ASSESSMENT OF VULNERABILITY TO EARTHQUAKE HAZARDS USING SPATIAL MULTICRITERIA ANALYSIS: ODUNPAZARI, ESKISEHIR CASE STUDY

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ABSTRACT

ASSESSMENT OF VULNERABILITY TO EARTHQUAKE HAZARDS USING SPATIAL MULTICRITERIA ANALYSIS: ODUNPAZARI, ESKISEHIR CASE STUDY

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The aim of this thesis is to develop a GIS methodology to assess urban vulnerability to earthquake through a spatial analytical procedure in which vulnerability is taught of as a spatial decision problem. The main concepts within the framework is vulnerability assessment. In its typology, the defined technology is highly current, emergent and necessary for the local goverments. Considering the discussions on subsidiarity for local area services such a knowledge is hoped to prove the capacity of local goverments. First earthquake losses were estimated. Earthquake loss estimation activities can be categorized into two series of phases:

i- pre-disaster phase; risk assessment, mitigation management

ii- post- disaster phase; emergency and rehabilitation management Two methods were used in estimating the primary damages and losses due to earthquake. In the first method spatial multicriteria analysis was performed to assign a vulnerability value to each building. As a second method SRAS(Seismic Risk Analysis Software) was used. Besides criteria for social risks, criteria for systematic vulnerability, which may influence the emergency response and management activities following the earthquake, were also considered. Criteria standardization, weighting and combining were accomplished by means of multi-criteria evaluation (MCE) methods, the theoretical background being based on the multi-attribute utility theory (MAUT). Expert knowledge based analysis was used and also three different earthquake scenarios about Odunpazari were run on SRAS. After the aggregation of the vulnerability values from building scale to neighbourhood scale, the urban facilities were analysed. Results showed that, 1/3 of the neighborhoods in Odunpazari are vulnerable to any possible earthquake.

KEYWORDS: GIS, Earthquake, Multi-criteria evaluation, SRAS, Vulnerability Assessement

ÖZ

MEKANSAL ÇOKLU KRITER ANALIZI KULLANILARAK DEPREME KARSI HASSASIYETIN DEGERLENDIRILMESI; PROJE ALANI: ODUNPAZARI, ESKISEHIR

SERVI, Mehmet

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Bu tezin amaci, depreme karsi hassasiyeti mekansal bir problem olarak ele alarak, mekansal analitik prosedürlerle birlikte kentsel alanlarda depreme karsi hassasiyeti degerlendirebilecek bir GIS metodolojisi gelistirmektir. Çalisma temel olarak bu hassasiyetin hesaplanmasina dayanmaktadir. Bu baglamda tanimlanan teknolojiler yerel yönetimler için oldukça önemli ve gereklidir. Bu tür çalismalarin yere yönetimlere depremlerdeki kayiplarin tahmininde yardimci olmasi beklenmektedir. Depremlerdeki kayiplarin tahmini iki asamada incelenebilir:

i-Deprem öncesi asama; risk yönetimi, risk azaltici önlemler

ii-Deprem sonrasi asama; ilkyardim ve iyilestirme çalismalari.

Bu tez çalismasinda depremde olabilecek kayiplarin ve hasarin tahminine yönelik 2 yöntem kullanilmistir. Ilk yöntemde mekansal çoklu kriter analiz yapilmis ve her bir bina için depreme karsi hassasiyet belirlenmistir. Ikinci yöntemde ise SRAS (Sismik Risk Analiz Yazilimi) kullanilmistir. Hassasiyet kriterlerine ek olarak sosyal kriterlerede dikkat edilmis, bunlarin deprem sonrasi ilkyardim aktivitelerinin yönetiminde önemli olacagi düsünülmüstür. Kriterlerin standartlastirilmasi, agirliklarinin belirlenmesi ve birlestirlimesi islemlernde Çoklu-Kriter Degerlendirmesi yöntemleri kullanilmistir. Bu yöntemler çoklu-özellik olanaklari teorisine dayanmaktadir. Uzman bilgisine dayali bir analizin yanisira SRAS programi ile üç farkli deprem senaryosu üretilmistir. Bina bazinda belirlenen hassasiyet degerlerinin mahalle ölçegine genellenmesinden sonra kentsel donatilar analiz edilmistir. Sonuçlar Odunpazari'nin mahallelerinin 1/3'ünün depreme karsi hassas oldugunu göstermektedir.

Anahtar Kelimeler: CBS, Deprem, Çoklu-Kriter Degerlendirme, SRAS, Hassasiyet Degerlendirmesi

To my family

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1. INTRODUCTION

1.1 Aim and Scope of The Thesis

Risk is a part of life. Therefore, there is a strong need for defining a systematic framework containing the risk parameters and the society parameters. As planning is a discipline, regulating the societal transformation and space formation-reformation, a risk management perspective should be added. That will lead to threat-proof cities.

The 1999 earthquake (Gölcük) and 2003 earthquake (Bingöl) experiences proved that Turkish cities are not earthquake resistant. It will be irrelevant to discuss the historical context of this issue. What should be concentrated on within context is the emergency of the issue and its technological necessities. When the information system of the local governments is briefly scanned after 1999 earthquakes, it is observed that they generally concentrated on Urban Information System (UIS). If we make a similar quick-look at central governments efforts they concentrated on post-disaster recovery and rehabilitation studies. But the missing part in local governmental context is comprehensive risk management strategy. As there is a bound relationship between data-knowledge-information and intelligence. Geographical Information Systems is in the core of the subject.

In planning process, local governmental capacity is very important. And also it should be stated that, local governments are not sufficiently aware of the earthquake risk management subject. For example the urban planning practice in Turkey is totally based on re-active structure. That is the structure of the urban development plans dictate the total control and management of the whole system entirely, which conflicts with rational decision making and multi-layered decision theory.

Namely plans are documents that are hard to change or update according to the possible emergent problems that cannot be foreseen beforehand. The disaster and its effect on cities at a non-predictable and non-guessable time is an example for such unforeseen problems. These discussions briefly prove that there is strong need for an effective preparation system. Regarding the discussions mentioned here, the necessity to urge the need for urban vulnerability and risk assessment system is felt for such a successful preparatory agenda.

In general, another current issue related to local government is subsidiary principle that aims to give the service easier and faster to the inhabitants. But in Turkey local governments are not sufficiently equipped for such a reform. The core of the discussion is administrative structuring versus technical adequacies. At this point one of the main technical equipments called GIS technologies is the corner stone of this revolution. "The value of GIS in urban vulnerability analysis arises directly from the benefit of integrating a technology designed to support spatial decision making into a field with a strong need to address numerous critical spatial decisions (Cova and Church, 1997).

Therefore by the help of GIS technologies, it is aimed to develop a GIS methodology for the analysis of urban vulnerability. In the study in addition to criterias related to physical weakness or strength of the built environment, organizational, social and systematic factors are also considered to understand the possible dimension of the earthquake damage. Building age, building condition, building type, number of storeys and soil structure are criterias to asses building risk that is combined with population distribution to find out social risk. Accessibility, health center distance are used for the systematic vulnerability assessment. That is combined with social risk value at the end to asses the main vulnerability value according to different earthquake scenarios by the use of SRAS. The application of this methodology will be used in classifying the neighborhoods of Odunpazari district of Eskisehir, in terms of their degree of vulnerability to earthquake hazards.

Some other criterias may be taken into consideration according to general structure and macro form of the urban area for different vulnerability assessments when anybody studies a city different than Eskisehir-Odunpazari or for Eskisehir-Odunpazari from different point of views

1.2 Method and The Sequence of The Thesis

Recently Eskisehir hadn't experienced a serious earthquake, which underlines the crucialty of risk mitigation studies and related measures. Such an experience in a non-disaster experienced city can be impressive and innovative for Turkish planning practice. Also the planning department's recent efforts in UIS are promising for risk management studies.

Within this context the outline of the thesis is as follows;

In the **first chapter** it is started with a brief summary of aim and scope of the thesis and problems related to, vulnerability analysis. Also some brief information is given about study area.

In the **second chapter,** the theoretical framework is discussed. General terminology such as, risk and vulnerability, urban vulnerability, vulnerability assessments are defined briefly.

In the **third chapter**, the methodology of the thesis is discussed. The evaluation criteria of the urban vulnerability assessment are described. Multi-Criteria Decision Analysis and Pairwise Comparison method are defined in this chapter. And also the SRAS (Seismic Risk Analysis Software) is described. Information about structure of SRAS is given. Also the steps of urban vulnerability analysis are discussed.

In the **fourth chapter,** the urban vulnerability analysis is mentioned, step-by-step. Also, information about urban database and study area are given. And information about software MCE to evaluate urban vulnerability is given. The earthquake scenarios (according to MCE and SRAS) are discussed in general and the earthquake scenario assumptions for Odunpazari Municipality region are introduced. Thematic data is presented which are about urban vulnerability (according to MCE and three different SRAS scenerios) of building and their aggregation to neighbourhood.

In the **fifth chapter**, the results of case study are discussed and concluding remarks about importance of vulnerability assessment are given, and recommendations on problems related to vulnerability assessment are mentioned in the fifth chapter.

2.THEORETICAL FRAMEWORK

Environmental risks and hazards are a major focus of research, generally concern, and they provide an important arena for interdisciplinary collaboration between social scientists, natural scientists, and engineers. The terms encompass a wide range of definitions and practices with considerable evolution of their meaning and use over time (Livermana, 2002). Crises can have international, domestic, local, or organizational dimensions, or they can involve a mixture: for example, threat of nuclear war, an embargo on the export of oil or wheat to hostile countries, or unrestrained conflict in large, nonprofit institutions. Crises also can involve danger to the physical integrity of citizens, inflicting damage arbitrarily or selectively: for example, the hijacking of a train or the kidnapping of a prominent political or corporate leader. Crises can also emanate from a threat to employment and economic prosperity, the closing of a plant in a single-factory town, the closure of a mine in a coal region, or the sudden drop of investment in a national economy (Rosenthal and Kouzmin, 1997).

Risk always exists in space and time. Also it's a composite concept containing values and threats. In general context value may be human, capital, natural, informational resources. And threats may be created by the nature or human himself. A society which is successful in evolving to a "risk society" as in Beck's formulation (Beck, 1992) will of course be more creative and self-confident.

Industrial Society is susceptible to catastrophic events, including technological disasters and social and political crises. Risk, uncertainty, crisis, collective stress, and "normal accidents" now need to be incorporated into a broader understanding of how governments and decision makers respond to the unless of crisis situations, unpleasantness in unexpected circumstances, representing unscheduled events, unprecedented in their implications and, by normal routine standards, almost unmanageable (Rosenthal and Kouzmin, 1997).

In the frame of research, the focus will be on the concept of vulnerability and its areas of use in the fields of planning and GIS.

2.1 Definitions of Risk and Vulnerability

Understanding the concept of risk first requires an understanding of a hazard. A hazard is an "activity or phenomenon that poses potential harm or other undesirable consequences to people or things" (Hall et al. 1992). The magnitude of a hazard is the amount of harm and the severity of the consequences resulting from that hazard” (De Rodes and Deneen, 1994).

Other important concept to understand risk is vulnerability. Vulnerability defines the inherent weakness in certain aspects of the urban environment which are susceptible to harm, due to social, biophysical, or design characteristics, whereas risk indicates the degree of potential losses in urban places due to their exposure to hazards and can be thought of as a product of the probability of hazards occurrence and the degree of vulnerability (risk = hazard X vulnerability) (UN,1991). To better understand the literature, vulnerability can be decomposed into several components of a risk chain a) the risk, or risky events b) the options for managing risk, or the risk responses and c) the outcome in terms of welfare loss. This definition can be used to understand which society can manage risk at any part of the chain (Alwang et al. 2001).

Most disaster management studies are based on some version of the relationship: Vulnerability= Hazard-Coping. Hazard is defined as a function of probability (shock value based on time elapsed since previous occurrence); predictibility (degree of warning available); prevalence (the extent and duration of hazard impacts); and pressure (the intensity of impact). Coping is a function of: perceptions (of risk and potential avenues of action); possibilities (options ranging from avoidance and insurrance, prevention, mitigation, coping); private action (degree to which social capital can be invoked); and a public action (Alwang et al. 2001).

The disaster management literature usually breaks vulnerability into two components i)risk mitigation or disaster preparedness and ii)disaster relief. Risk reduction, mitigation and some coping activities are usually lumped together into “mitigation activities” and the remaining coping activities are referred to a disaster relief.

Government agency scientists and the general public are often concerned with different aspects of risk. Scientists use a number to express a risk assessment, which commonly represents a probability of risk to the public. But people see risk as personal--a specific risk to themselves or their communities. "The tension between the public and agencies is also related to the disjunction in how the public and government officials perceive risk" (De Rodes and Deneen, 1994).

Risk communication cannot always be expected to decrease or eliminate conflict. Scientific risk assessment has been characterized as a cold, numbers-only process; but it is against our emotive human nature to function solely in a sterile, quantitative environment. On the other hand, to find decisions solely on collective emotion is to waste intellectual resources and better judgment. Some middle ground is obviously necessary. (De Rodes and Deneen, 1994).

2.2. Urban Vulnerability

Risk is a part of life. Everyday use generally defines risk as the chance of loss or injury, and hazard as a source of danger (Livermana, 2002). Therefore, there is a strong need for defining a systematic framework containing the risk parameters and the society parameters. As planning is a discipline regulating the societal transformation and space formation-reformation a risk management perspective should be added. That will lead to threat-proof cities.

Urban vulnerability to natural hazards such as earthquakes is a function of human behavior. Several models of urban vulnerability have been proposed to address the various ways by which society becomes subject to hazard impacts (Menoni, 2001).

"People respond to the hazards they perceive" (Slovic et al. 1982). And 1999 earthquake and 2003 earthquake (Bingöl) experiences proved that Turkish cities are not disaster resistant and society is weak in risk perception. It exceeds the limits and frame definition of our thesis to discuss the historical context of this issue. What we should concentrate on within our context is the emergency of the issue and its technological necessities. If we briefly scan the information system of the local governments after 1999 earthquakes they generally concentrated on Urban Information System (UIS). If we make a similar quick-look at central governments efforts they concentrated on post-disaster recovery and rehabilitation studies. But the missing part in local governmental context is comprehensive risk management strategy. As there is a bound relationship between data-knowledge-information and intelligence. Geographical Information Systems is in the core of the subject.

Over the past decade and a half, environmental policy in the United States has come to rely more and more heavily on the evolving science of risk assessment (Perhac and Ralph, 1998). This process has the potential to transfer innovative experience from USA to Turkey, regarding to the trends to establish a FEMA like organisation in the agency structure of Turkey. Those efforts, to establish a financial resource rich and insurance integrated agency has the potential to support vulnerability assessment studies and projects.

More and more cities and counties are preparing local hazard mitigation plans. Every community faces a different mix of hazards and development exposed to hazards. Similarly, every community has different resources and interest to bring to bear on its problems. Project Impact takes advantage of this pre-disaster local planning trend, by encouraging partnerships with business and reflecting shared interests through planning (Jamieson, 2000).

