be formed by filling up defined attributes of a building by user. Afterwards modified data can be uploaded to the web environment. Using a checking mechanism users can reach data of individual who lives in an independent section through GDPC online. Users can determine damage status of independent sections and mark the ones which are not inspected. Updated data is sent by user to the system and data become available in building inventory indicated with a defined attribute that data has come from a mobile source. Depending on damage and water level information entered to independent sections of building, objects in the working field can be thematized. Using a dedicated button, user can take and send photo of inspected building or independent section.

4. RESULTS

A disaster management software (DMS) is designed for Samsun AFAD which is the Provincial Disaster and Emergency Directorate of Samsun City, Turkey, in order to collect and process data belonging to buildings and inhabitants using base maps and user selected layers. This software brings the advantages of GIS to officers to help them making their decisions and preparations much better that conventional methods. Using modules dedicated for each task defined by AFAD, the whole process can be managed electronically saving officers from burden of hard documentation. Mobile application module establishes the communication between center and field officers helping them working efficiently in an organized manner. Using this application missing or duplicate building and inhabitant data is avoided. Overall, this system offers a comprehensive preparation for a possible disaster, aids officers keep the control in hand during disaster and provides maximum care for citizens after a disaster.

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BIOGRAPHICAL NOTES

Kurtulus Erinc Akdogan, recieved his B.S., M.S. and Ph.D. degree in electrical and electronics engineering from Hacettepe University, in 2001, 2004 and 2011, respectively. Between 2001 and 2010, he worked as a research assistant at Hacettepe University in the Department of Electrical and Electronics Engineering. Between 2011 and 2012, he worked as a post doctoral researcher in Medical Device Development Facility (MDDF) Laboratory in Department of Biomedical Engineering at University of Southern California, Los Angeles, California (USA). In 2014 he has joined back to the research team in Hacettepe University as a postdoctoral researcher. Currently he is working as a researcher in Proline Integrated Intelligence Corporation.

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