Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 22 (2016) 382 – 390

Procedia Technology

9th International Conference Interdisciplinarity in Engineering, INTER-ENG 2015, 8-9 October 2015, Tirgu-Mures, Romania

Improving Disaster Resilience Using Mobile Based Disaster Management System

Can Aydin[a,]*, Cigdem Tarhan[a], Ahmet Selcuk Ozgur[a], Vahap Tecim[a]

[a]*Management Information Systems, Faculty of Econ. and Admin. Sci., Dokuz Eylul University, Dokuzcesmeler Kamp., Izmir 35160, Turkey*

Abstract

The use of ICTs can help to produce information and make better decisions for effective disaster management system. ICT is considered to necessary enhance adaptation capacity and supports feedback, ensure information access, enables active participation, reduces vulnerability. Mobile technologies are appropriate for providing these needs to improving resilience. Nowadays with the widespread use of mobile devices, benefiting as an information sharing environment after disaster is inevitable. The use of mobile technologies by citizens after a disaster increases resilience against disasters. The aim of the study is to increase disaster resilience by using mobile technologies to ensure citizens play an active role in disaster management.

© 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the "Petru Maior" University of Tirgu Mures, Faculty of Engineering

Keywords: Management Information System; Mobile Technologies; Disaster Resilience; Geographical Information System; Disaster Management System.

1. Introduction

Cities are vulnerable to natural hazards because of higher densities of population and urban sprawl. Suffering from hazards, however, is complicated by many factors including social and economic inequity, the uneven quality

* Corresponding author. Tel.: +90-232-3010788; fax: +90-232-4251020.
E-mail address: can.aydin@deu.edu.tr

2212-0173 © 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the "Petru Maior" University of Tirgu Mures, Faculty of Engineering
doi:10.1016/j.protcy.2016.01.027

of human settlements and lack of education. Deficiencies in reliable infrastructure, resources and information networks generate vulnerable conditions and impede adaptation [1].

Reducing losses necessitates preparedness to take preventive measures prior to a potential disaster, accumulating experience to respond to a disaster, and managing it effectively in case of a disaster. Disasters are inherently complex environments, therefore; fast and accurate attainment of data from the disaster site, producing information from data quickly and subsequently making informed decisions regarding action to be taken at the disaster site based on this information is of vital importance. The use of information and communication technologies (ICTs) can help to produce information and make better decisions for effective disaster management system.

Today ICTs are used in many areas to facilitate and accelerate human lives. Public, private and civil society sectors already use existing ICTs, offering the potential to reach broad populations, and engaging them directly in processes of decentralized decision-making [2]. This engagement provides reducing vulnerability to risk and improve disaster resilience [3]. Especially mobile devices enable people to access the internet in anywhere without limitations. New generation (3G and 4G) communication technologies provide very fast sound, image and data transfer [4]. In literature, many studies can be found regarding mobile technology use in disaster management. Foresti [5] designed advanced system for emergency management which fuses the mobile social data and bottom-up communication with smart sensors. Mobile social data is consisted of user generated content from socio-mobile applications. This data handle with using web crawling techniques from other social media applications. Other mobile application is designed for enhancing communication between patient and doctor with mobile application after disaster [6]. There is building damage assessment application developed by [7]. Another application is FEMA’s 2011 application named ROVER (Rapid Observation and Visual Estimation of Risk) for estimating risk for disaster area [8]. When all these studies are analyzed it can be seen that mobile-based applications support a more effective disaster management in many ways.

The current disaster management approach supports direct participation of the emergency response of citizens and post-disaster recovery processes [5]. However traditional disaster management system is applied therefore citizens have no contribution to the disaster management process. With the absence of contributing citizens, effective and efficient disaster management cannot be performed. ICTs are particularly important as infrastructure for communication, knowledge storage, and social interaction [9]. ICT is considered to necessary enhance adaptation capacity and supports feedback, ensure information access, enables active participation, reduces vulnerability and provide information data collection longer periods of time. Mobile technologies are appropriate for providing these needs to improving resilience. Nowadays with the widespread use of mobile devices, benefiting as an information sharing environment after disaster is inevitable. The use of mobile technologies by citizens after a disaster increases resilience against disasters [10] [11] [12] [13]. In this context, this paper’s research question is “How to improve disaster resilience via mobile based disaster management system?” Therefore, the aim of this study is to increase pre and post disaster resilience by using mobile technologies to ensure citizens play an active role in disaster management.