Disaster specialists increasingly emphasize the importance of having a pro-active land use and growth management policy designed to prevent or lessen loss, rather than simply reacting to the crises when disasters strike. Growth management can be broadly construed to include not just standard land use planning practices, but also standards guiding the density, type, construction and rate of development The general idea behind this approach is to prevent development in hazardous areas in the first place, or to ensure that structures are designed to withstand hazards and public facilities that are crucial to responding to a disaster (e.g., street capacity for evacuation) are available (Berke, 1998).

The enormous losses experienced in natural disasters and the exposure to even larger losses in the future do not occur by accident. They are the result of conscious policy choices at all levels of government. State and local governments have failed to constrain the intensive development of areas at risk from a variety of natural disasters (Burby, 1999).

Risk-cost-benefit analysis weights the costs versus the benefits of mitigating an estimated level of risk (Perhac and Ralph, 1998). Determining what mitigation strategies and measures are best for an area is done through a planning process. During this process, the various hazards are inventoried, the full range of possible measures are evaluated and the most appropriate and affordable ones are recommended for implementation (Tobin, 1991).

As it becomes increasingly clear that we cannot afford to address fully all environmental problems, risk assessment is being called on, not simply to support individual regulations and clean-up standards, but to help set environmental priorities (Perhac and Ralph, 1998).

It should be evident from the preceding discussion that where and how the public is appropriately involved in comparative risk assessment, and who is involved in the name of the public, depends in large measure on the rationale for public involvement and on answers to some very fundamental and difficult questions that arise in regard to any given rationale (Perhac and Ralph, 1998).

2.3. Vulnerability Assessment

Disaster planning and management, impact and response, even research, are largely social processes (Morrow, 1999). There are many different techniques to assess earthquake hazards in urban area. Some of them evaluate only physical condition criteria of buildings to evaluate hazards, on the other hand, others prefer to add some other criteria like population, accessibility etc… These evaluation methods can be named as “Assessment of Vulnerability”. The vulnerable groups in Pendik-Istanbul in terms of their social conditions for any possible hazards were evaluated by vulnerability analysis (Haki, 2003).

The access people have to resources, including employment, health-care, social support, financial credit, legal rights and education are part of what makes them vulnerable to, or secure from, disaster (Blaikie et al. 1994). This access includes both the resources people have as a result of employment, savings and social networks, as well as newly available resources from national or local relief programs after a disaster. (Bolin and Stanford, 1998). In conceptual terms, the most vulnerable are those households with the fewest choices; those whose lives are constrained, for example, by poverty, gender oppression, ethnic discrimination, political powerlessness, physical disabilities, limited employment opportunities, the absence of legal rights and other forms of domination (Cannon, 1994).

These 'clusters of disadvantage' (Chambers, 1983) are revealed in actual disasters where the elements of vulnerability play themselves out in the lives of people as they attempt to cope with the additional burdens imposed by the disaster and recovery.

The dwellings of the poor are often located in vulnerable locations, such as floodplains. While the affluent build large homes in coastal floodplains for the ambiance, the poor are likely to have little alternative if their livelihoods are tied to tourism, fishing and other coastal enterprises. Urban squatter camps are usually concentrated precariously on the most marginal and vulnerable land. Nearly every community has some residents who are totally vulnerable -- the homeless living in cardboard boxes, under expressways or in flimsy hovels (Morrow, 1999).

Land use planning can be a powerful tool for reducing losses from natural disasters. Planning programs reduce losses by affecting both the location and the design of urban development (Godschalk et al. 1998) and by helping create a knowledgeable constituency of citizens who support hazard mitigation programs (Burby and May, 1998). By guiding urban expansion and redevelopment to locations that are free of hazards, planning programs eliminate the possibility of significant damage. (Burby, 1999). In relation with the tools and techniques used in plan preparation process, risk and vulnerability assessment techniques has a significant role in planning activities. There are many loss estimation methodologies in the assessment of vulnerability to earthquake hazards. Some of them are used widely like ATC-13 and FEMA/NIBS (Küçükçoban, 2004).

The word 'vulnerability' means many things to many people. It has become a common term in development and disaster management circles. Engineers may speak of vulnerable structures. Planners may speak of vulnerable economies (Handmer and Wisner, 1999). Innovative approaches to cooperation can reduce the vulnerability of communities at risk (Yahmed and Kawaguchi, 1996).

Major emergencies are becoming more frequent and more severe. The devastating effects they have on development and social stability, the emergence of so-called "complex" emergencies and the large media coverage given to these events have focused the attention of scientists, technicians and politicians on them (Yahmed and Kawaguchi, 1996).

The resources needed for relief purposes are huge and the consequences of emergencies on overall development are incalculable. New ways to prevent or at least mitigate the effects of these crises on people and on human development have been proposed. Many of them are based on the concept of a continuum from relief to development and preventive diplomacy. Vulnerability reduction and emergency preparedness programmes are of primary importance in reducing the need for disaster relief (Yahmed and Kawaguchi, 1996).

The introduction of HAZUS in the United States has sparked interest and activity in earthquake and multi-hazard loss estimation at the Federal, state, and local level. The annualized loss methodology developed in this study presents a rational decision-making basis for the creation of seismic risk management policies. In addition to developing a nationally consistent risk-ranking scheme to identify high-risk areas, the annualized losses and loss ratios provide the means to evaluate the benefits of mitigation strategies. The methodology also has the flexibility to be extended to a multiple hazard regional risk assessment to compare the risk from natural disasters worldwide. Risk assessment and loss estimation provides a unique opportunity for international collaboration and partnership as we work together to create safer communities for the future (Stuart, 2000).

Environmental protection, as a component of sustainable development consistent with poverty alleviation, is fundamental to the prevention and mitigation of natural disasters (Yahmed and Kawaguchi, 1996).

Sustainable development programs require involvement and leadership at the local level; this important concept is inadequately applied in the disaster context. The proposed identification and targeting of at-risk groups does not imply helplessness or lack of agency on their part. (Morrow, 1999) Plans most strongly advance the livable built environment principle. The remaining sustainability principles received less attention from plan elements (Berke, 2000).

Sustainable development represents a broad framework in which to consider disaster recovery and natural hazards management. While disagreement exists about what sustainable development includes, or how it might be defined, achieving a pattern of human settlement, which generally keeps people and property out of harm's way, is increasingly vital. Land use patterns which fail to take into account the location of high-risk areas (e.g., floodplains, high slope terrains, and shoreline erosion zones) are not sustainable. Moreover, housing ill designed to withstand predictable physical forces (e.g., hurricane force winds) is also not sustainable (Beatley and Berke, 1997).

Disaster specialists have increasingly emphasized that both the pre-disaster planning and post-disaster recovery periods offer opportunities to strengthen local organizational capacity to facilitate long-term social, economic, and physical development. Under this approach external aid can be used to build and support local organizations to be more effective in carrying out sustainable-development initiatives that endure long before and after a disaster. Such initiatives not only foster mitigation of risk and equitable aid distribution but also reinforce local capacity to resolve long-standing problems involving deficient affordable housing stocks for the poor, deforestation practices that induce watershed erosion and flooding, occupation by poor slum dwellers on landslide-prone hillsides, and deteriorated or nonexistent public infrastructure (e.g., water, sewer, roads). (Berke, 1995).

3.METHODOLOGY

3.1 Approach

The proposed methodology in assessing the urban vulnerability is based on the techniques of spatial multi-criteria analysis. The spatially referred data (input) are combined and transferred into a resultant vulnerability score (output).

The proposed process involves five stages (Figure 3.1). The first stage is identifying the measures that determine the scope of the analysis. The second stage is estimating building collapse. The third stage is standardization of the evaluation criteria by appropriate membership functions. In the fourth, the criteria are compared pairwise using the analytical hierarchy process (AHP) developed by Saaty (1980). In the fifth stage, building vulnerability values are aggregated into neighbourhood.

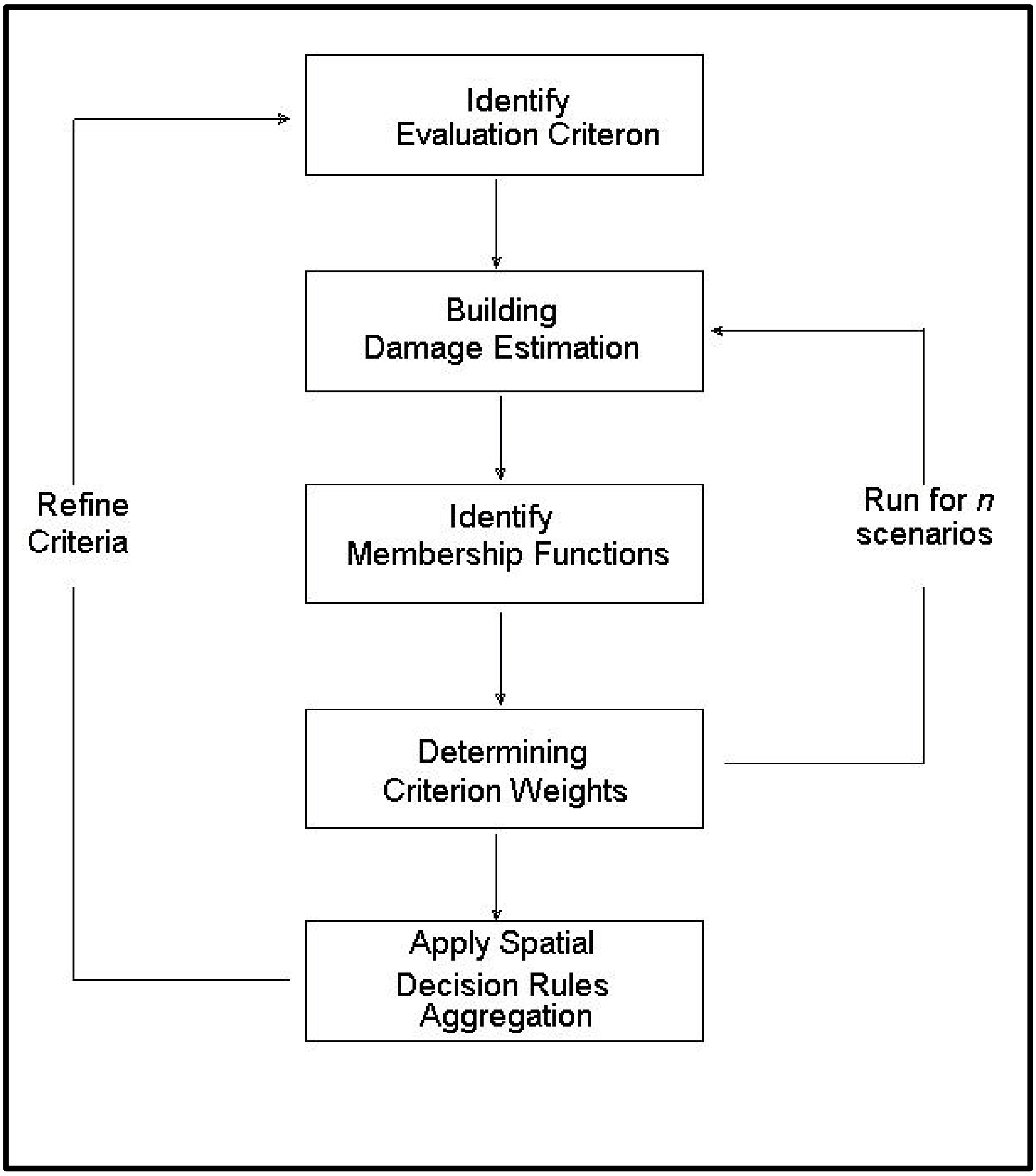

Figure 3. 1 Framework for the study

3.2 Identify Evaluation Criteria

The first stage of the process is identifying evaluation criteria. It is the most important part of the process. Because, criteria that are selected will be used in spatial vulnerability analysis and also different criteria give different results leading different spatial vulnerability distribution. They must be suitable for vulnerability definition.

Malczewski (1999) recommends that a criteria is considered good if it is:

- comprehensive (i.e. clearly indicates the achievement of the associated objectives)
- measurable (i.e. lends itself to a quantification/measurement)

Beside, this Rashed and Weeks (2003) state that a set of criteria is good if it is:

- complete (i.e. covers all aspects of decision problem)
- operational (i.e. is meaningful for a decision definition)
- decomposable (i.e. is amenable to partitioning into subsets of criteria, which may be necessary to facilitate a hierarchical approach to decision analysis)
- non-redundant (i.e. avoids the double counting of decision consequences)
- minimal (i.e.) has the property of the smallest set of complete set if criteria characterizing the consequences of decisions)

In this thesis four main criteria under two groups are selected .

A-Criterias for social risks, these include:

1- Population Distrubution (short-term social losses)
2- Building Collapse (long-term social losses)

B-Criterias for systematic vulnerability, which may influence the emergency response and management activities following the earthquake:

3- Health Center Distance
4- Accesibility

3.3 Estimating Building Collapse

Two approaches are used in estimating the building damage that may occur due to an earthquake (Figure 3.2). In the first approach five criterias, which were determined by the experts, are compared pairwise using AHP (Saaty,1980). In the second approach SRAS developed by Küçükçoban (2004) is used in estimating the building damage

a-The *building collapse* criteria are:

- Building age
- Building type
- Building condition
- Number of storey
- Soil structure of building

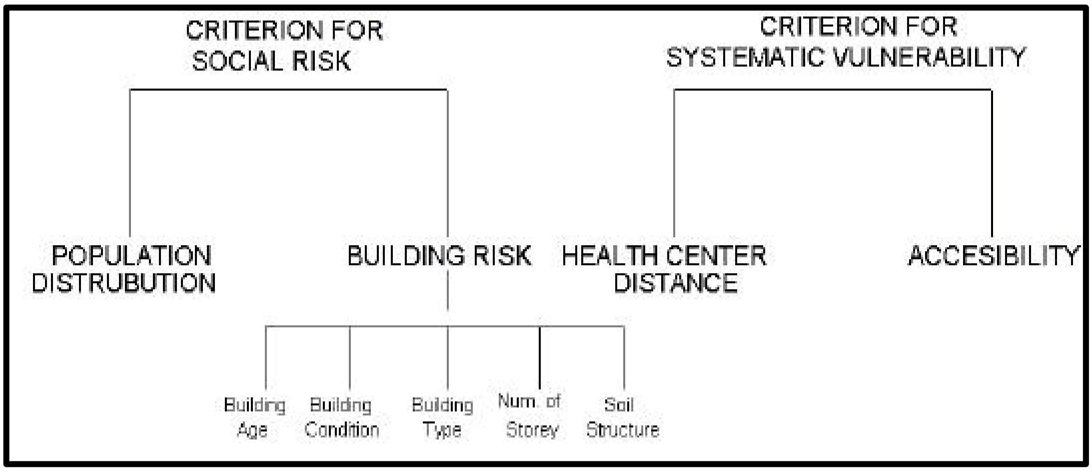

Figure 3. 2 Criterias used in estimating the building damage

b -SRAS (Seismic Risk Analysis Software)

SRAS, which is a software developed by Küçükçoban (2004) is used to calculate sesimic risk and probable damage distrubition for a specified region caused by a deterministic earthquake. Fault locations and building stock layouts are entered in terms of coordinates. Results are also provided in latitudes and longitudes, making mapping of results simpler and faster. It is capable of handling four attenuation relationships and three displacement demand computation methods.

