

Primljen / Received: 21.11.2015.

Ispravljen / Corrected: 31.8.2017.

Prihvaćen / Accepted: 3.4.2018.

Dostupno online / Available online: 30.12.2018.

Application of iOS / Android based assessment and monitoring system for building inventory under seismic impact

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Professional paper

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Application of iOS/Android based assessment and monitoring system for building inventory under seismic impact

The possibility of creating an "ID card" for each new and existing building in urban areas, based on transfer of necessary data into electronic format, is analysed in the paper. Local governments, public institutions, organizations, and building owners are thus able to obtain parametric information about the building using smart phones or tablets. Thanks to QR application, the access to building Inventory under seismic impact has become extremely fast and easily accessible via smart phones and tablets. The proposed IOS/Android system greatly reduces the need to go through administrative formalities to obtain information and documents relating to an earthquake-prone building.

Key words:

seismicity, loss estimation, IOS/Android, Quick Response (QR) code

Stručni rad

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Primjena iOS/Android sustava u ocjenjivanju i praćenju građevinskog fonda izloženog utjecaju potresa

U radu se analizira mogućnost stvaranja "osobne iskaznice" za svaku novu i postojeću zgradu u urbanim područjima prenošenjem potrebnih podataka u elektronički format. Gradske vlasti, javne institucije, organizacije i vlasnici zgrada tako mogu dobiti parametarske podatke o zgradi koristeći pametne telefone ili tablete. Zahvaljujući QR aplikaciji, pristup građevinskom fondu koji je izložen seizmičkom utjecaju postao je izuzetno brz i lako dostupan putem pametnih telefona i tableta. S predloženim iOS/Android sustavom umnogome je smanjena potreba za administrativnim formalnostima za pristup informacijama i dokumentima neke građevine osjetljive na utjecaj potresa.

Ključne riječi:

seizmičnost, procjena gubitaka, IOS/Android, Quick Response (QR) kôd

Fachbericht

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Anwendung des iOS/Android Systems bei der Einschätzung und Überwachung des Baufonds, welcher der Auswirkung von Erdbeben ausgesetzt ist

Die Abhandlung analysiert die Möglichkeit, einen "Personalausweis" für jedes neue und bestehende Gebäude in städtischen Gebieten zu erstellen, indem man die erforderlichen Daten in elektronische Form überträgt. Die Stadtverwaltungen, öffentliche Institutionen, Organisationen und Gebäudeeigentümer können somit Parameterdaten über das Gebäude durch Nutzung von Smartphones oder Tablets erhalten. Dank der QR-Anwendung ist der Zugang zu dem seismischen Einflüssen ausgesetzten Baufonds durch Smartphones und Tablets. Das vorgeschlagene iOS/Android System hat die Notwendigkeit administrativer Formalitäten für den Zugang zu Informationen und Unterlagen eines Gebäudes, das für Erdbeben anfällig ist, erheblich verringert.

Schlüsselwörter:

Seismizität, Verlustschätzung, IOS/Android, Quick Response (QR) Code

1. Introduction

Recent devastating earthquakes and the resulting major loss of life and property have given rise to publication of a considerable number of studies, research papers and measurement reports. Negative characteristics of the structures situated in earthquake zones increase the level of risk [1].

It is necessary to archive the information about buildings that are susceptible to earthquake impact. Archiving the characteristics associated with such structures, and the access to such information, are important to local governments, relevant public institutions, organizations, and building owners. Although it is true that a number of data and documents about these buildings are readily available, most of them are very difficult to obtain as they are kept in various institutions. Thus, keeping this information in a common database, and making it quickly and easily accessible, is seen as an appropriate solution both by relevant public institutions and building owners. Considering the current rate of development of information technologies, the data access tools such as QR codes have been increasingly and very rapidly introduced in many sectors. If QR codes are allocated to buildings, many relevant data and parameters can be retrieved rapidly and easily. The seismic risk to building inventory is of growing interest to scientific community and decision makers, because an increasing urbanization and concentration of population in earthquake prone - and hence highly vulnerable - areas [2].

It is important to determine and analyse the increasing housing stock in cities, and determine and manage all information related to buildings/structures in terms of spatial planning and urban regeneration. To make proper preparations for a possible earthquake, it is important to estimate beforehand what type of structures and areas will be mostly affected by earthquake action, and what are possible consequences of such influence. The loss estimation is a frequent method for evaluating seismic risk and estimating loss or damage due to seismic action. This analysis enables determination of information related to potential losses and damage. The availability of this information in electronic media highly facilitates the decision making process.

With regard to possible earthquakes, it is important to know seismic performance of structures in terms of mitigating the loss of life and property. However, the mere quantity of buildings to be analysed makes the assessment process inefficient. Therefore, the solution is seen in using a quick and accurate method for assessing the existing building stock [3].

The data matrix procedure is widely used in many sectors of the today's technologically advanced world. In this study, the data matrix procedure has been selected for evaluation of the existing building stock in Turkey. By making the data matrix of an existing building, the parametric information about the structure was transferred to an electronic database.

Various parameters are needed as input for rapid scanning methods for determining the earthquake risk priorities, and for loss estimation aimed at determining loss of life and

property in a future earthquake event. Parametric data valid for each existing structure and new buildings are transmitted to an electronic media and are made available for application by appropriate users.

A dynamic web space was created in Php language with the QR Code for guidance. The MYSQL database, enabling rapid and convenient data manipulation, was used. The tables belonging to the database were hosted on the server and a central database was created. The areas were determined taking into consideration the number, text, option, or manual entry of the area format. One of the most significant issues in developing software programs is to prevent users from making mistakes when entering data. The areas in which mistakes in data entry can be made by the administrator were extended by the developed software, and so the only possible thing is to select an option. The administrators are prevented from making mistakes as they receive the building location information from smartphones and are then permitted to take action. The software sets up a sound substructure to obstruct inadequate entry of crucial data.