2. The Earthquake Fact of Turkey

The Report of United Nations Development Programme Bureau for Crisis Prevention and Recovery [14] presents the destructive effect of natural hazards at the beginning of the 21th century. Especially, developing countries face great risk from disasters because of the rapid and uncontrolled growth of cities; for example, Turkey experienced some major earthquakes in the 20th century, which caused the death of at least 110.000 people, about 250.000 injuries, and 600.000 building damages.

Turkey is a seismically active area within the complex zone of collision between the Eurasian Plate and both the African and Arabian Plates, see in Fig.1. [15]. Much of the country lies on the Anatolian Plate, a small plate bounded by two major strike-slip fault zones, the North Anatolian Fault and East Anatolian Fault. The western part of the country is also affected by the zone of extensional tectonics in the Aegean Sea caused by the southward migration of the Hellenic arc. The easternmost part of Turkey lies on the western end of the Zagros folds and thrust belt, which is dominated by thrust tectonics [16]. Figure 2 presents the earthquakes, which magnitudes have been over 5.0 since 1900 in Turkey. The green points magnitudes’ are between 5.0 - 6.0, the blue points magnitudes’ are between 6.0-7.0 and the red points magnitudes’ are between 7.0-8.0 [17].

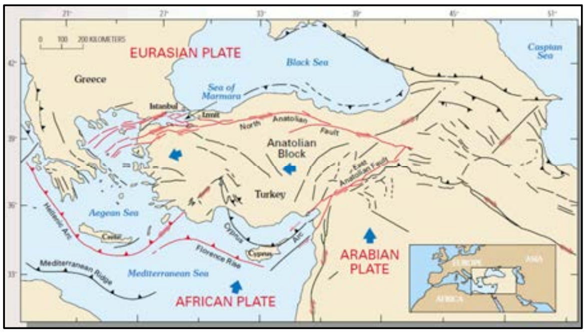

Fig. 1. Earthquake zones of Turkey

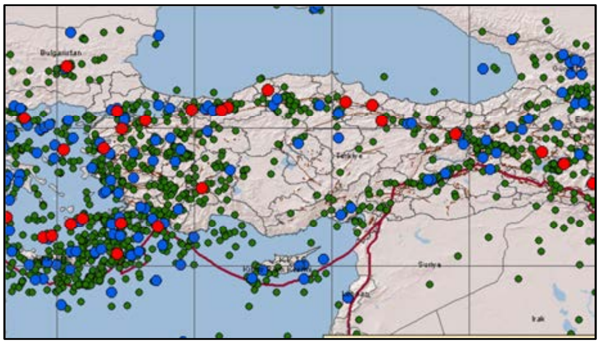

Fig. 2. Earthquakes, magnitudes > 5 since 1900 in Turkey

Fig. 3. The case area: Izmir

Izmir Province, west of the Anatolian Peninsula, is located in the middle of the Aegean coasts. It is surrounded by Balikesir from North, Manisa from east and Aydin from south. City lands, 37°45' and 39°15' north latitude and 26°15' and 28°20' east longitude, is torn between. The distance of the north-south is approximately 200 km and the distance of the east-west is 180 km (see in Fig.3.) [18]. Izmir is the third biggest city in Turkey in terms of population and socio-economic situation. There are 4.2 million people living in Izmir. Izmir survived as a big city throughout its history of 5000 years and has been frequently renovated under geological influences. Izmir has been greatly affected by earthquakes, fires and flood in its history.

Izmir is one part of the seismically active the Aegean Plate. It shows a very complex, active, movie and rapidly changing tectonic pattern due to the relative motions of surrounding tectonic plates. According to history readers, earthquakes have been the most damaging natural disasters that have affected the Izmir built up area. There have been at least 20 disastrous earthquakes with magnitudes greater six reported, which are in literature [16].

3. Research Methodology

Within this study; mobile technologies have been used to increase disaster resilience in context with an effective disaster management. There are three main reasons mobile technologies are chosen; the first one is that people are increasingly accessing the internet through mobile devices. The second, mobile technology allows location based query and the last one is that mobile technology is changing the user's web surfing habits [19]. In this context, the mobile based disaster management system is set on Android platform. MySQL is used for database design and PHP is used for ensuring the exchange of data between the databases (see in Fig. 4.). Android Studio is used in order to design graphical user interface.