SRAS has a modular structure (Figure 3.2). There are three main structures; input, calculation and output. Also each one of them has special process, criteria and files.

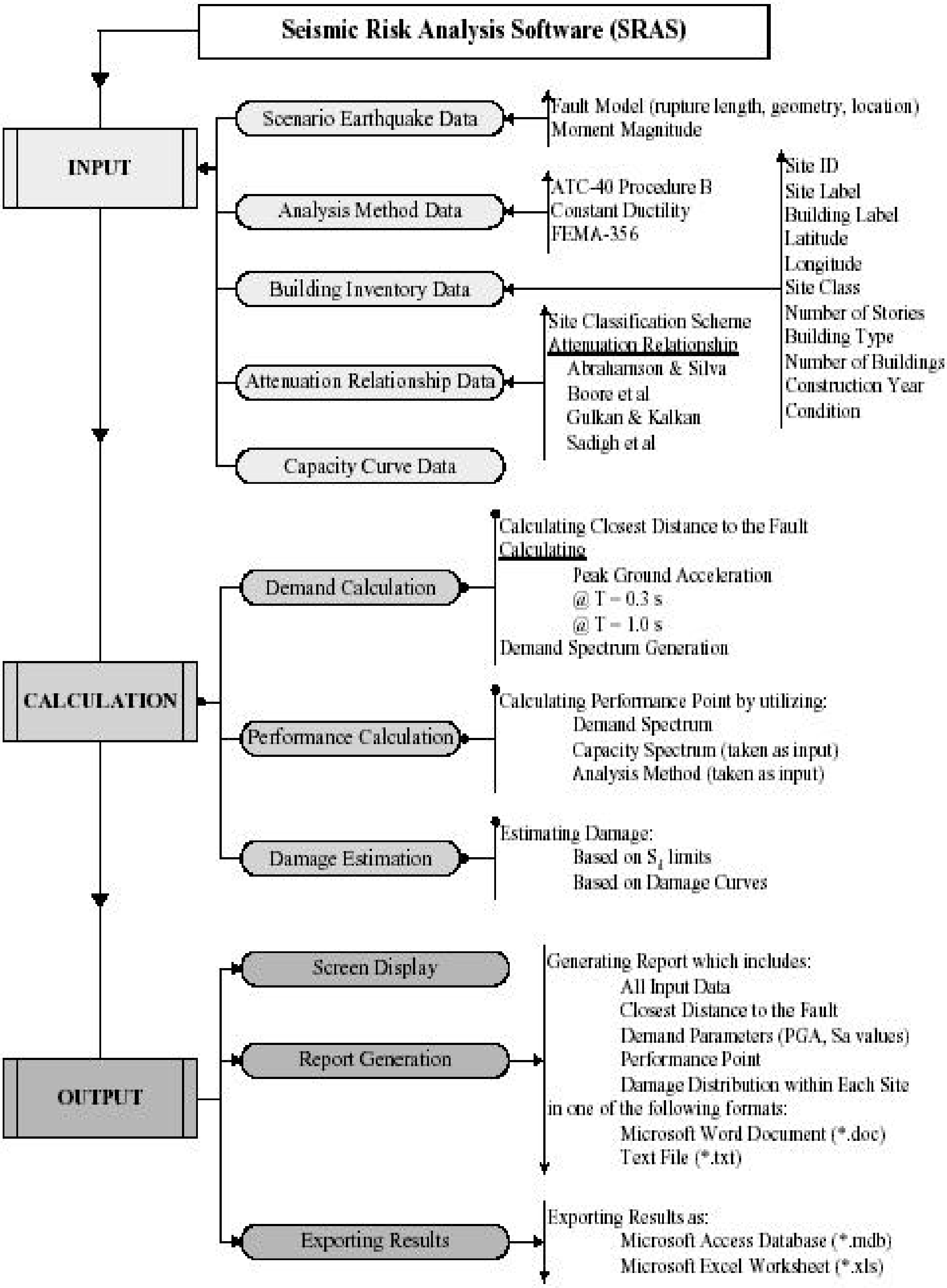

Figure 3. 3 Structure of SRAS (Küçükçoban, 2004)

SRAS needs five data sets to start analysis. Building inventory data, attenuation relationship data, scenario earthquake data, capacity curves for each building type and analysis method data are the fundamental inputs to SRAS.

Next phase is, the calculation phase. There are three parts in that phase, which are demand calculation, performance calculation and damage estimation. Demand calculation part, initially, finds the shortest distance between each building in the region and the scenario earthquake fault and then generates smoothed acceleration response spectrum expected under each building. Subsequently, performance calculation module computes performance point using the generated demand curve and provided capacity curve for each building.

Finally, damage estimation module predicts the performance of each building under the scenario earthquake induced forces. Results obtained from the analysis are exported to a database file or displayed on the screen. And also, a report is created which includes the site-based distribution of damage and all input data.

3.4 Standardizing the Criteria

Evaluation criteria can be in different measurement scales. Therefore they can be standardized into a common scale. Identifying membership functions for each criteria give such standardization. Some of those membership functions can be defined with expert-knowledge. In this study, Dr. Ahmet YAKUT gave some suggestions, especially for standardization of *building risk's criteria*. Also some criteria's membership functions are specified .

3.5 Determining Criteria's Weights

3.5.1 Multi Criteria Decision Analysis-Pairwise Comparison Method

Multi-criteria decision analysis (MCDA) is a quantitative approach in evaluating decision problems that involve multiple variables. MCDA can be applied to a set of spatial objects. Also GIS databases combine spatial and non-spatial information. GIS should also contain spatial query and analytical capabilities such as measurement of area and distance, overlay capability and corridor analysis. Therefore GIS is an ideal tool to use in analyzing and solving multiple criteria problems.

Multi-criteria decision analysis has six elements: a goal or a set of goals the decision maker attempts to achieve, the decision maker or makers, a set of evaluation criteria (objectives and/or attributes), a set of decision alternatives, set of uncontrollable variables, set of outcomes (Malczewski, 1999).

Spatial multicriteria decision problem involves a set of geographically defined alternatives from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria (Malczewski, 1999). Spatial multicriteria decision analysis (Figure 3.4) can be thought of as process that combines and transforms geographical data(input) into a resultant decision(output) (Malczewski, 1999).

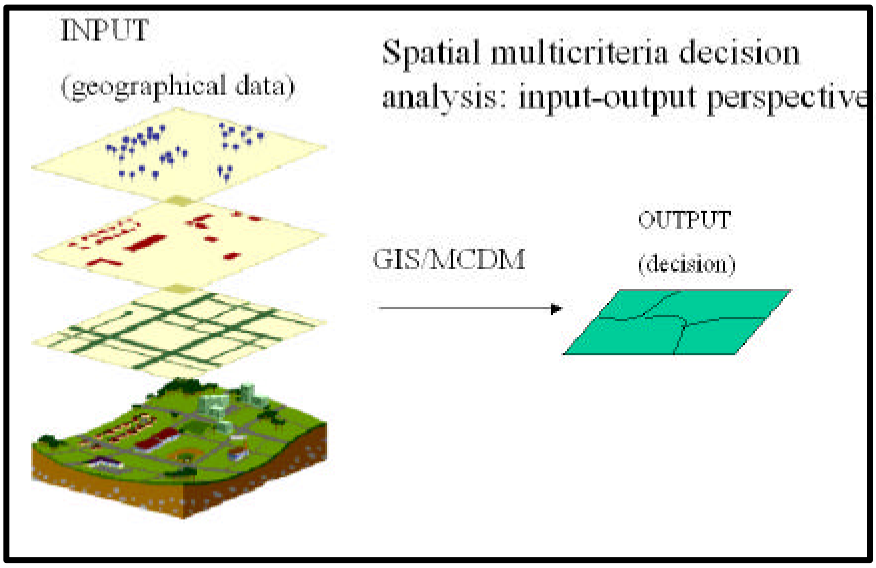

Figure 3. 4 Spatial multicriteria decision analysis

GIS handles a quantity of data of various sources, most often with a spatial reference. The data can be interpreted in maps or transformed and treated through models and then interpreted in maps and finally transformed into indicators and criteria values. MCDA techniques will transform many indicators and criteria obtained through a GIS approach into a recommendation for a course of action that should be the "preferred one" for the decision maker concerned (Figure 3.5).

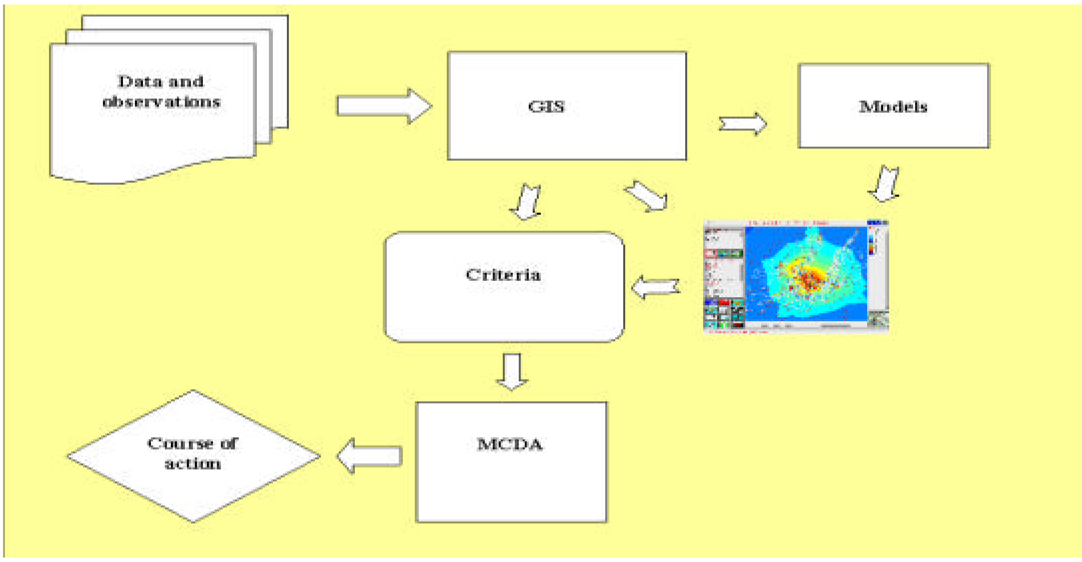

Figure 3. 5 Multicriteria decision process

Multicriteria decision making problems typically involve criteria of verifying importance to decision makers. This is usually achived by assigning a weight to each criterion (Malczewski, 1999).

A weight can be defined as a value assigned to an evaluation criteria that indicates its importance relative to other criteria consideration. The larger the weight, the more important is the criteria in the overall utility. The weights are usually normalized to sum to 1 (Malczewski, 1999).

The pairwise comparison method was developed by Saaty(1980) in the context of the analytical hierarchy process. This method involves pairwise comparions to create a ratio matrix. It takes as an input the pairwise comparisons and produces the relative weights as output. Specifically, the weights are determined by normalizing the eigenvector associated with the maximum eigenvalue of the ratio matrix

3.5.2 Applying Spatial Decision Rules

Having created standardized maps for the evaluation criteria, the task is to apply decision spatial rules based on these criteria to identify areas with higher and lower risk produced.

The relative importance of each criteria must be established in terms of a weight that determines its contributes to the overall risk. One of the widely adopted techniques is the analythical hierarchy process (AHP) developed by Saaty(1980). This process is implemented in excell files. The AHP approach allows to assess the relative weight of multiple criteria in an initiative manner. The fundemental input to the AHP is the decision maker's or expert's answers to a series of questions of general form:"How important is criteria A relative to Criteria B?". These are termed pairwise comparison. Responses are gathered in verbal form and subsequently codified on nine-point intensity scale (Table 3.1). Saaty's basic method to identify the value of the weights depends on matrix algebra and calculates the weights as the elements in the eigenvector associated with the maximum eigienvalue of the matrix. Final results will include the weight of each criteria in addition the measure of inconsistency which informs if or not the preferences assigment needs to be revised.

Table 3. 1 The AHP pairwise comparison continuous rating scale

Less Important				More Important				
Extremely	Very Strong	Strongly	Moderately	Equally Important	Moderately	Strongly	Very Strong	Extremely
1/9	1/7	1/5	1/3	1	3	5	7	9

3.6 Aggregation Criteria

After calculation of vulnerability value for each building, the next step is to apply spatial decision rules derived from determined criteria. As a result of this, relative vulnerability values can be seen on map. The vulnerability value gives a chance to make comparison between "map based on one criteria" and "map based on vulnerability value (multi-criteria)". Therefore importance of each criterion can be detected.

Final step is aggregation of vulnerability values from building to neighbourhood. Aim of this operation is to identify earthquake sensitive neighborhoods in the city. Also these sensitive neighborhoods will be the initial importance for local authorities to create earthquake resistant cities.

For this aggregation, many methods can be used. Moreover, in this study, highest vulnerability value of buildings in the neighbourhood will be accepted as neighbourhood’s vulnerability value. This acceptance will give the most correct idea about neighbourhood. Because, if there will be only one building which has very high vulnerability value than other buildings in other neighbourhood, it will create a sensitive condition for itself and its environment.

4.CASE STUDY: Odunpazari-Eskisehir

4.1 Study Area and Data

4.1.1 Study Area

The study area used to test the proposed methodology in is Eskisehir-Odunpazari district. Eskisehir located on north-west of center Anatolia is surrounded by Afyon from south, Konya from south-east, Ankara from east and north-east, Bolu from north-west, Bilecik and Kütahya from west (Figure 4.1). Its area is about 13 652 sq kilometers.

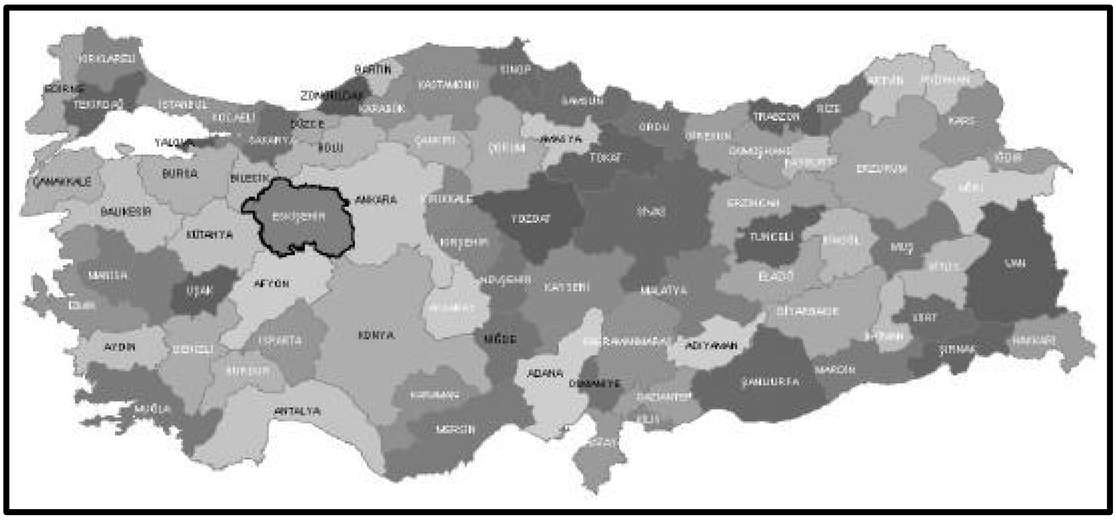

Figure 4. 1 Location of Eskisehir

Eskisehir's population is about 706 009 according to data from the 2000 census. There is an increase in the population between 1990-2000 (Figure 4.2). Nearly 80% of this population lives in urban areas.