Vulnerability is defined as "a state combining physical, economic and environmental factors, which increases system sensibility to danger". Earthquake vulnerability is defined as a risk factor that may occur in a risk element or risk group if a predicted earthquake hazard occurs. The evaluation of regional earthquake vulnerability is a basic concept in hazards research and a critical step in earthquake planning, prevention, and mitigation. Assessing regional vulnerability to earthquake is a complex problem that involves many factors, such as population density, economic development, average age of buildings, average height of buildings, earthquake intensity, quality of building materials, and lifeline systems [4-10].

In this study, preference is given to either smartphones or QR, which is a popular coding technology and one of the fastest ways to get information through efficient use of contemporary technologies for buildings in earthquake-prone regions. Earthquakes mostly harm people due to their negative effects, especially to residential structures. Out of possible harmful effects, a major one involves damage to buildings constructed as residential structures. By means of this study, an extremely fast and reliable software infrastructure is established to make the preliminary assessment of buildings under earthquake risk, and deliver this information to either the residents or persons to purchase a house, or to academicians for scientific research purposes or, most importantly, to public authorities.

In this study, soil properties, seismic past of the region, and building and demography data, are transferred into a database, and considered in the calculation of earthquake vulnerability. The QR code was generated on an example of a typical building. All the data were identified as the input, which enabled calculation of earthquake effects on the building. These specific data were entered separately by means of an administrator panel for each building. Thus, an identity card was made for each building. Any updates to the system can be made in parallel with any changes of building data using the QR code. With this system, a database

will eventually be established to monitor the buildings and gain an easy access to the Building Inventory information. Thus, the establishment of a proper system has been enabled. The system is easily accessible through intelligent monitoring and the data are constantly updated. With the study, the Building Inventory data will be provided, and no data would be lost over time. A great advantage of this study is that it enables robust monitoring of the buildings. An easy access to the Building Inventory information is enabled. In literature, the authors have not found any study on the QR code application for buildings. This study provides information about earthquake risk assessment, earthquake vulnerability, building inventory, work area, history of seismic activity, as well as the listing of input data. An appropriate data entry was made for the selected buildings. The data provide information regarding software system algorithms generated to enable entry of building data. The issue of how the QR code should be used by the administrator and users is also considered. It is also extremely significant to additionally make use of computer and web technologies in the recording and system monitoring activities. It is clear that either some academic studies or commercial activities may also be under way to develop such a web-based software system. With technologies developing quite rapidly, it is expected that access to information will be growing accordingly. The ways to get to the data are considered in the study, with an emphasis on smart phones, which are regarded as a significant product of the present-day technological advancements. The use of smart phones enables fast and reliable access to information. The QR code system was added to the study to enable faster and more reliable access to data. In this way, both ex-ante and ex-post earthquake information related to the buildings was compiled quickly and reliably, and users were enabled to display such information.

2. Earthquake risk assessment

The earthquake risk assessment is regarded as a young and evolving new discipline that has been introduced as a logical continuation of the earthquake hazard research conducted by Luis Esteva [11, 12] and Allin Cornell [13].

As stated in an elementary definition of this discipline, outlined by the EERI Committee on Seismic Risk in 1984, "seismic risk is the probability that social and economic consequences of earthquakes will equal or exceed specified values at a site, at various sites or in an area during a specified exposure time" [14]. In literature, opinions differ considerably as to when and where the earthquake risk assessment was actually started. Luis Esteva [11, 12] and Allin Cornell [13] were the first to initiate the field of seismic risk assessment in 1968. On the other hand, Whitman et al., point to some earlier earthquake loss assessment studies, such as NOAA1 study for San Francisco [15], which was followed by more than thirty other earthquake loss studies for various US regions [16]. However, these studies were long preceded by the John Freeman's book Earthquake Damage and Earthquake Insurance [17], which specified what is

nowadays considered to be the earthquake loss estimation [18]. Afterwards, earthquake loss estimation was mostly considered in the scope of the insurance sector, until publication of Cornell's work in 1968 [14].

3. Earthquake vulnerability methods

Vulnerability can simply be defined as sensitivity of exposure to seismic hazard(s). The vulnerability of an element is usually expressed as percentage loss (or as a value between zero and one) for a given hazard severity level [19]. In case of a large number of elements, like building stocks, vulnerability may be defined in terms of damage potential relating to a class of similar structures subjected to a seismic hazard.

Calvi et al. [8] divided vulnerability assessment methods into two main categories - empirical or analytical - both of which can be used in hybrid methods. Empirical (or observed or qualitative) assessment methods are based on the observation of damage incurred during past seismic events. Main types of empirical methods are: Damage probability matrices (DPM), Vulnerability Index Method, Continuous Vulnerability Curves, and Screening Methods.

Analytical (or quantitative) methods are based on the relationship between seismic intensity and expected damage, which is provided by a model with direct physical meaning. Types of analytical methods are: Analytically-Derived Vulnerability Curves and DPM, Collapse Mechanism-Based Methods, Capacity Spectrum-Based Methods, and Fully Displacement-Based Methods.

Perhaps a key for rapid assessment of these buildings lies in a hybrid approach, whereby experimental and analytical methods are combined in order to obtain quantitative and more reliable results for the group of buildings [20].