Fig. 4. Research methodology

It can be seen that developing mobile technologies being used in the post disaster citizens emergency response and recovery processes increase disaster resilience. For this reason within this study an information-based application allowing map-based queries to be made of damage estimation, people and resource search and vital post-disaster locations like assembly areas, tent cities using mobile technologies has been made. When developing a damage estimation tool, various models found in literature were examined. Of these the peak ground model was used to determine the damage. There are many different approaches within the peak ground acceleration model as well. Among these the widely used [20] model was used. Geographical technologies were also used in the person and resource search module along with the important location query module in order to provide map-based query and reports.

The general form of the ground motion parameter estimation equation is in equation 1 and 2; where Y is the ground motion parameter (peak ground acceleration PGA), M is the magnitude; r_{cl} is the closest horizontal distance from station to a site in km; h is depth in km; T_1, T_2 and T_3 values are determined by soil types; V_s is a fictitious velocity and $C_{1\text{-}7}$ are constraints of our equation. The result of this equation calculates PGA of the earthquake. The values of variables mentioned above, can use for forecasting of loss ratio in model selected areas. For example, a moderator would determine the damage in a neighborhood, where the earthquake is magnitude 7.6, 2 km far away from the center of earthquake and has rock ground type. Using this methodology is important in terms of obtaining rapid response for decision-makers both in damage estimation updates in the area and the effective resource management.

$$Ln\,Yv = C_1 + C_2(M-6) + C_3(M-6)^2 + C_4(M-6)^3 + C_5 \ln r + C_6\,\Gamma_1 + C_7\Gamma_2 \quad (1)$$

$$r = ({r_{cl}}^2 + h^2)^{1/2} \quad (2)$$

where Y is in g, C_1= 0.055, C_2= 0.387, C_3= - 0.006, C_4= 0.041, C_5= - 0.944, C_6= 0.227, C_7= 0.030, h=7.72 km, σ_{rock}= 0.629, σ_{soil}= 0.607 and $\sigma_{softsoil}$= 0.575.

Use three site classes
Γ_1= 0, Γ_2=0 Rock: average V_s= 700 m/s, 27 records
Γ_1= 1, Γ_2=0 Soil: average V_s= 400 m/s, 26 records
Γ_1= 0, Γ_2=1 Soft soil: average V_s= 200 m/s, 47 records

"Missing person and resource search and insertion" module is completely based and designed on interactive end-user data entrance and queries. Therefore, based on the concept of social media it is designed two different graphical user interfaces for each module. The first module allows users to enter data about loss person or resource. The second one allows users to make queries of them. The accuracy of the system test is carried out using the rating system in question. For example, when a user enters information into system about a help distribution on the street, the system accepts that information and determines its value as the lowest rating. If multiple users indicate the same distribution for the same area at the same time, this information's rating starts to increase.

4. Mobile Based Disaster Management System

To reduce risks from disasters, we must mobilize a broad coalition of partners, from village chiefs to government ministers, from family-run shops to international corporations, from school principals to hospital directors. Interviews with experts were performed before the components of the system design process and what kind of tools would be needed before and after the disaster has been determined. In this context, the system is composed of the modules of "damage estimation", "location search", "missing person search and report" and also "resource search and report" (see in Fig.5.). Fig.6 presents the detail screen shots of "latest earthquakes" and "disaster backpack" tools.

In the "location search" part, district and neighborhood based meeting place, tent city, logistic support control center, security control point, police office; hospitals could be searched on the interactive map. Missing person and resources search and report modules aim the information entrance and reporting about missing people after disasters. Another module, "Damage estimation" provides a predetermination of the damage, may occur in the neighborhood of localities according to the distance from the basement types and epicenter. In addition to all of these tools, there are also different tools to enable public awareness about disasters such as the latest earthquakes and earthquake disaster case. Using "recent earthquake" tool, the recent earthquakes presents on the map via Bogazici University Kandilli Observatory. "Disaster case" module explains what it should have to be prepared after a disaster in it. This tool is not only providing awareness of the disaster but also increase the disaster resilience of citizens.