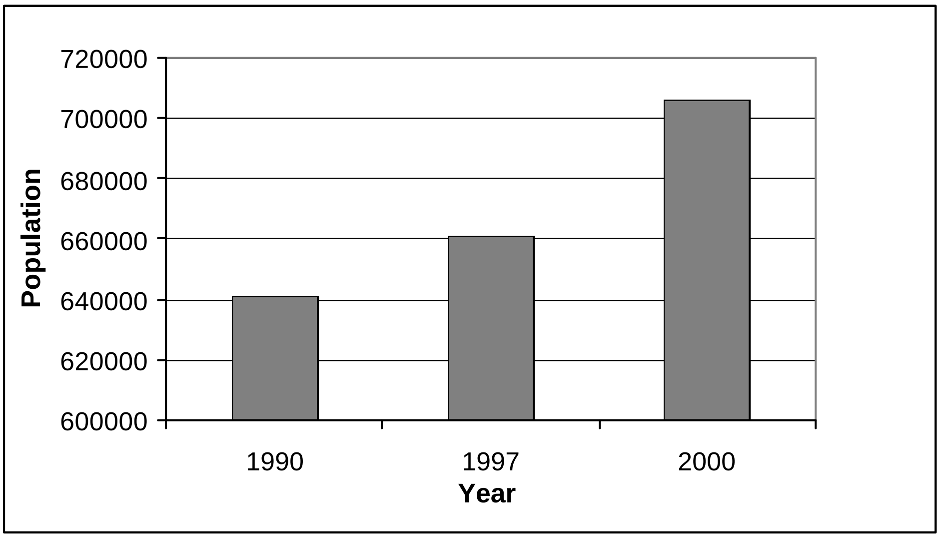

Figure 4. 2 Eskisehir's population between 1990-2000

Eskisehir has 32 municipalities. two of them are districts of Eskisehir Greater Municipality; Tepebasi and Odunpazari. Odunpazari is settled on the second-degree earthquake zone.

The population of Odunpazari is about 274 000 according to data from the 2000 census and also there are nearly 28 000 buildings in Odunpazari (Figure 4.3).

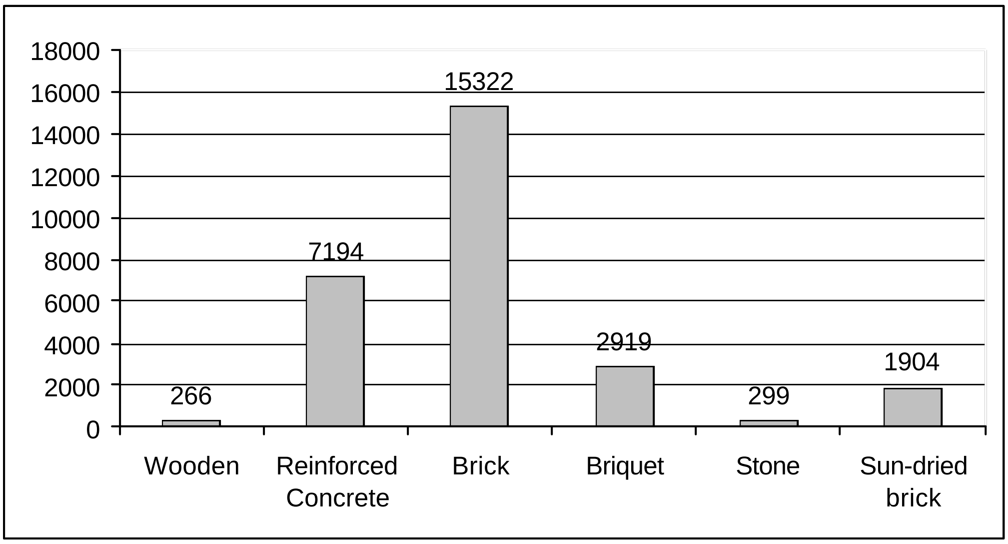

Figure 4. 3 Building types of Odunpazari

Odunpazari is settled in the second-degree earthquake zone. Nearest faults are Inönü-Dodurga fault zone, Eskisehir fault zone and Kaymaz fault zone (Figure 4.4). On the other hand North Anatolian Fault Zone is nearly 85 km far from the district.

Figure 4.4 Fault zones (General Directorate of Mineral Research and Exploration)

Earthquake having the biggest magnitude 6.4 occurred in 1956 in Eskisehir fault zone. About 13000 buildings were affected in this earthquake (1379 of them were hardly damaged). Between the 1978-1996, among the earthquakes occurred in Eskisehir (Table 4.1), the biggest one had magnitude about 3,7. Also 1999 Gölcük Earthquake caused a serious damage in Eskisehir.

Table 4. 1 Eskisehir fault zone's earthquakes between 1978-1996 (Mag. >=3) (General Directorate of Disaster Affairs)

DATE	Lattitude (North)	Longtitude (East)	Deep (Km.)	Magnitude	Distance (Km)
07.04.1978	40	29.4	10	3.2	100
25.10.1983	40.17	29.49	13	3.3	99
25.10.1983	40.11	29.46	12	3.1	99
06.05.1984	40.01	29.5	10	3	92
30.12.1984	40.19	29.5	4	3.7	100
15.04.1992	40.14	29.47	7	3	99
08.07.1996	40.15	29.48	13	3	99

4.1.2 Urban Data

I-Raw Data

In this study many types of data were collected from different source. Those can be named as *raw data.* The definition of the *raw data* can be seen in Table 4.2.

Table 4. 2 The description of raw data of Eskisehir.

DATA	LOCATION	SOURCE
268 soil structure analysis points and results.	Odunpazari Municipality area	Eskisehir Greater Municipality.
Odunpazari buildings and their physical structure database (Building type, Condition, Number of Storey, Age etc..)	Odunpazari Municipality area	Eskisehir Greater Municipality.
Public buildings location and usage (Health center, hospital, police station, pharmacy, school etc..)	Eskisehir Greater Municipality area	Eskisehir Greater Municipality.
Dormitories addresses and their capacity	Eskisehir Greater Municipality area	General Directorite of Civil Defense
Hospitals capacity	Eskisehir Greater Municipality area	General Directorite of Civil Defense
Information about construction machine in Eskisehir. (location etc..)	Eskisehir Greater Municipality area	General Directorite of Civil Defense
Road map of Eskisehir city center	Eskisehir Greater Municipality area	Eskisehir Greater Municipality

Ikonos satelite images of Eskisehir (about 770 ha)	Part of Eskisehir Greater Municipality area	Eskisehir Greater Municipality
Earthquake records about Eskisehir (historical earthquakes, magnitudes, epicenter, losses, etc..).	Eskisehir Greater Municipality area	General Directorite of Civil Defense
Information about earthquakes in Turkey (epicenters, magnitudes, faults etc…).	Turkey	Civil Engineering Department of METU
Eskisehir neighborhoods map	Eskisehir Greater Municipality area	Eskisehir Greater Municipality

II- Processed Data

Raw data were processed in order to be used in the study. After that process, different types of data were obtained. They can be classified as:

- Graphical data
- Tabular data
- Prepared data (both tabular and graphical)

Graphical data are digital map layers about Odunpazari. All graphic data are stored in database file as a Netcad Spatial database format. Each layer is stored as different database table.

Database file name is *bina.mdb* and it includes all graphic (Figure 4.5) and non-graphic data.

BUILDING is the first table, which includes building geometry (the vector objects). Buildings are stored as polygon object and UTM-3° WGS-84 (Gauss-Krugger) is used as projection parameters. There are 27 904 building objects in this table

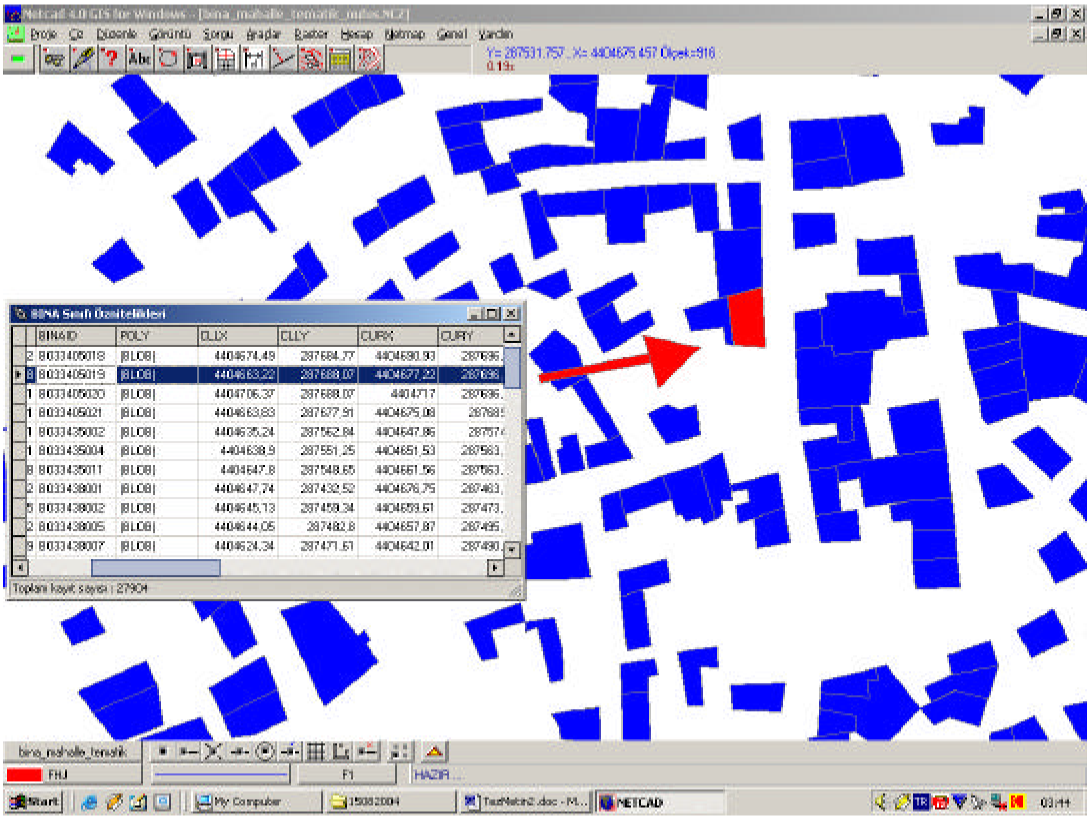

Figure 4. 5 Graphic data of BINA table

BUILDING table (Table 4.3) also includes 21 columns. Value of some columns comes from “Code Tables”, that is, where the columns include look-up values.

Table 4. 3 BUILDING table structure

COLUMN NAME	COLUMN INFO	DATA SOURCE
BUILDING_ID	ID number of Buildings	CV
BUILDING_AGE	Construction Date Period	CT
BUILDING_TYPE	Structure Type	CT
NUM_OF_STOREY	Number Of Storeys	CV
BUILDING_COND	Building Condition	CT
POPULATION	Population of Building	CV
NEIGHBOURHOOD	Name of Neighbourhood	CV
HS_DISTANCE	Distance of Nearest Health Center	CV
ROAD	Type of Service Road	CT
DAMAGE_SRAS	Damage Values from SRAS	CV
VUL_PCM	Vulnerability Value of First Step Calculation with MCE Software	CV

VULF_PCM	Vulnerability Value of Final Calculation with Result of First Step	CV
VULF_SRAS	Vulnerability Value of Final Calculation with Result of SRAS	CV
SOIL STRUCTURE	Soil Structure Type of Building	CV
POLY	Netcad Spatial Database Column	CV
CLLX	Netcad Spatial Database Column	CV
CLLY	Netcad Spatial Database Column	CV
CURX	Netcad Spatial Database Column	CV
CURY	Netcad Spatial Database Column	CV
MERKEZX	Center X Coordinate of Building	CV
MERKEZY	Center Y Coordinate of Building	CV

**CV: Column Value, CT: Coming from Code Table*

NEIGHBOURHOOD is the second graphic-data table, which includes polygon object as a neighbourhood. There are 31 neighborhoods in Odunpazari. Also it is UTM-3 ° WGS-84 (Gauss-Krugger) map projection. A sample from neighbourhood data is given in Figure 4.6 and the tabular structure is given in Table 4.4

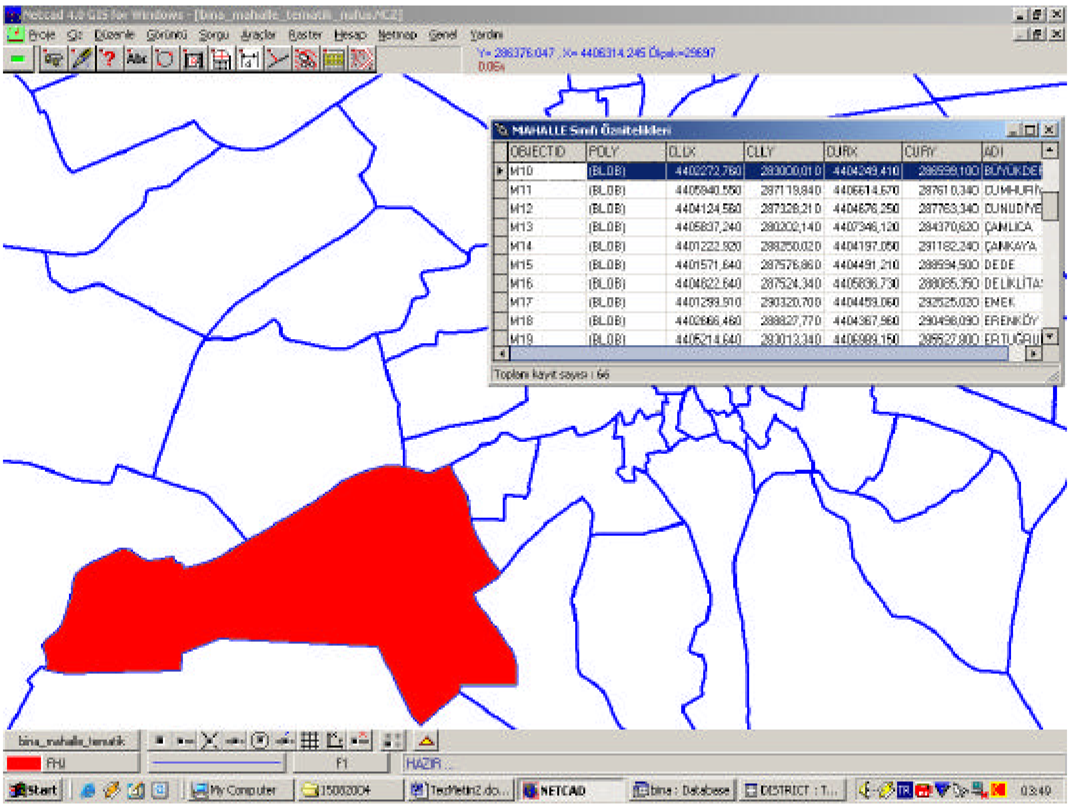

Figure 4. 6 Graphic data of NEIGHBOURHOOD table

Table 4. 4 NEIGHBOURHOOD table structure

COLUMN NAME	COLUMN INFO	DATA SOURCE
OBJECTID	ID Number of Neighbourhood	CV
NAME	Name of the Neighbourhood	CV
POLY	Netcad Spatial Database Column	CV
CLLX	Netcad Spatial Database Column	CV
CLLY	Netcad Spatial Database Column	CV
CURX	Netcad Spatial Database Column	CV
CURY	Netcad Spatial Database Column	CV

**CV: Column Value, CT: Coming from Code Table*

ROAD is the third graphic-data table. It includes road segment to calculate distance of nearest health service and to find service roads. The graphic data of road is given in Figure 4.7 and the tabular structure is listed in Table 4.5.