A relatively simple and fast analysis of potential seismic vulnerability was proposed by Morić et al. [21]. The research starts with a detailed analysis of the concept on which seismic vulnerability analysis of structures is based, especially the notion of damage index (DI), as a numerical value indicating the level of structural damage. They consider that the seismic response analysis of regular structures is acceptable if it is done as a simplified non-linear dynamic analysis with the time history function of ground motion as input load, and an SDOF model with the known weight, elastic stiffness, damping, elastic base shear capacity, and post-elastic stiffness representing the structure. A DI formula was presented, where the DI is defined as a linear combination of plastic deformation, stiffness degradation, and energy dissipation of a structure during an earthquake. The results of this methodology are presented in many articles [20, 22, 23].

4. Building inventory

Prediction and evaluation of the sensitivity of city territory and premises to seismic action is quite useful to competent authorities and administration [24-28].

A database is drawn up as an inventory of buildings categorised by typology. It requires too much time and high cost, but is nevertheless—critical for measuring damage after an earthquake [10, 29].

In the Global Earthquake Model (GEM), the Building Taxonomy is a creative and internationally accepted initiative in that it provides an effective communication platform among various international parties, which includes constant identification and classification to evaluate seismic hazard throughout the world [29, 30].

The data collection forms, with primary characteristics of buildings identified by GEM typology, were designed and used for the database as a means to evaluate consequences of catastrophes. This includes evaluation of 13 attributes that can influence seismic behaviour: direction, material of the lateral load-resisting system, lateral load-resisting system, height, date of construction or retrofit, occupation, building position within a block, shape of the building plan, structural irregularities, exterior walls, roof, floor, and foundation system [10, 31-34].

4.1. Existing building typologies

Designing a database for the risky buildings would be very useful in evaluating earthquake damage. Essentially, the fragility functions need to be considered for the building classifications, the data requirements, and the basic databases. The classification system selected to characterize buildings by the level of damage or loss would enable an integrated analysis of seismic risk. There are a number of parameters that are effective in determining the risk of earthquake damage for any structure [33-37].

Table 1. Structural system types used in this study [38]

Structural system type	
Masonry	
M1	Rubble stone
M2	Adobe
M3	Broken stone
M4	Cut stone
M5	Brickwork
M6	Brickwork (RC floor)
Reinforced masonry	
M7	Reinforced masonry
Reinforced concrete	
RC1	RC frame system
RC2	RC walls system
RC3	RC Frame + RC walls system
S	Steel
W	Wood

In this study, data entry is made for parameters needed for building statistics and loss estimation analyses, as well as for those identified in GEM. For the injured or dead persons, data entry may be made in order to determine any loss of life. In addition, the person evaluating the building can add his or her comments by opening a separate section called 'Other Information' at the bottom row of the data entry table. All these parameters are given in Table 2. The structural system type given in the European Building Typology was used in this study, see Table 1. Moreover, in this study, a data entry can be made for construction damage differing from the GEM. The levels specified in the European Macroseismic Scale (EMS-98) were used in entering construction damage levels. This procedure ranks among the most widespread observational damage estimation (macroseismic) methods. The EMS-98 scale is a damage matrix involving the probability of reaching certain building damage levels for buildings belonging to a specific damageability class under various seismic levels [38-42].

4.2. Study area

The history of Bitlis city dates back to the New Stone Age that is usually described as the Neolithic Era. This region has witnessed many civilizations such as Hittites, Assyrians, Urartians, Persians, Macedonians (Alexander), Romans and Byzantines, Selchuks, Ayyibidis, Kharzem Shahs, Mongolians, Anatolian Selchuks, Ilkhanidis, and Ottomans. Therefore, Bitlis has a rich historical and cultural heritage [43]. In this study, Tatvan/Bitlis province was selected as the case study. It is considered to be one of important provinces in that strategic corridor of Turkey (Figure 1). Tatvan is a town and a district in Turkey's Bitlis Province in the Eastern Anatolia Region. The centre town of Tatvan is situated on the west coast of Lake Van. Tatvan, with a population of 100,000, is the largest municipality of Bitlis and was selected for analysis in this study [44].

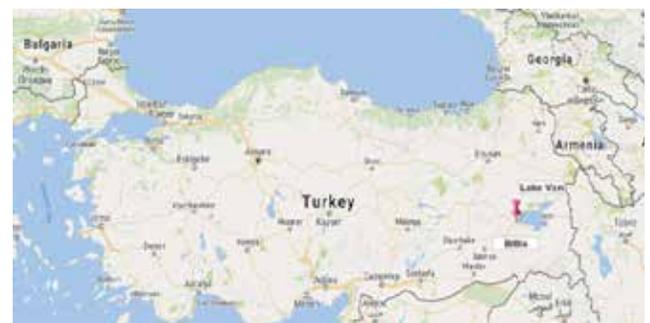


Figure 1. Location of study area [45]

4.2.1 Seismicity of Bitlis

Eastern Anatolia is a Turkish region characterized by concentrated seismic activity. General tectonic setting of Eastern Anatolia is mainly controlled by collision of the roughly northerly moving Arabian plate with the Anatolian plate along a deformation zone known as the Bitlis Thrust Zone. The collision

follows a westward extrusion of the Anatolian plate along two notorious transform faults with different sense of slip, the dextral North Anatolian Fault and the sinistral East Anatolian Fault zones, which join each other at the Karliova Triple Junction (KTJ) in Eastern Anatolia (Figure 2) [46-51].

The province of Bitlis lies in the Lake Van Basin in Eastern Anatolia. The Lake Van basin is located in eastern Turkey, a region that has over time suffered very severe tectonic damage. The Lake Van basin is a seismically active region as indicated by historical records [52-56].