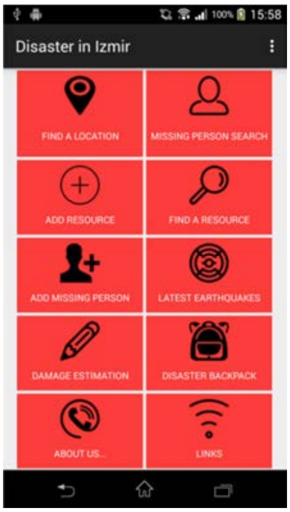

Fig. 5. Mobile GUI of Disaster Management System

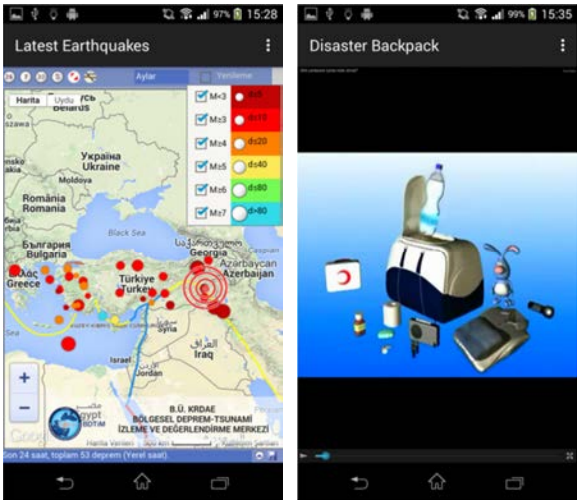

Fig. 6. “Latest earthquakes” and “disaster back pack” screens

4.1. Main findings of Damage Estimation

First, for the damage estimation module, the ground acceleration values determined above were calculated within the city of Izmir. Then on a neighborhood basis damage status was classified as serious, moderate and slight damage by visualizing the values on a map. After this stage, according to the disaster manager’s damage status, a map-based report was prepared in order to track which areas collapsed bridges or closed roads and neighborhoods are. The results ensure that both citizens and managers execute a more effective emergency response. In this way even though distributed rescue and the other types of team in city, the shortest path to the disaster area for the rescue team or residents can be determined. This tool will provide an effective way for decision makers to make decisions after the quake. Effective disaster management provides enabling better risk assessment improved decision-making. Faster assessment and feedback of data to coordination centers improved prevention, preparedness, response approach to disaster risk reduction (see in Fig.7.).

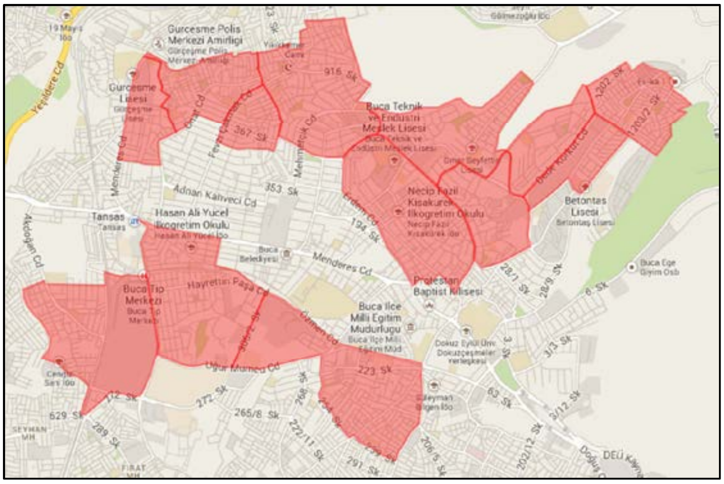

Fig. 7. Moderate damages neighborhoods

4.2. Location Search

Although many disasters have occurred which led to loss of life and property so far in Turkey, disaster awareness has not yet occurred. Therefore, citizens need to be more awareness and informed. Moreover, there should be studies about what needs to be done after the disaster before the disaster some information about the work to be done. Citizens are directed to the wrong place with the wrong or incomplete information in panic after the disaster. They are unaware of the necessary locations for collecting areas after disasters and to provide the necessary needs. This module provides displaying the search results on the map according to the pre-disaster and post-disaster questioning neighborhoods vital locations. This situation causes waste of time, which is vital for people after the disaster. Using this module, the post-disaster meeting locations can easily be found by citizens and they reach those points without time loosing. Thus, with this module, it is aimed to increase citizen's disaster resilience (see in Fig.8.).

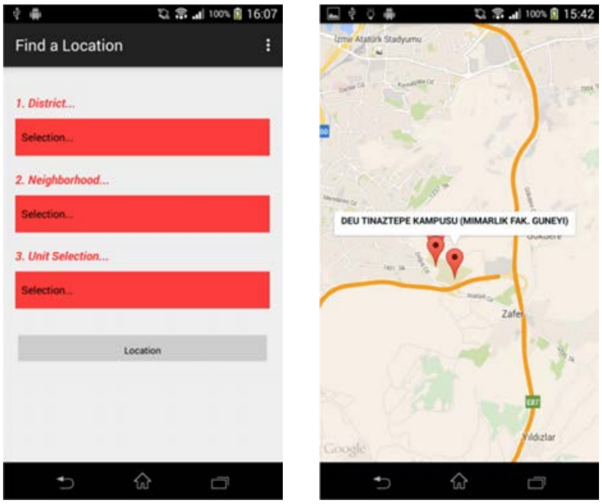

Fig. 8. Location Search (Search: Dokuz Eylul University)