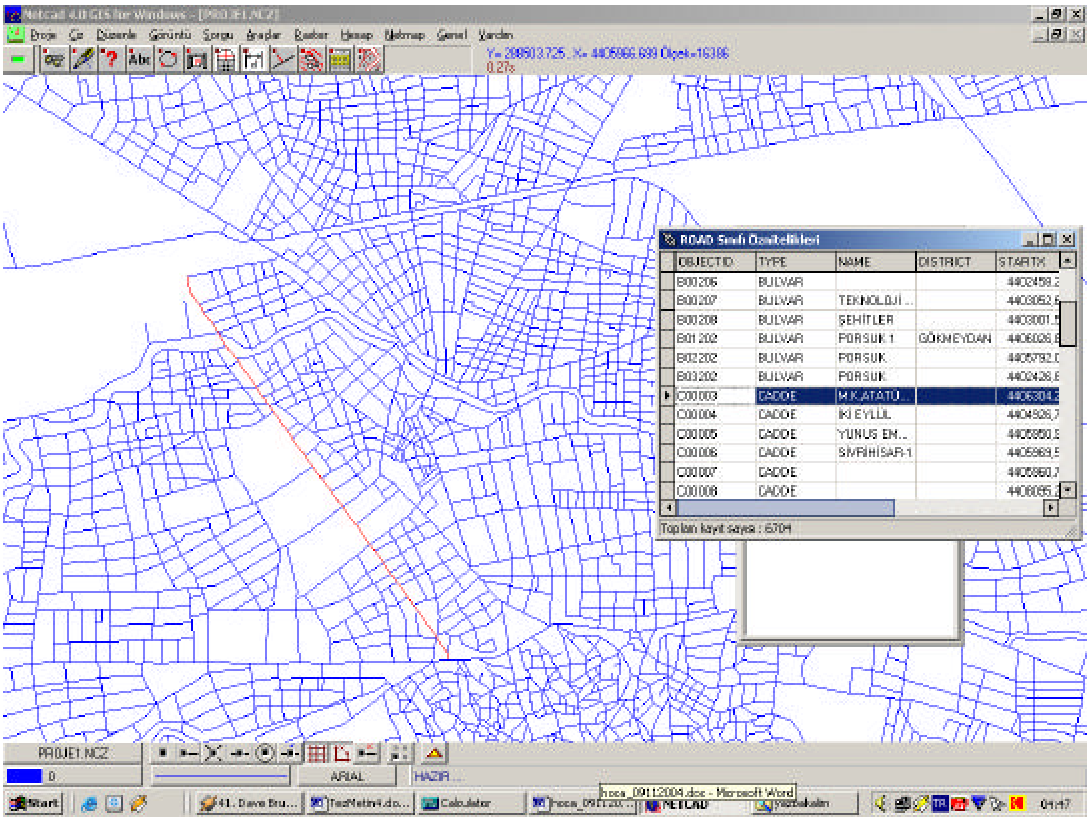

Figure 4. 7 Graphic data of ROAD table

Table 4. 5 ROAD table structure

COLUMN NAME	COLUMN INFO	DATA SOURCE
OBJECTID	ID Number of Roads	CV
TYPE	Type of Road	CV
NAME	Name of Road	CV
POLY	Netcad Spatial Database Column	CV
CLLX	Netcad Spatial Database Column	CV
CLLY	Netcad Spatial Database Column	CV
CURX	Netcad Spatial Database Column	CV
CURY	Netcad Spatial Database Column	CV
STARTX	Netcad Spatial Database Column	CV
STARTY	Netcad Spatial Database Column	CV
ENDX	Netcad Spatial Database Column	CV
ENDY	Netcad Spatial Database Column	CV

**CV: Column Value, CT: Coming from Code Table*

Beside, the main tables, "Code Tables" are generated, which includes look-up value coming from membership functions. "BUILDING_AGE", BUILDING_CONDITION", "BUILDING_TYPE", "NUMBEROFSTOREY", "ROAD_CODE" are the generated code tables and their tabular structure are given in Tables 4.6 - 4.10.

Table 4. 6 BUILDING_AGE table structure

COLUMN NAME	COLUMN INFO
CODE	Look-Up Code which is used in BUILDING table
AGE	Age of Building
VALUE	Membership Functions Value which is coming from membership degree charts

Table 4. 7 BUILDING_CONDITION table structure

COLUMN NAME	COLUMN INFO
CODE	Look-Up Code which is used in BUILDING table
CONDITION	Building Condition
VALUE	Membership Functions Value which is coming from membership degree charts

Table 4. 8 BUILDING_TYPE table structure

COLUMN NAME	COLUMN INFO
CODE	Look-Up Code which is used in BUILDING table
TYPE	Type of Building
VALUE	Membership Functions Value which is coming from membership degree charts

Table 4. 9 NUMBEROFSTOREY table structure

COLUMN NAME	COLUMN INFO
CODE	Look-Up Code which is used in BUILDING table. Also referring number of storey of building
VALUE	Membership Functions Value which is coming from membership degree charts

Table 4. 10 ROAD_CODE table structure

COLUMN NAME	COLUMN INFO
CODE	Look-Up Code which is used in BUILDING table
TYPE	Type of Road
VALUE	Membership Functions Value which is coming from membership degree charts

All those tables are used for each scenario run.

Also there is other table group, which derived from some calculations. Data in these tables are prepared with some process. HS_DIST is the first table of this group. It includes distance of nearest health service to buildings. Its values come from shortest path analysis results. HS_DIST table (Table 4.11) has three columns. The result column (DISTANCE column) of this table is used in BUILDING table

Table 4. 11 HS_DIST table structure

COLUMN NAME	COLUMN INFO
BUILDING_ID	ID Number of Building
HS_ID	ID number of Nearest Health Service
DISTANCE	Distance of Nearest Health Service

ROAD_BUILDING is the other table (Table 4.12), which includes building's service roads. It is calculated with overlay analysis and shortest path analysis. It has two columns and ROAD_BUILDING result column (ROAD_ID column) is used in BUILDING table with ROAD_CODE table.

Table 4. 12 ROAD_BUILDING table structure

COLUMN NAME	COLUMN INFO
BUILDING_ID	ID Number of Building
ROAD_ID	ID number of Service Road

SOIL_STRUCTURE is the third derived table (Table 4.13), which includes soil structure information about building. Its result column (SOIL_STRUCTURE column) is used in BUILDING table. SOIL_STRUCTURE table has 7 columns.

Table 4. 13 SOIL_STRUCTURE table structure

COLUMN NAME	COLUMN INFO
OBJECTID	ID Number of Building
SOIL_STRUCTURE	Soil Structure Type of Building
POLY	Netcad Spatial Database Column
CLLX	Netcad Spatial Database Column
CLLY	Netcad Spatial Database Column
CURX	Netcad Spatial Database Column
CURY	Netcad Spatial Database Column

The last prepared table is SRAS (Table 4.14), which includes results of SRAS software run. It gives the building damage. Its result column (DAMAGE column) is used in BUILDING table. SRAS table has two columns.

Table 4. 14 SRAS table structure

COLUMN NAME	COLUMN INFO
BUILDING_LABEL	ID Number of Building
DAMAGE	Damage of Building

Final table is user defined data input table. There is only one table, which is CRITER_TABLE (Table 4.15). That includes four columns. The values entered by the user are used for vulnerability calculation. Data entry can be done with MCE software.

Table 4. 15 CRITER_TABLE table structure

COLUMN NAME	COLUMN INFO
CRITER_COLUMN	Column selection from BUILDING table for vulnerability calculation
CODE_TABLE	Code table selection to get membership function values
DIV_CALUE	Division value entry (That is maximum value of criteria)
CRITERION_WEIGHT	Criteria's weight value entry that is coming from excel sheet.

Database tables, which were used to urban vulnerability analysis, can be grouped as *code tables, main tables, prepared tables, data entry tables* (Figure 4.8).

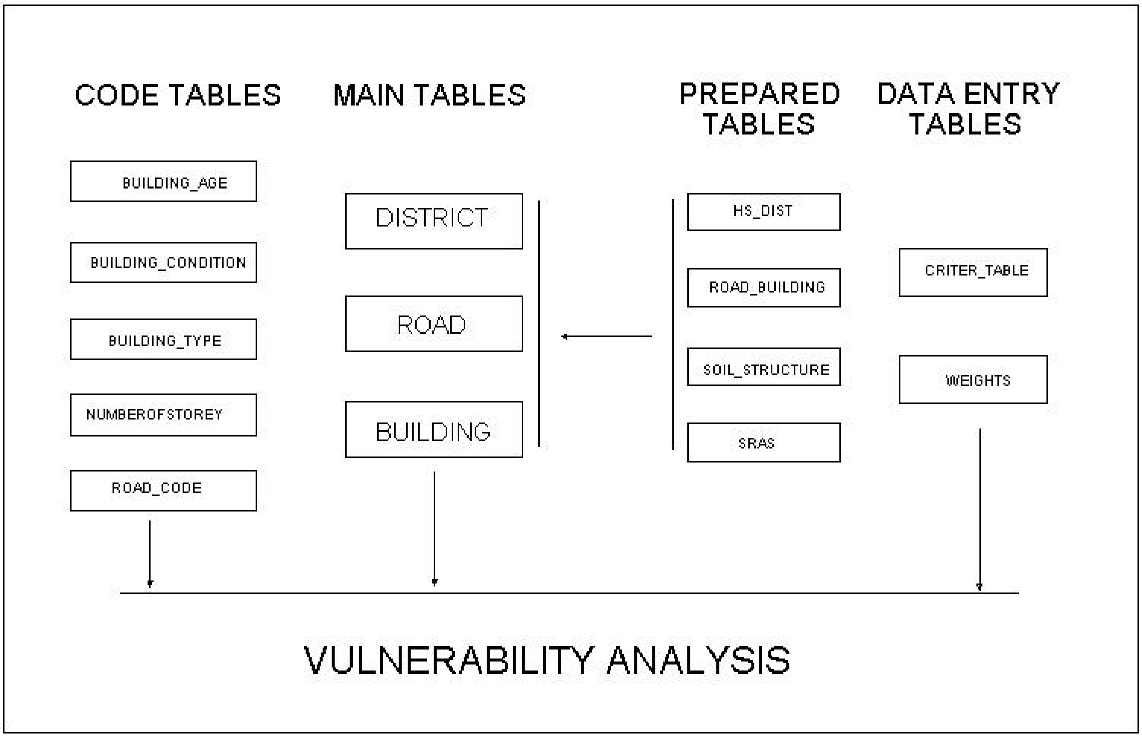

Figure 4. 8 Grouping of the database

4.2 Identifying Evaluation Criteria for the Case Study

In assessing the urban vulnerability to earthquake for Odunpazari district, four main criteria under two groups are selected. The selection of these criteria has been based on the framework of "systematic vulnerability" developed by Menoni and Pergalani (1996).

A. Criteria for social risk, these include:

1- Population Distrubution (a proxy for short-term social losses) : This criteria including living population in building is the most important criteria to vulnerability analysis of this case study. Because human life losses has not only dramatic and emotional results but also it has economic and social results. The more people live in building, that building can be accepted as more vulnerable.

2- Building Collapse (long-term social losses) : Building collapse is one of the native results of earthquake disasters. Especially in Turkey there are too much building losses after earthquakes. Therefore, that heavy result causes also both social and economic losses. For example, homeless people, re-constrution cost, repairing cost.

In the case study, two different methods were used to calculate *building collapse*. First one is MCE approach where a code was developed and used. It was used to calculate vulnerability of building according to physical criteria. Second one is SRAS (Seismic Risk Analysis Software). It was used to calculate building damage according to soil structure and physical criteria. This step will be explained in section 4.3.

B. Criteria for systematic vulnerability, which may influence the emergency response and management activities following the earthquake:

3- Health Center Distance: Emergency activities are important to decrease losses also to decrease vulnerability. In this study, “Nearest Health Services Distance” is used as criteria in the evaluation of vulnerability.

Netcad 4.0 GIS Network Analysis tool and NCMacro module were used to calculate the nearets health service distance. Database includes road segments and buildings as a spatial object. Netcad 4.0 GIS Network Analysis tool uses “Dijkstra’s Shortest Path Algorithm” to find a shortest path. Then, special script was developed with NCMacro tool (NHS Script) and it is used to find distance of nearest health services (codes are available in Appendix A).

In finding the distance of nearest health services, one building record from database is selected, centerX and centerY coordinates of the building are calculated. Also centerX and centerY coordinates of health centers are found from graphical data. Then linear distances of building to health services are found (Figure 4.9).

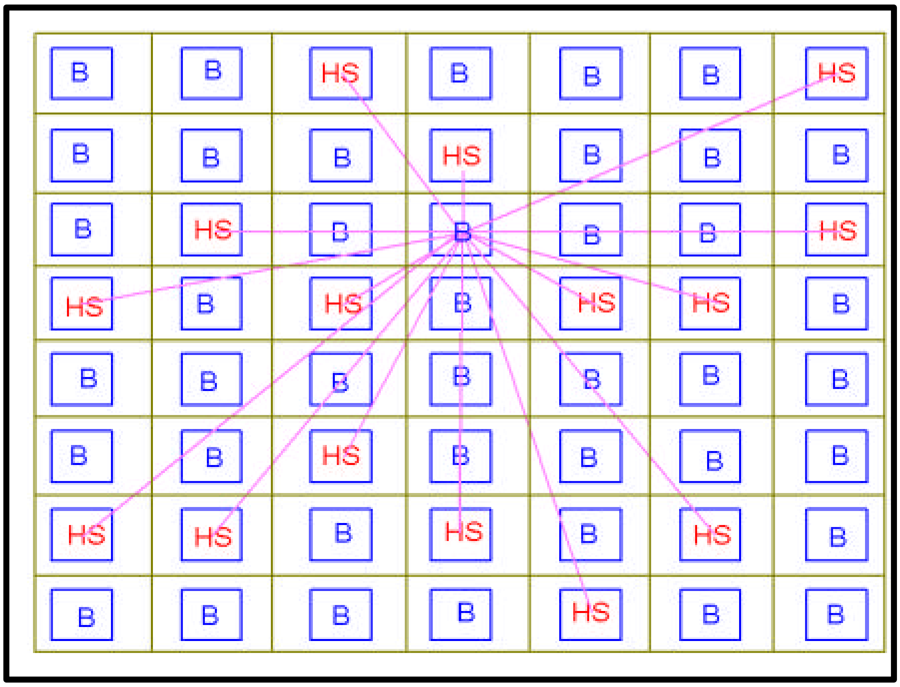

Figure 4. 9 Linear distances of building to health services

Then, nearest five health centers (according to linear distance) are selected and shortest path analysis is used to find the road distance between building and those five health center (Figure 4.10).