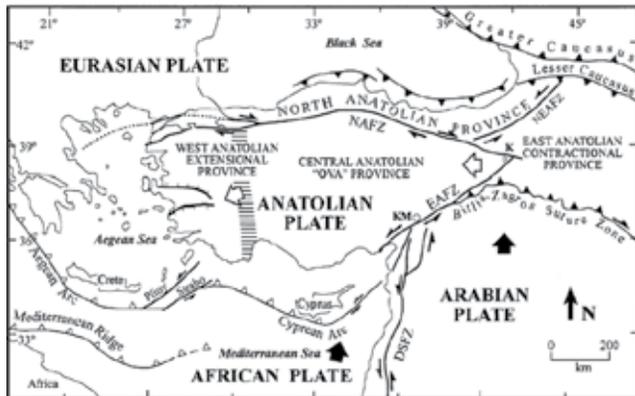


Figure 2. Tectonic map of Turkey with major structural features [57]

Conjugate strike-slip faults of dextral and sinistral character, parallel to North and East Anatolian fault zones, are dominant structural elements of the region. Some of these structures include Ağrı Fault, Bulanık Fault, Çaldıran Fault, Ercis, Fault, Horasan Fault, Iğdır Fault, Malazgirt Fault, Süphan Fault, Balıkgölü Fault Zone, Baskale Fault, Çobandede Fault Zone, Dumlu Fault Zone, Hasan Timur Fault Zone, Kavakbası Fault,

Kağızman Fault Zone, Doğubayazıt Fault Zone, Karayazı Fault, Tutak Fault Zone, Yüksekova-Semdinli Fault Zone, and the Northeast Anatolia Fault Zone (Figure 3) [57, 58]. The faults are seismically active and are at the origin of many earthquakes. Bitlis is located in the Lake Van Basin where the risk of seismic activity is high [60]. Earthquake risk map of the region is presented in Figure 4. It can be seen from this map that the building located within the borders of Tatvan district of the province of Bitlis belongs to the Seismic Zone 2. This is an indicator that the earthquake risk factor of the building is high.

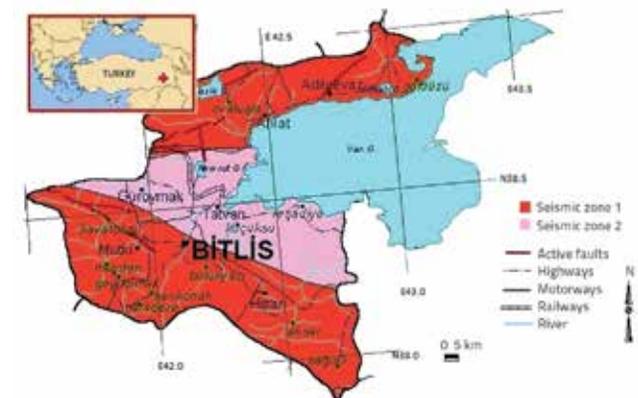


Figure 4. Seismic risk map of region [61]

4.2.2. Characteristics of studied building

In this study, several parameters belonging to the buildings are transferred to the data base to be considered as an example. Necessary explanations are made in this section through the

building that has been selected as an example. The data belonging to other buildings are provided at <http://www.smarthomescada.com> [62]. The building taken as an example is a reinforced concrete building located in the province of Bitlis, Karataş District, 366 square metres, parcel no. 37, in the 2nd degree of an active seismic belt. The photograph of the building is shown in Figure 5a. The geometrical location of the building is given in Figure 5b. This geometrical location was obtained using the inquiry application service offered at the web site of the General Directorate of Land Registry in Turkey.

According to Table 2, the system administrator who will enter data into the system can load the data about the building thanks to the data matrix application, by filling in required spaces. The data matrix operations are described in detail in Section 5.2.

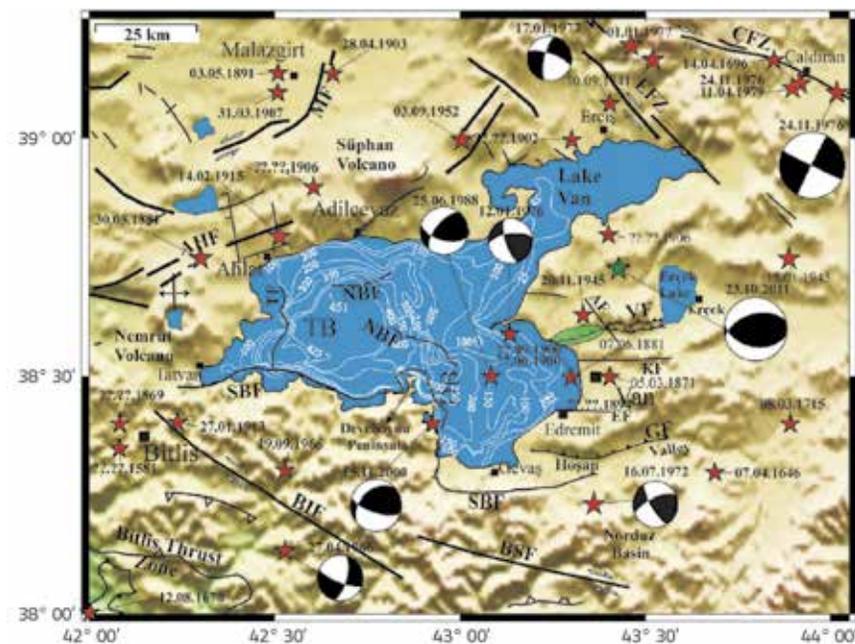


Figure 3. Significant tectonic structures of Van Lake Basin [59]



Figure 5. a) Photograph of reinforced-concrete building, b) The location of the studied building [63]

5. Methodology

Local authorities have been increasingly required to go to the source of economic growth and improve their public services in urban and rural communities. At the same time, the use of information technologies in the administration of residential buildings has become a necessity.