4.3. Missing Person and Resource Search and Insertion

In this context, using the missing person search (see in Fig.9) and insertion through social relations, it is aimed to create a social networking environment. In this module, the physical properties information of the missing people, date to be lost and last seen location-based information is intended to reach out to other users. The resource insertion and search module (see in Fig. 10) is performed for cost-effective and post-disaster resource allocation. This also a social networked based optimization tool. It is aimed to share and follow vital things such as food, water or clothing distribution points by citizens.

In "Resource insertion" module, location name, type (water, food, hot meal), lead time (between 01:00- 02:00 pm), resource origin, inserted by and detail information are collected. Using as a base of these information, other citizens who use the application will have access to resources more effectively. On the other hand, this module assists the decision-makers, managers where the resources, coming from different organizations, are distributed. Thus, all assistance from home and abroad will be distributed in a cost-effective manner. Users also benefit from the information sharing to help aid distribution in areas with concentrations of whether people in the optimum ratio can be achieved.

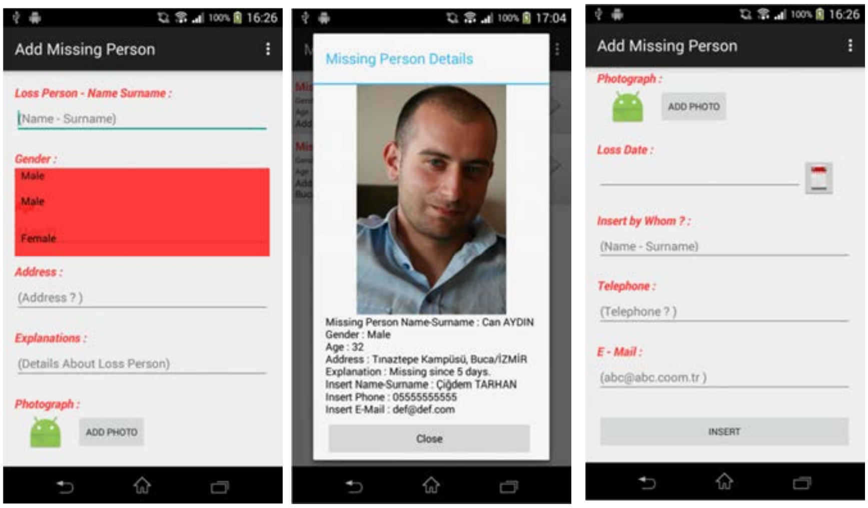

Fig. 9. Missing Person Add and Search

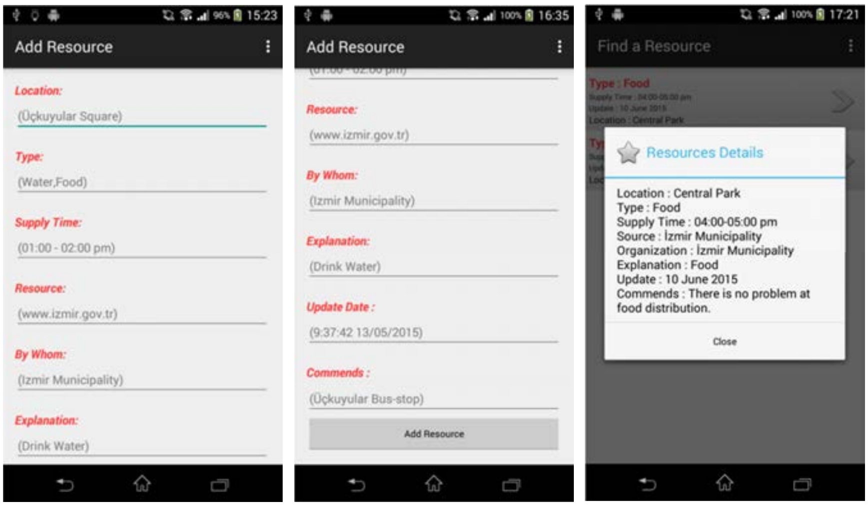

Fig. 10. Resource Insertion and Search

5. Results and Evaluation

Turkey is located in a region where natural disasters such as earthquakes, floods, forest fires and landslides occur frequently. In this scope this is an issue of importance for our country. As can be seen after the major earthquakes of 1999 and 2011 citizens under the risk of an earthquake have no disaster resilience. Within this context, as part of effective disaster management, increasing disaster resilience was intended by using mobile technologies. Successful disaster management strategies depend on the availability of accurate information presented in an appropriate and timely manner. Information is also important as it increases the transparency and accountability of the decision-making process and it can therefore contribute to good governance. The results of the study proved the study's hypothesis, "mobile based disaster management tools have a positive contribution to the disaster resilience." Additionally, the mobile application allows the users to perform share and inform vital information after disaster and decision makers to conduct efficient management of disaster with making better decisions. At the next step of the study, this system is going to be tested on more people or situation, so, it will have the opportunity to compare the results.

References

[1] Casillas CE, Kammen DM. Environment and development. Science 2010; 330(6008):1181-1182
[2] Hanna NK. Enabling enterprise transformation. Business and grassroots innovation for the knowledge economy. New York: Springer; 2010.