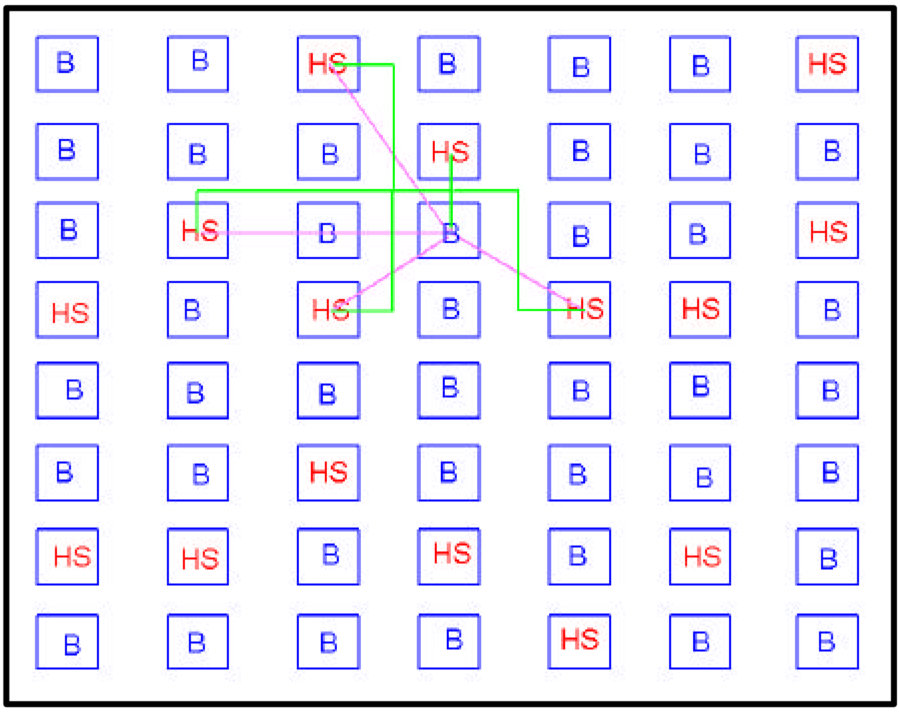

Figure 4. 10 Road distance between building and those five health centers

Finally, health center, which has shortest distance on the road network, named as “Nearest Health Service” and its distance, is taken as an input for vulnerability calculation. This progress is done for all records in main tables (BUILDING).

4- Accesibility: Accesibilty is also an other criteria which is used in vulnerability analysis. For this criteria, degree of service road for each building are calculated. In row data there are five types of road (HIGHWAY, BOULEVARD, AVENUE, STREET, CULDESAC). In vulnerability analysis, HIGHWAY is accepted the least vulnerable service road , CULDESAC is the most.

To find service road of each building, NCMACRO (Netcad Macro Module) and Netcad 4.0 GIS softwares are used. Spacial script is developed for this process (Code is available in Appendix A). In finding the service road of each building, the nearest road is found for each edge of building. Then, those roads are compared and the least vulnerable one is accepted as a service road of building. This process is done for each building in Odunpazari.

4.3 Standardization of Criteria

Evaluation criteria can be in different measurement scales. Therefore they can be standardized into a common scale. Identifying membership functions for each criteria give such standardization. Some of those membership functions can be defined with expert-knowledge. In this thesis study, Dr. Ahmet YAKUT gave some suggestions, especially for standardization of *building collapse’s criteria*. Also some criteria’s membership functions will be user-defined.

The first criteria is *Building Type*. Based on expert knowledge. Sun-dried brick type buildings are accepted the most vulnerable, however, wooden buildings are accepted as the least vulnerable ones (Figure 4.11)

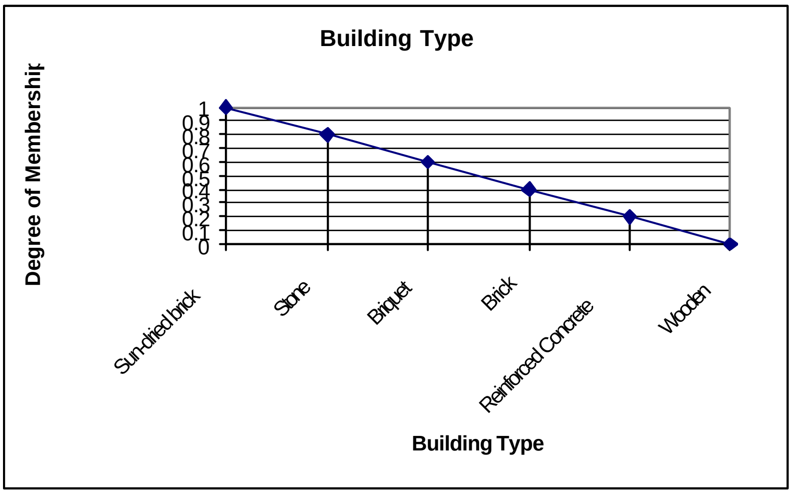

Figure 4. 11 Membership degrees of Building Type

The second criteria is *Building Condition*. Based on expert knowledge, buildings, which are ruin, were accepted as the most vulnerable ones, however, well situation buildings are accepted as the least vulnerable (Figure 4.12)

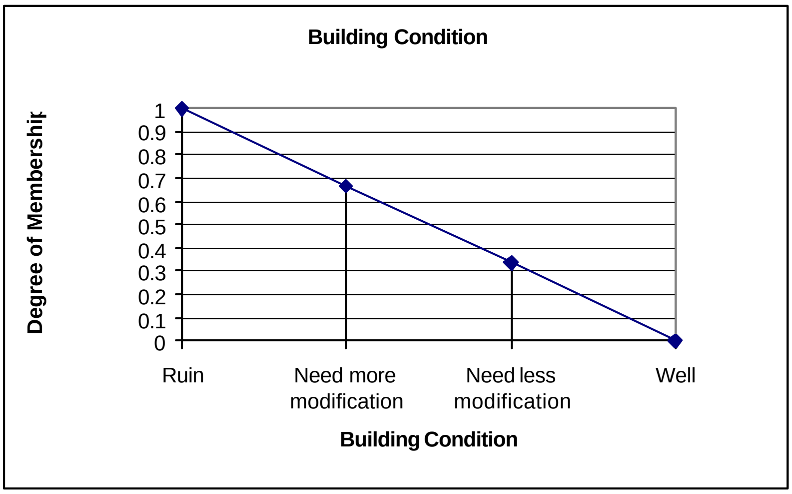

Figure 4. 12 Membership degrees of Building Condition

The third criteria is *Number of Storey*. Based on expert knowledge, number of storey is accepted as having a linear vulnerability degree until the seventh floor. If building has more than seven storeys it is accepted as the most vulnerable (Figure 4.13).

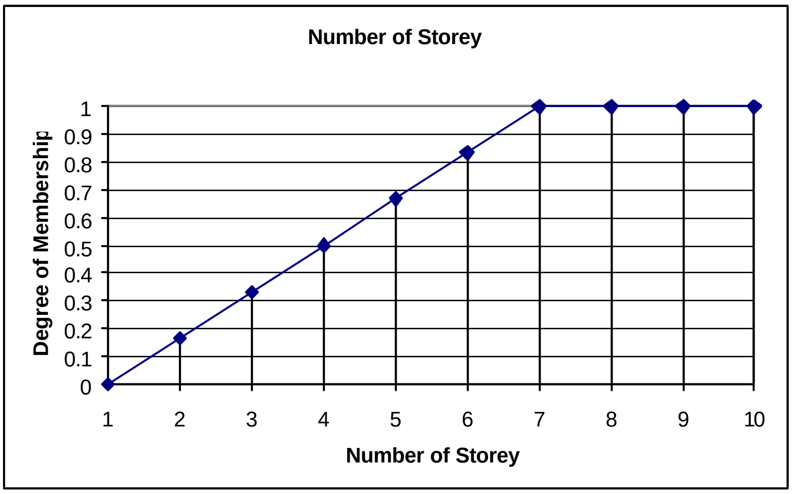

Figure 4. 13 Membership degrees of Number of Storey

The fourth criteria is *Building Age*. Based on expert knowledge and housing policy in Turkey, 1962, 1975 and 1999 construction law can be accepted as a crucial point. Until 1962, vulnerability, value is accepted as having a linear decrease than there is a sharp increase because of housing policy and legal structure. After 1975, increase becomes smooth and after 1999 earthquake (Gölcük), since strong arrangements are done on construction law. Therefore vulnerability is accepted as decreasing (Figure 4.14).

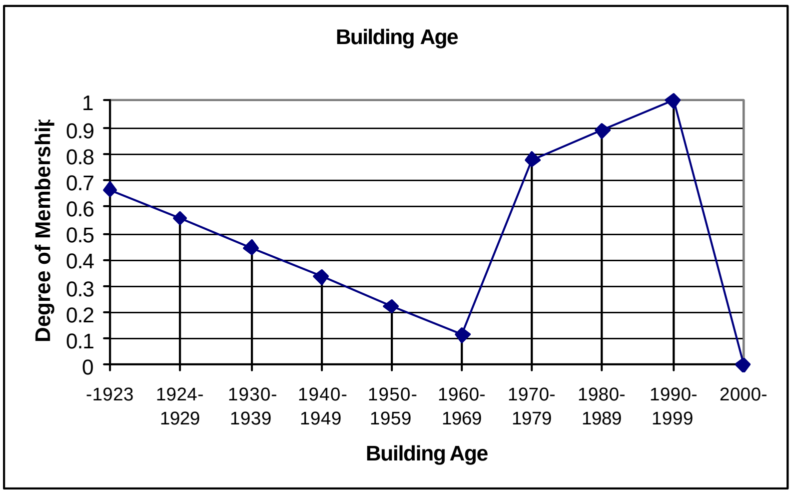

Figure 4. 14 Membership degrees of Building Age

The fifth criteria is *Population*. Buildings, which have more population, are accepted as the most vulnerable ones, however, having less population are accepted as the least vulnerable ones (Figure 4.15)

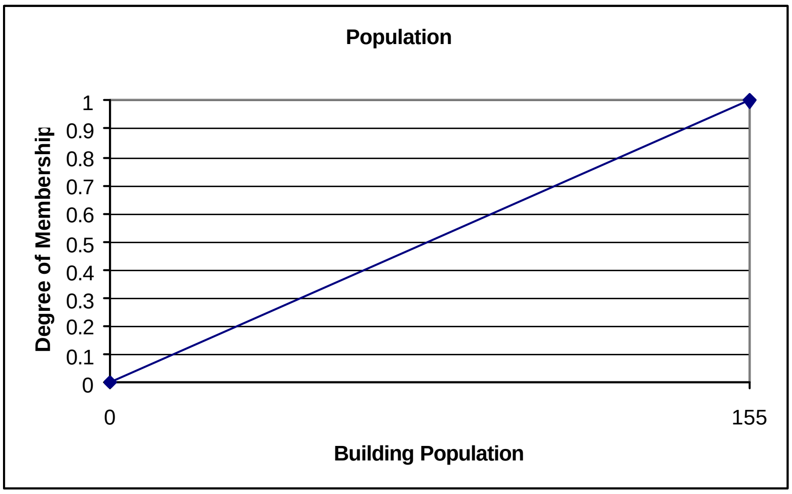

Figure 4. 15 Membership degrees of Population

The sixth criteria is *Accessibility*. Buildings, which can be accessed on cul-de-sac, are accepted the most vulnerable ones, however, accessed on highway are accepted as the least vulnerable one (Figure 4.16).

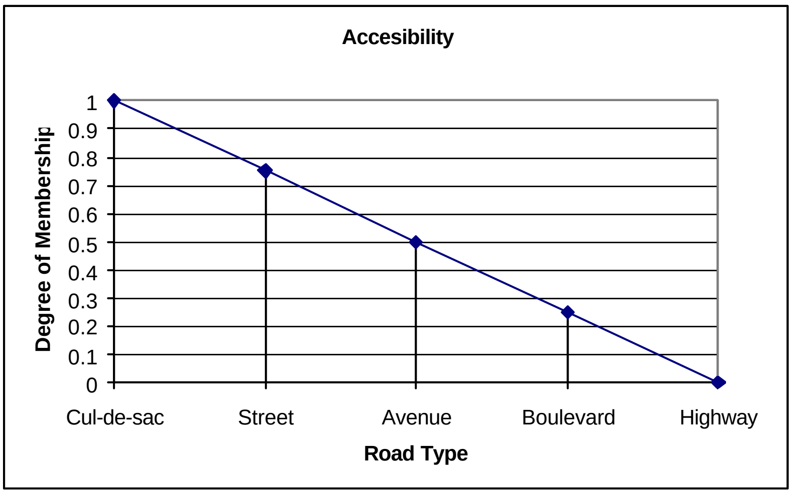

Figure 4. 16 Membership degrees of Accessibility

The seventh criteria is *Distance*. Buildings, which are far from health services, are accepted as the most vulnerable ones, however, being close to a health service is accepted as the least vulnerable ones (Figure 4.17).

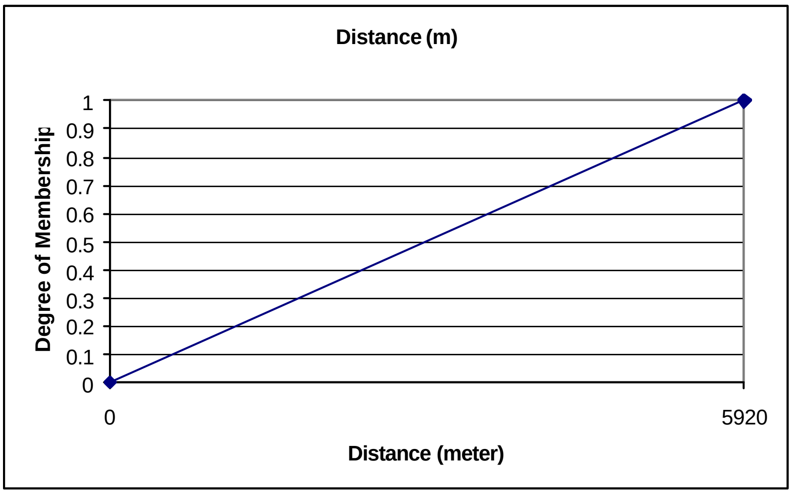

Figure 4. 17 Membership degrees of Distance

The eighth criteria is *Building Collapse Vulnerability.* The highest one is the most vulnerable one (Figure 4.18).