In Turkey, Local governments perform information archiving about the places where the masses are living. Since a healthy relationship between the data collected by the local governments has not been established, other users in

Table 2. Characteristics of the studied buildings

Province	Bitlis	Visual quality	Good
Town	Tatvan	Vertical Irregularity	None
District	Karataş	Irregularity in plan/torsion	None
Street/Avenue	Mazi	Building regulation/pounding	Adjacent
Building Door No.	1	Soft/weak story	Yes
Square	366	Heavy overhangs	Yes
Parcel	37	Short column	None
Latitude	38,487251	Hillside effect	None
Longitude	42,291970	Structural System Type	RC1
Base area [m ²]	406,28	Number of storeys	7
Night population	50	Soil type	Z2
Daytime population	20	Seismicity of the region	II
Characteristics	Ground floor + mezzanine + 5 floors	Year of construction	2007
Usage of building	Commercial + residential	Injured People	0
Current State (Damage)	None	Dead People	0
Area of Residential part [m ²]	2.493,96	Area of Commercial part [m ²]	350
Fire ladder	No	Elevator	(Yes, No), Yes
Natural gas installation	No	Heating system of building	Central heating
Previous disasters	2011 Van earthquakes	Retrofitting / Repair	No
Height [m]	21	Shape of the building in plan	Rectangular
Building position within a block	Corner	Exterior Walls	Briquette
Roof	Wood + Sheet Metal	Floor	RC
Foundation system	Raft	Occupancy	Commercial + residential
Aggregate Building: floors	Staggered floors	Aggregate Building: elevation	Buildings with different height
Non-structural elements	No	Number of independent sections	16
Other information	Reinforced concrete frame structure is composed of floors, beams, columns and foundation. The building was exposed to the 2011 van earthquake. But no damage was registered.		

need of this information face serious challenges when trying to access relevant data. These difficulties manifest themselves when attempts are made to access accurate information on mass habitation facilities.

As a result of the developments in computers, smart devices, and internet technologies, local authorities have begun to collect and store spatial data via computer media and to produce new information as a result of the analysis.

In building evaluation and monitoring systems, the desire to benefit from information technologies has been increasing on a daily basis. Accordingly, the use of mobile devices such as smart phones and tablets, which have become small computer systems, has been continuously increasing. Such devices are wireless, portable, and characterized by large memory capacity. Considering the overall spreading of building inventory, it is highly significant to have parametric data about buildings, and to ensure easy and quick access to such data. Detailed examination of structures is very difficult in terms of cost and technical staff requirements. In this sense, rapid screening methods for prioritization of the existing structures can be found in relevant literature. The purpose of rapid screening methods is to determine risk priorities for structures, and to ensure that right decisions are made. With these methods, the building performance score is calculated by collecting parameters given by the method without entering the building, or by entering the building only partly, and risk priority decisions are reached through comparison. In the scope of the law issued by the Ministry of Environment and Urban Planning, Republic of Turkey, the first stage evaluation methods focusing on building features and earthquake danger can be used in order to detect regional distribution of the buildings that might be risky, and priorities in specific areas [64]. The following parameters are used in the first stage method:

- Type of structural system
- Number of Storeys
- Current condition and visual quality
- Soft /weak story
- Vertical irregularities
- Heavy overhangs
- Irregularity in plan / torsion
- Short column
- Building regulation / pounding
- Hillside effect
- Seismicity and soil type

In this study, all parameters specified in the law related to detection principles for risky-buildings, and reinforced-concrete buildings in particular, as issued in 2013 by the Ministry of Environment and Urban Planning, Republic of Turkey, were used in the application of the data matrix.

In this study, the data needed for the loss estimation models used in the calculation of the earthquake-generated loss of life and property, were also used in the application of the data matrix. Loss estimation models are described as the most important tools needed for risk reduction. The key information

on the potential damage and loss can be obtained through such loss estimation models. By making risk-based damage analysis about the matters such as disaster management, risk mitigation, planning, preparedness, response, and possible improvements, the models can be used to reduce the loss of life and property, and protect people and institutions against natural disasters. With the help of these data transferred to the data matrix application, loss estimation models can easily be used easily for urban communities. The following parameters are used for the loss estimation analysis:

- Structural system type
- Number of storeys
- Seismicity of the region and local soil conditions
- Year of construction
- Night/daytime population.

5.1. Building assessment and monitoring systems

Because of its price and simplicity, a large-scale seismic vulnerability assessment method is popularly used as a means of reducing the susceptibility and hence the risks [24, 65]. Additionally, to save lives and resources, an effective means is needed for development of the region-wide earthquake contingency plans and stability programs [66]. Without a fast and accurate method, it would be ineffective to monitor and assess the expanding stock of buildings because of the shortage of time and skill [67]. According to available literature, several methods, often involving criteria based on some characteristics of the structure, are applied for the evaluation and monitoring of buildings. Nevertheless, the QR code system is not suitable for them. Some of these methods are mentioned below.

The Rapid Observation of Vulnerability and Estimation of Risk (ROVER) is a portable software for conducting the building safety screening before and after the earthquake, free of charge. Risk researchers, practitioners, and authorities may use the ROVER software throughout the world. The ROVER web browser on a smartphone, tablet, or other mobile device enables construction professionals such as engineers, architects, etc. to reach regional data about buildings via internet using any PC with or without Windows. The ROVER's FEMA 154 module is used to obtain potential damage data through pre-earthquake screening of constructions, while ATC-20 is helpful for determining which building is safe after the earthquake [68-72].