[3] Eriksen S, Aldunce P, Bahinipati CS, Martins R D'A, Molefe J I, Nhemachena C, O'Brien K, Olorunfemi F, Park J, Sygna L, Ulstrud K. When not every response to climate change is a good one: Identifying principles for sustainable adaptation. Climate Development 2011;3(1):7-20
[4] Gomez K, Goratti L, Rasheed T, Reynaud L. Enabling disaster -resilient 4g mobile communication networks. IEEE CommunicationsMagazine 2014.
[5] Foresti G, Farinosi M. Situational awareness in smart environments: socio-mobile and sensor data fusion for emergency response to disasters. J Ambient Intell Human Comput 2015; 6:239–257.
[6] Santhi A, Sadasivam G S. Design and development of compact monitoring system for disaster remote health centres. Indian Journal of Medical Microbiology 2015; 33(5): 11-14
[7] Fujiu M, Ohara M and Meguro K. Development of remote building damage assessment system during large-scale earthquake disaster. 15th World Conference on Earthquake Engineering (15WCEE), Lisbon, Portugal; 2012.
[8] FEMA. FEMA P-154 Rover CD, Rapid Observation of Vulnerability and Estimation of Risk. Federal Emergency Management Agency, Washington D.C.Federal Emergency Management Agecny. 2011.
[9] Eakin H, Pedro M W, Hsu D, Gil Ramón V R, Contreras E F, Cox M P, Hyman T A N, Pacas C, Borraz F, González-Brambila C, Barido D P L and Kammen D M. Information and communication technologies and climate change adaptation in Latin America and the Caribbean: a framework for action. Climate and Development 2015;7(3): 208-222.
[10] Cimellaro G P, Scura G, Renschler C S, Reinhorn A M and Kim H U. Rapid building damage assessment system using mobile phone technology. Earthq Eng & Eng Vib 2010;13: 519-533.
[11] Yates C, Partridge H. Citizens and social media in times of natural disaster: exploring information experience. Information Research 2015; 20(1), 659.
[12] Gomez R, Pather S. ICT evaluation: are we asking the right questions? The Electronic Journal on Information Systems in Developing Countries 2012;50(5) 1-14.
[13] Haynes K, Tanner T M. Empowering young people and strgentening resilience: youth centered participatory video as a tool for climate change adaptation and disaster risk reduction. Children's Geographies 2013;13(3): 357–371.
[14] UNDP, U. N. D. P. B. f. C. P. a. R. A Global Report: Reducing Disaster Risk A Challenge For Development (Report No. 92-1-126160-0). New York, USA. 2014.
[15] Strand P. Earthquake interactions and seismic forecasting. http://www.geology.um.maine.edu/geodynamics/AnalogWebsite/UndergradProjects2010/PeterStrand/html/BackgroundPage.html, 2015.
[16] AFAD. www.deprem.gov.tr, 2015.
[17] AFAD. http://www.deprem.gov.tr/sarbis/images/TURKIYE_1900_20XX_M58.png, 2015.
[18] Google Earth, 2015.
[19] Vinson F. Top 10 Reasons why mobile technology is more important than ever. 2013 http://localorganicrankings.com/top-10-reasons-why-mobile-technology-is-more-important-than-ever/
[20] Kalkan E, Gülkan P. Site-dependent spectra derived from ground motion records in Turkey. Earthquake Spectra 2004; 20(4): 1111–1138.