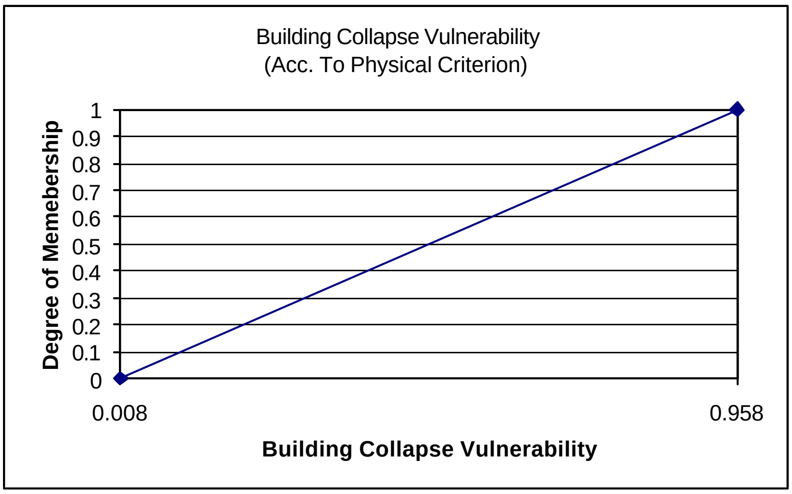

Figure 4. 18 Membership degrees of building collapse vulnerability

The ninth criteria is *Building Collapse Percentage*. SRAS gives results about building damage percentages. The highest one accepted as the most vulnerable one (Figure 4.19).

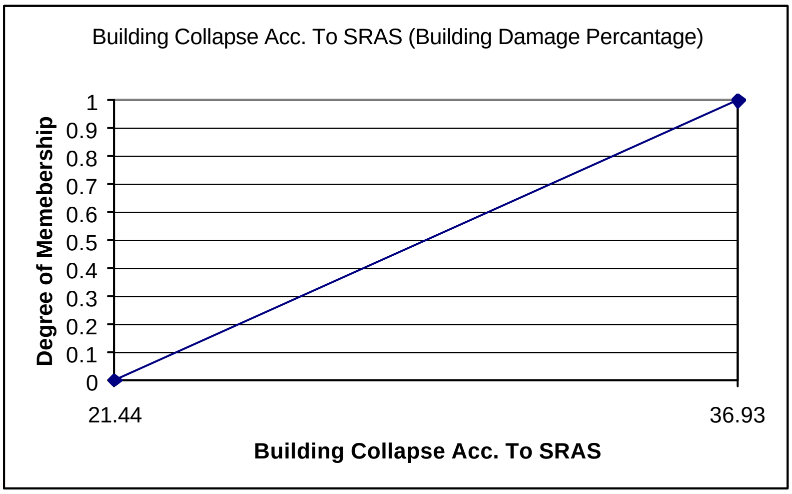

Figure 4. 19 Membership degrees of building collapse percentage

4.4 Estimating Building Collapse

4.4.1 MCE Software

MCE software includes one excel sheet (mcda_pcm_pcv.xls) and one program application (MCE Software). Excel sheet was used for pairwise comparison and also used in calculating relative criteria weight according to physical criteria (Physical Condition of Building, Building Type, Number of Storey, Age of Building).

In this excel sheet, "spatial multicriteria decision analysis-pairwise comparison method" is used to create ratio matrix. At first "intensity of importance" values (Table 4.16) are considered for each criteria and its named as "pairwise comparison matrix".

Table 4. 16 Intensity of importance

CRITERIA	PHYSICAL_COND.	BUILDING_TYPE	NUM_OF_STOREY	AGE
PHYSICAL_COND.	1	3	4	5
BUILDING_TYPE	1/3	1	3	4
NUM_OF_STOREY	¼	1/3	1	2
AGE	1/5	1/4	½	1
TOTAL	1,78	4,58	8,50	12

Second step is about computation of criteria's weights. This step involves some mathematical operations on "pairwise comparison matrix" (Table 4.17).

Table 4. 17 Pairwise comparison matrix

CRITERIA	PHYSICAL_COND.	BUILDING_TYPE	NUM_OF_STOREY	AGE
PHYSICAL_COND.	0,561	0,655	0,471	0,417
BUILDING_TYPE	0,187	0,218	0,353	0,333
NUM_OF_STOREY	0,140	0,073	0,118	0,167
AGE	0,112	0,055	0,059	0,083
TOTAL	1,000	1,000	1,000	1,000

Third step is estimation of the consistency ratio. In this step, the consistency of comparison is determined (Table 4.18).

Table 4. 18 Estimation of the consistency ratio

CRITERIA	PHYSICAL_COND.	BUILDING_TYPE	NUM_OF_STOREY	AGE	TOTAL
PHYSICAL_COND.	0,526	0,819	0,497	0,386	2,227
BUILDING_TYPE	0,175	0,273	0,373	0,309	1,130
NUM_OF_STOREY	0,131	0,082	0,124	0,154	0,492
AGE	0,105	0,068	0,062	0,077	0,313

If the consistency ratio indicates a reasonable level according to “Random Inconsistency Indicies”, the relative criterion weights are determined (Table 4.19).

Table 4. 19 Relative criterion weights

CRITERIA	WEIGHT
PHYSICAL_COND.	0,526
BUILDING_TYPE	0,273
NUM_OF_STOREY	0,124
AGE	0,077
TOTAL	1,000

MCE program application (Figure 4.20) is developed on DELPHI 6.0 platform (codes are given in Appendix A), which is running on Microsoft access database files. Also it has a user interface to calculate vulnerability of each building.

Application uses a special designed database files. That means, there are some tables, which are necessary for this application. Also some formulas and parameters are needed.

Membership degrees of criteria (detail explanation about membership degrees will be given section 4.4) are used as input parameters. Some membership degrees are coming from code tables others are calculated from formulas.

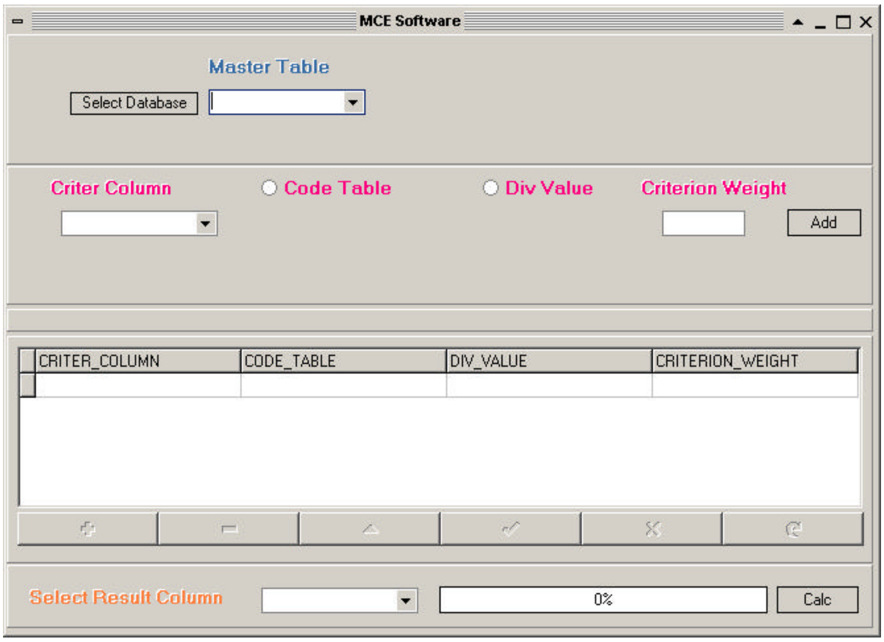

Figure 4. 20 MCE program application

Step-1: To find building vulnerability according to four physical criteria firstly database file(bina.mdb) and *master table* from that database (BUILDING) are selected. After that first *criter column* (phyiscal criteria) is selected. Then *code table* of *criter column* is selected and finally *relative criteria weight* of selected criteria is written in text box. All that input parameters are added computation grid with *add* button. This process is repeated for all criteria (Figure 4.21).

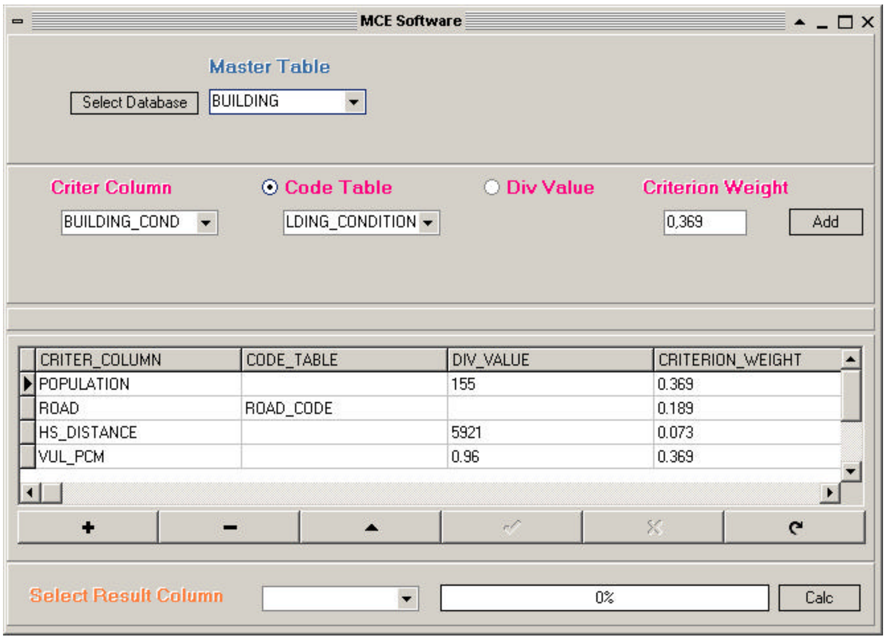

Figure 4. 21 The interface in Step-1 in running the application program

Step-2: Before the calculation, result column (VULF_PCM) is selected. Then vulnerability calculation of buildings is finished with press *Calc* button (Figure 4.22). Also sample results can be seen in Appendix B.

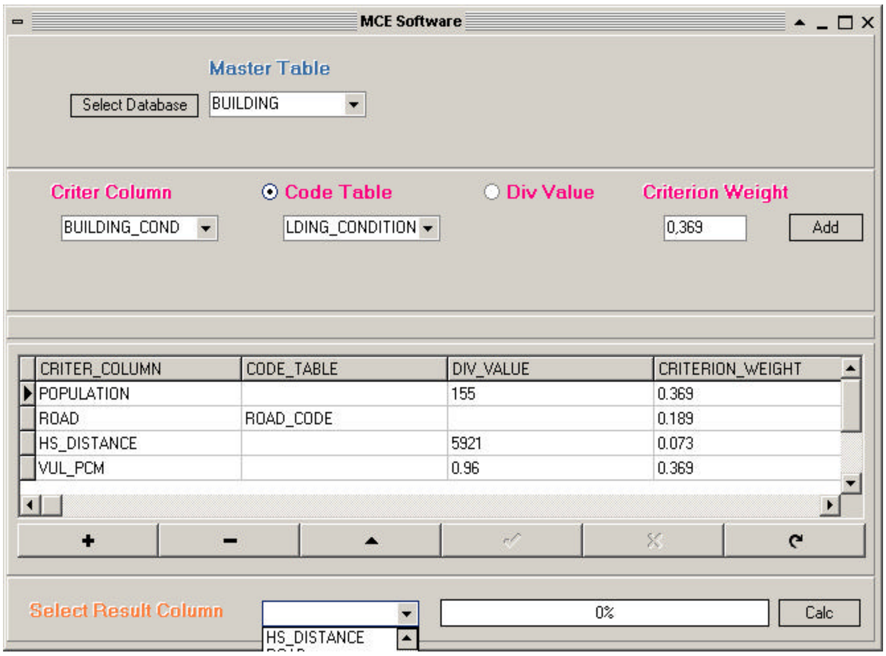

Figure 4. 22 The interface in Step-2 in running the application program

4.4.2 SRAS (Seismic Risk Analysis Software)

Before the usage of SRAS, *soil structure* of each building are determined with voronoi analysis. Because SRAS needs *soil structure* type (site class). Soil structure analysis points, there are 268, are used to create *Voronoi Polygons* (Figure 4.23). Such a processess also needs more detail information. Ideally, like Adapazari, microzonation can be done for more trustable soil structure information. Moreover, soil structure information is necessary for each building. Then *voronoi polygons*'s soil structure type information was aggregated to buildings whose center point coordinates is inside of the polygon. For this operation overlay analysis is used. With this method each building has a soil structure information.

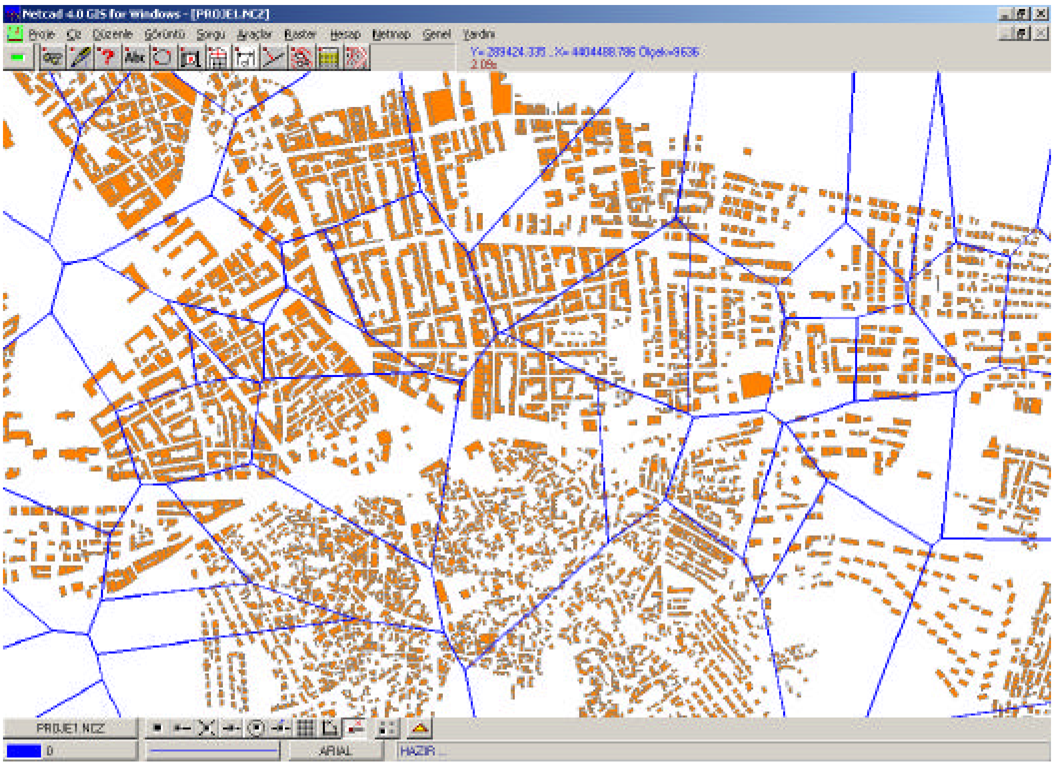

Figure 4. 23 Voronoi polygons derived from soil stucture data

After that operation, other input values are prepared to calculate the physical damage of building. Those input values can be listed as:

-center x, y coordinates of building

-site class (soil structure type)

-number of storeys

-building type

-building condition

Also those values are saved in excel sheet to be used in SRAS application.