The application on which the earthquake data is collected, analysed, and visualized, i.e. the Isibat, has a client server feature, and uses mobile hardware or software such as Geoweb and network technologies. An iPhone application delivers signals on the screen, menu and map to the online clients in the region to get the data required in the evaluation of seismic susceptibility or measurement of earthquake damage. It is possible to search and view the data contained in the database. The application was developed under the Urbasis² project for the on-site data collection and risk assessment in earthquake-prone city zones. The Building Inventory database management is a useful contribution to the evaluation of the risks and losses in a particular urban region [24].

The Global Earthquake Model's Mobile Inventory Data Capture Tool (IDCT), an Android application that can easily be loaded, supports the earthquake damage risk evaluation through data collection methods for buildings such as remote sensing, direct field observation, and statistically-inferred mapping schemes. The means designed are: optical satellite or aerial sensors providing the building footprint and height data. The experts make use of online or face-to-face surveys to produce information about the system including the type, year, and life cycle of the structure. There are some attributes on data entry sheets such as: construction material, occupancy type and use, age, height, building irregularity, lateral load resisting system, ductility, building condition and site description, roof and floor system, materials, shape and type, financial and occupancy exposure, post-earthquake damage and free text comments' [37, 73].

The Urban Rapid Assessment Tool (Urban RAT) is quite innovative and develops the building inventory faster using an integrated ArcGIS-Google-Android system. Its two components are:

- Urban RAT Desktop, a virtual survey on PC, and ArcGIS software
- Urban RAT Mobile, a digital on street survey, and Google Android application.

They enable faster and more extensive data collection using multiple engineering parameters such as the location, year of construction, floor area, occupancy, construction quality, design quality, design code, design redundancy, structural walls, weak column, vertical and plan irregularity, space between adjacent buildings, etc. The sidewalk survey can be made using the Urban RAT Mobile device, especially in cases when the Google Street View is ineffective. The data collection becomes so efficient that the users can gather more information about the buildings in a shorter period of time as compared to manual methods [25, 74, 75].

Developed for a global database of building inventory, the Earthquake Engineering Research Institute's World Housing Encyclopaedia (WHE) provides an extensive public database for houses and their features and includes over 135 reports from 40 countries divided by type, as well as the data from the U.S. Geological Survey's Prompt Assessment of Global Earthquake's Response (PAGER) Project. The WHE-PAGER improves the WHE by the ways of:

- Adding the region outside of an urban area,
- Measuring objectively the spreading of building types,
- Giving information about residence,
- Making professional or technical estimates about vulnerability, and
- Using analytical techniques in testing vulnerability in the labs [29, 76-78].

The Rapid Risk Evaluation (ER²) is an earthquake risk assessment tool that is still in the development phase. It makes use of the Shake Map and vulnerability algorithms. One

of two components of the software is the almost real-time risk analysis, which help the federal government enhance its capacity to determine and report on consequential effects of big earthquakes and foster emergency management and public safety in urban communities. The second, national, extensive online database is intended to include the entire building stock, and develop scenario analyses for seismic risks and damage including all habitations [25].

5.2. The data matrix application

The QR code application forms the basis of the building evaluation and monitoring system, and can operate on the IOS / Android-based mobile devices. The application ensures that the information belonging to building can be monitored, replaced, or added online, thanks to a data matrix pasted on the building via a mobile device. The overall operating algorithm of the application is presented in Figure 6. Different algorithms for the software development system were formed according to Figure 6. Two different algorithms were used in the software infrastructure. The one used by the administrator differs from the one used by the users. The main reason why two distinct algorithms were developed is to ensure that the users can only see information on the database, but can not make any changes to the data. However, any building data change can be made by the user who connects to the system as administrator. Thus, the software operates differently depending on whether it is used by users or administrators. Flow diagram of the algorithms is given in Figure 7. The software has two different panels: the admin panel and the operator panel.

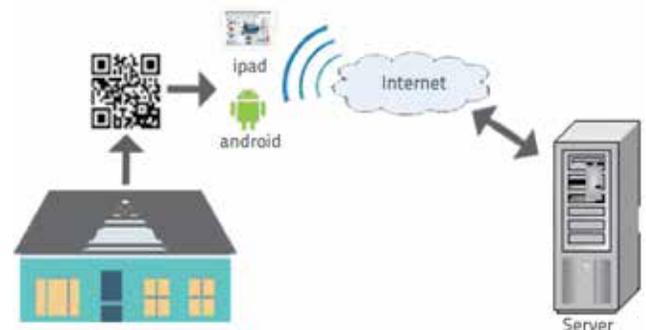


Figure 6. Algorithm for use of data matrix

After entering the username and password, the system administrator must enter initial data about the building. In addition to having the authority to create a data matrix of the building, the administrator also has the authority to replace or delete the building data that have already been entered. The administrator can also adjust the data display style the user is allowed to see. In this respect, the administrator can set the encryption text that must be entered by the user to see the building-related information. The administrator can also select the option of full visibility when wishing to make the building information visible to all users. In the algorithm destined for the user, the latter can look through the data matrix attached to the building with his/her

smartphone. If there is no encryption, the user can see the information directly. If an encryption has been set, the user can see the building information after entering the user name and password. If this initial data is not entered, the user is not allowed to view the information about the building.

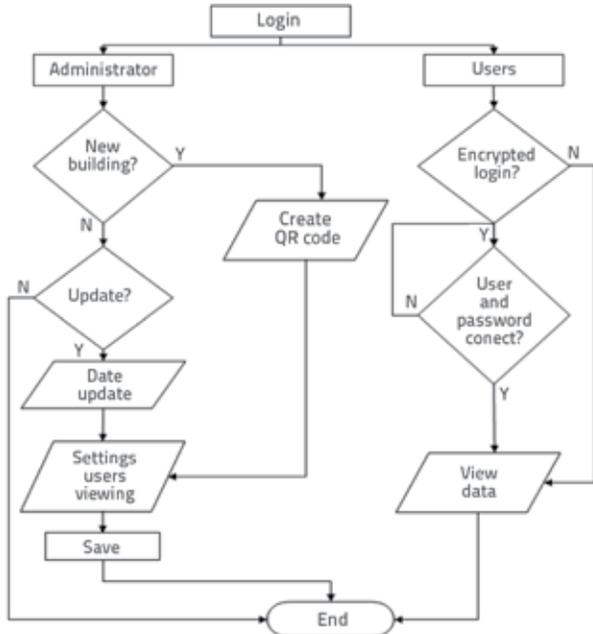


Figure 7. Algorithm for software system

The data about the buildings can also be monitored via the web. The user groups that have the administrator status can enter the building information in the system without going to the building. Since the data matrix for each building is created by the administrator, he or she has the authority to update the information about the building by swiping the data matrix belonging to the building he or she wishes to see.

5.3. Application example

Examples of applications belonging to the software developed are shown for both the administrator and the user. To enable the QR code use by IOS/Android based smart phones or tablets, the data matrix reading software can be downloaded, depending on the operating system used by the device, from the application centres free of charge.



Figure 8. Login QR Code

Figure 9. Login screen

In order to access the application system, an appropriate information must be entered in the user input screen as shown in Figure 9, after generation – via smartphone - of the QR code for a particular building, as shown in Figure 8. In this step, the logged-in entity is subject to redirection depending on whether the entity is the user or administrator. The process varies depending on the group (administrator group or the user group). Administrator operations are explained in Section 5.3.1, while user-related operations are described in Section 5.3.2.

5.3.1. Administrator operations

To activate the assessment and monitoring software, the person having the administrator status has to create the QR code belonging to the admin, as shown in Figure 8. From the interface screen shown in Figure 9, the user can enter the parametric data belonging to the building by using smart phone or tablet, subject to entry of correct password. The ID number generated is the number belonging to the building and, since there is a separate QR code for each building, there must also be a separate ID for each building. According to the ID number created, the data input is made by the administrator in the areas shown in Figure 10.



Figure 10. Data entry screen for ID = No. 1 building

In the areas shown in Figure 10, the users must select Encrypted Access button existing under the ID number in order to set the encrypted or unencrypted login to the system. In case this area

is marked, users must use password when logging into the system. Users are also created by the administrator. These users have the right of access to information related to their own building only.

For example, the information about the building designated as ID = 1 has been entered in the database by the administrator, as shown in Figure 8. While restrictions are made to some areas to prevent incorrect entries, some areas enable selection between optional entries. When the administrator intends to reconstruct some building parameters, or when he wants to delete the information about the building, he can log into the software by swiping QR code set for the admin.

The administrator can also load images of the building taken before to the Image Update area located in the area shown in Figure 8, and he can also upload to the database any photo taken by his smart phone or tablet.

Considering that data entry can simultaneously be made for more than one building in different regions, the administrator position can even be granted to several persons. The users assuming the administrator position are the user groups authorized to enter all the data in Table 1 including the ID number (the first identity number, which may be given for one building only - a warning signal is given by the software when access to other buildings is attempted), address, and latitude and longitude of buildings. The administrator also performs the activities of creating QR code for a building and associating this label with the building. In addition, the administrator can store images of the building into the database. Thanks to these images, the users can easily detect whether the QR code generated actually belongs to a particular building. In general, the following activities can be performed by administrators:

- Addition of building information
- Arrangement of building information
- Deletion of building information
- Generation of QR code
- Arrangement of QR code
- Deletion of QR code
- Arrangement of user rights

Furthermore, if coordinates of a building are recorded in the database by the administrator, the mapping and location information, a service from Google Company, can automatically be displayed. Thus, the avenue or street where the transaction has been made can easily be found. The option of Map or Satellite is provided for image positioning, and the address

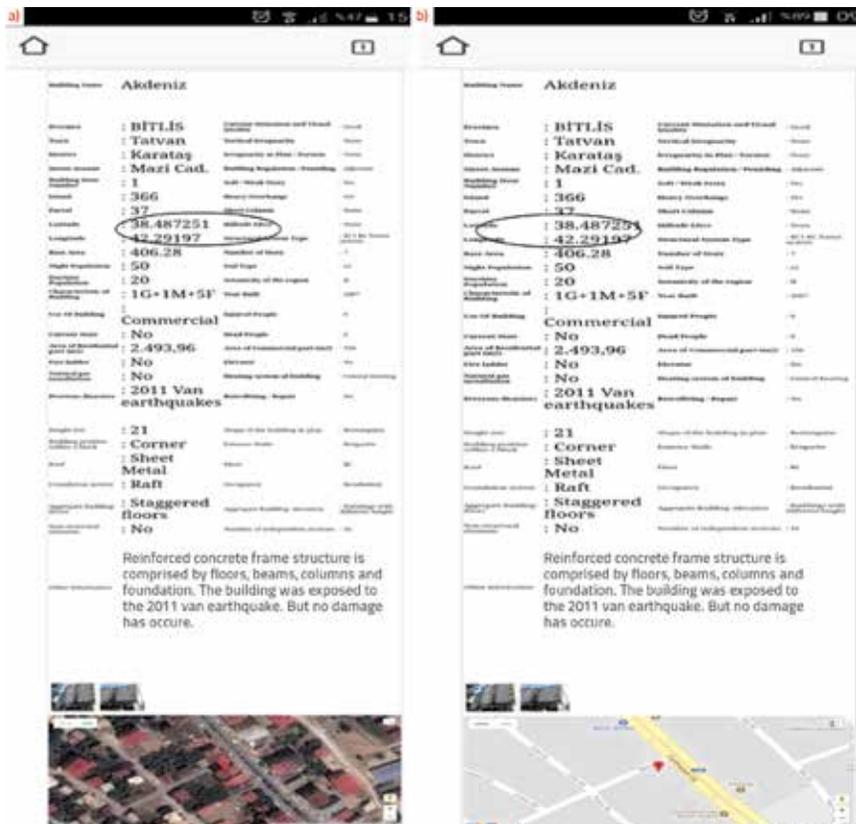


Figure 11. a) Satellite display; b) Map display

and positioning point can be seen. This software has the infrastructure that can operate through the GIS system as well. As shown in Figure 1, the location information about Apartment Akdeniz, for example, is displayed as a red point based on the corresponding latitude and longitude data. The user, in Figure a, can see the image of the building with the "Satellite" option and, in Figure b, he or she can find the information about the avenue and street in which the building is located.

5.3.2. User operations

The other part of the monitoring and evaluation system is the user. The users are created by the administrator. Besides creating users for households, the administrator can make a similar process for public institutions and organizations. If the administrator so desires, he can allow public institutions and organisations to change all or some of the information. To enable display of building parameters by the users, the user situation must first be identified by the administrator. In this study, the encrypted entry was preferred to screen the users. Depending on each ID number, the administrator creates users from the household belonging to that particular ID number. The QR code sample belonging to Akdeniz Apartment is shown in Figure 12a. By swiping the QR code attached to the building, the user can access parametric information belonging to the building, subject to prior entry of the user name and password. This is shown in Figure 12b.

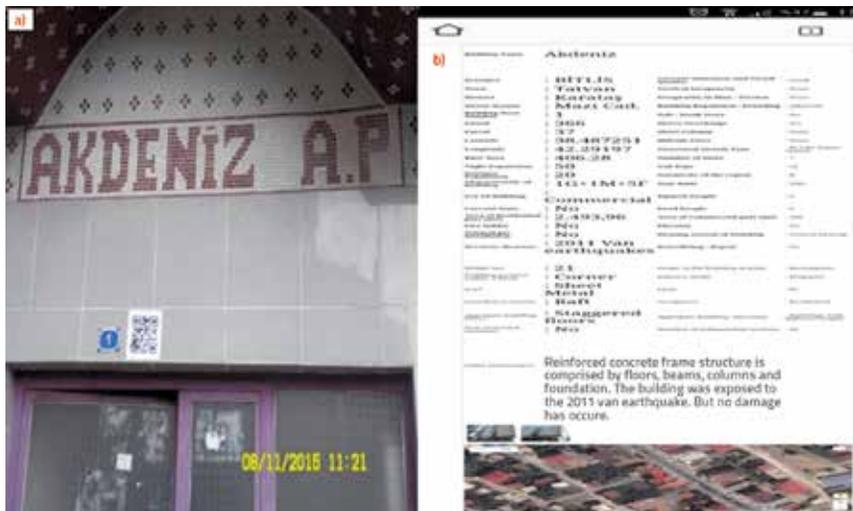


Figure 12. a) QR application; b) user tracking screen for Akdeniz Apartment, ID=1

6. Conclusions

In the scope of this study, the inventory of reinforced concrete buildings in urban areas is transferred to the electronic media, and an ID card was created for each building using electronic media. These identity cards bring together the information that is supplied by or requested from various institutions. The process is conducted using the MYSQL database that can operate very fast via the Internet. The persons residing in the buildings are provided access to updated information about the building.

The aim of this study was to create an electronic database for reinforced concrete buildings as well as an ID card for each existing and newly constructed building. It is estimated that the data obtained in this way will reduce the effects of possible earthquake damage.

Systematic assessment of buildings is important in terms of determination of the damage or loss of life in case of an earthquake event. This study can be used as a decision support tool for the analysis of earthquakes and building relationships. In this study, the data collected from the field were integrated into the electronic media and the resulting information was shared in a quick, easy and appropriate manner.

This study will provide understanding about the kind of damage that is likely to occur in various types of buildings. In addition, useful information will be obtained after an earthquake event.

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The transfer of this data to electronic media enables determination of the intensity of the earthquake and of the number of buildings that have been damaged to varying degrees. As a result, main activities to be carried out in such circumstances can be arranged more easily.

By classifying the data about the buildings, the earthquake zones will be identified more realistically within this database, and the disaster management activities will be better organised. This classification can also serve as the basis for creating a resource for advanced studies about these issues. By identifying the features of damaged buildings and their structural elements,

the earthquake hazard may be reduced through use of this information for planning and design of new buildings. This will contribute to the development of current regulations on seismic design and construction.

This study enables public institutions and organizations related to local administrations to directly access the building inventory and the data, which is made available in electronic format. Electronic monitoring systems in buildings will facilitate building monitoring operations.

With the help of after-earthquake data, the determination of damage to the buildings, their classification, and the decision-making process for their use, can be made in a controlled manner. In the established system involving a single database, all data can be defined, stored, processed and analysed more accurately and effectively. Thus, the time and money can be saved in the decision-making and implementation process, and an appropriate resource planning infrastructure can be created.

The administration process based on the building information technology infrastructure, consistent with the method discussed in this study, can effectively be used for making information-based strategic plans. Also, the building inventory data can be obtained regardless of the venue. The study can easily be deployed with the support of local government. This study can be extended by adding new modules, and its sustainability can easily be achieved.

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