After input data preperation, SRAS is used to calculate physical damage of building. Firstly *building inventory file* (excel sheet about building) is selected (Figure 4.24).

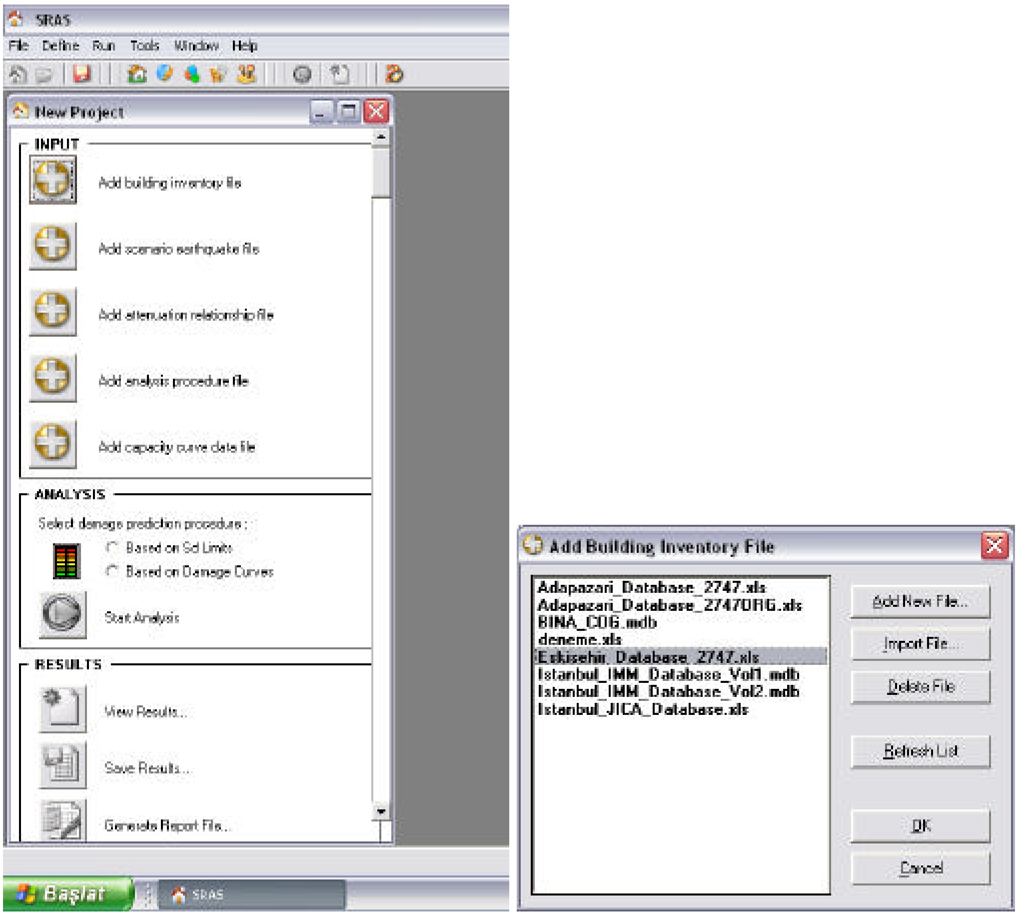

Figure 4. 24 Selection of excel sheet

Secondly, scenario earthquake file is created (Figure 4.25). In that file coordinates of fault verticies and magnitude of earthquake are used as input parameter. This step is run three times. At first time Eskisehir fault is selected as a default fault and 6.4 (maximum magnitude value on Eskisehir fault) is used as magnitude of earthquake. At second time North Anatolia Fault zone is selected as a default fault and 7.4 is selected as magnitude. Also finally, Inönü faut is selected and 5.0 (maximum magnitude value on Inönü fault) is used as magnitude of the earthquake. Because of the nearest two fault zone are Eskisehir fault zone and Inönü fault zone, the biggest magnitude on that zone are accepted as sample earthquake.

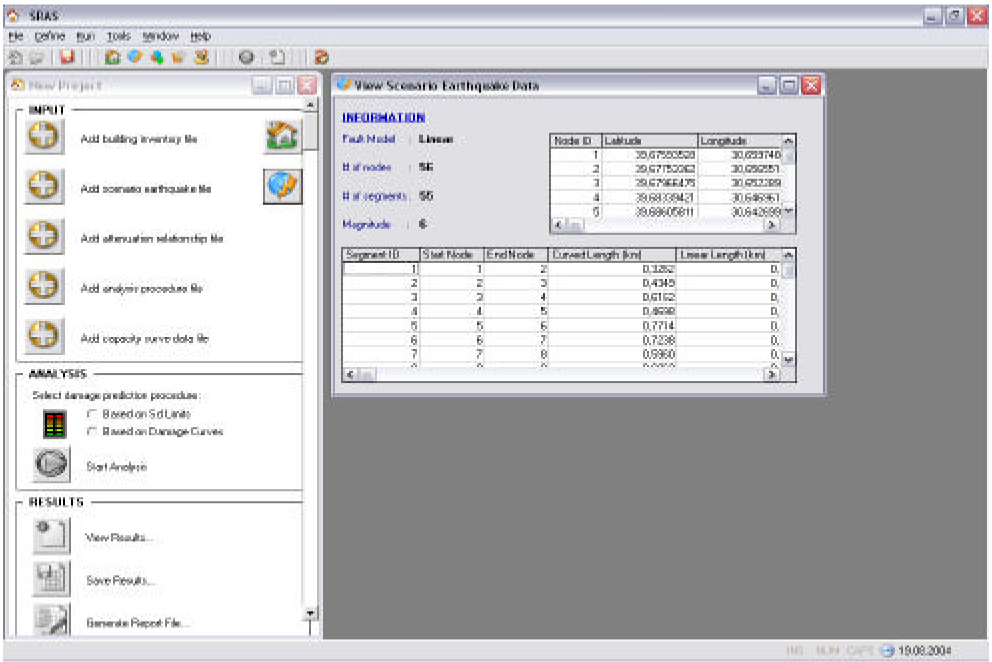

Figure 4. 25 Creating scenario earhquake file

Thirdly, attenuation relationship file is selected (Figure 4.26). Gülkan_TEC.att is selected because site class in database is suitable for that attenuation file.

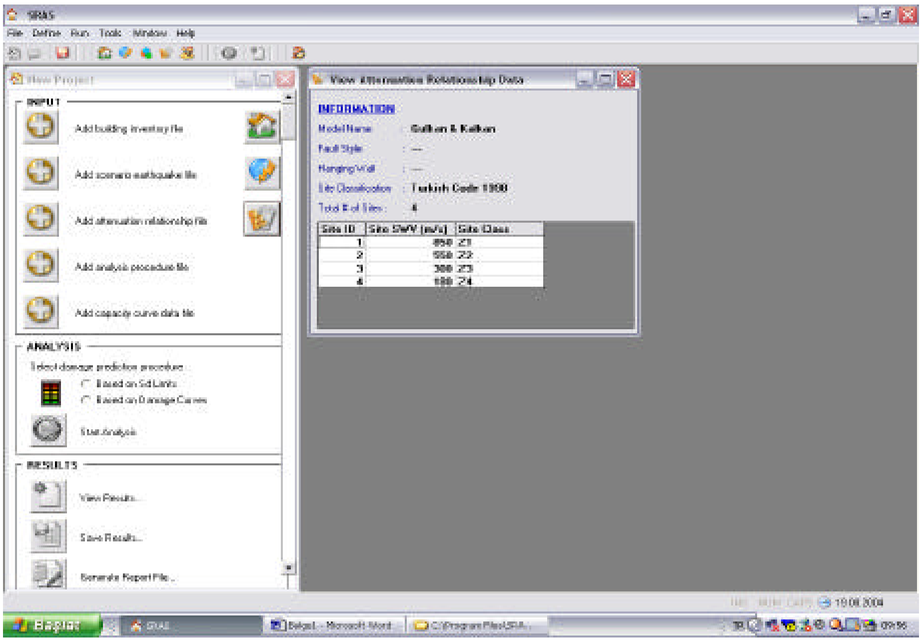

Figure 4. 26 Attenuation file selection

Then, FEMA356.apf is selected as *analysis procedure file* (Figure 4.27). Because SRAS is based on HAZUS SR-99 (produced by FEMA) and also has a similar structure.

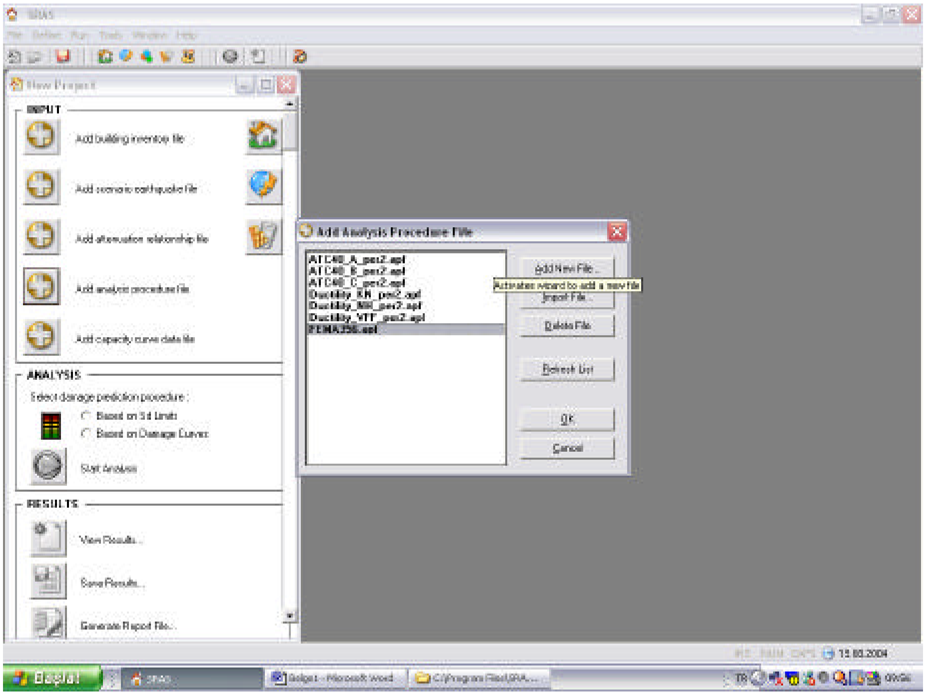

Figure 4. 27 Analysis procedure file selection

Finally, *adapazari_buildings.ccf* is selected (Figure 4.28) as *capacity curve data file* and *damage curves* are defined (Figure 4.29) according to building type.

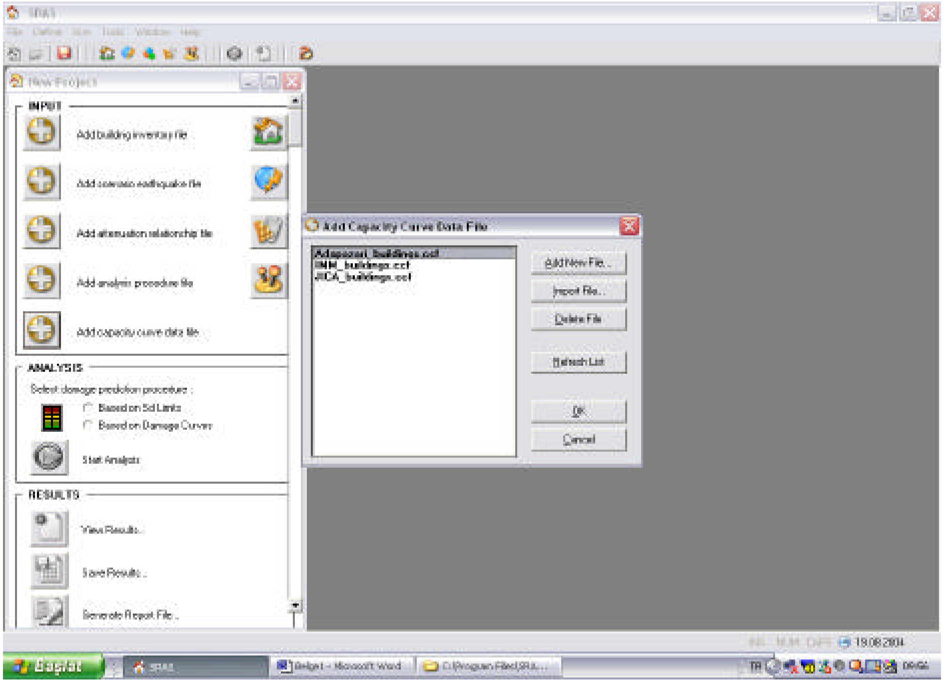

Figure 4. 28 Selection of capacity curve data file

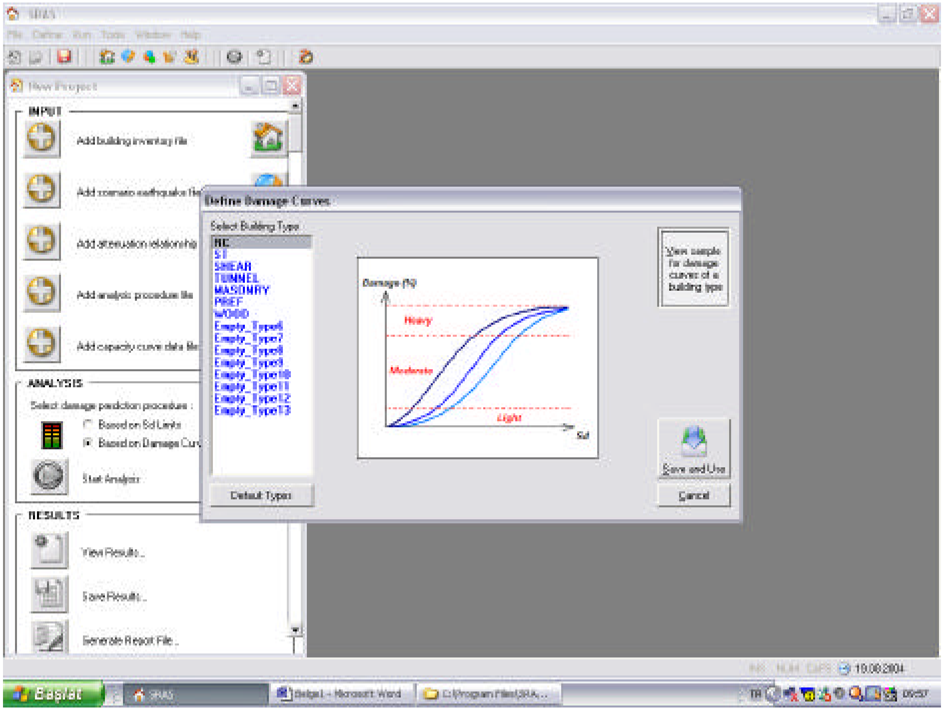

Figure 4. 29 Defining damage curves according to building types.

After all that process SRAS calculates building damage (Figure 4.30).

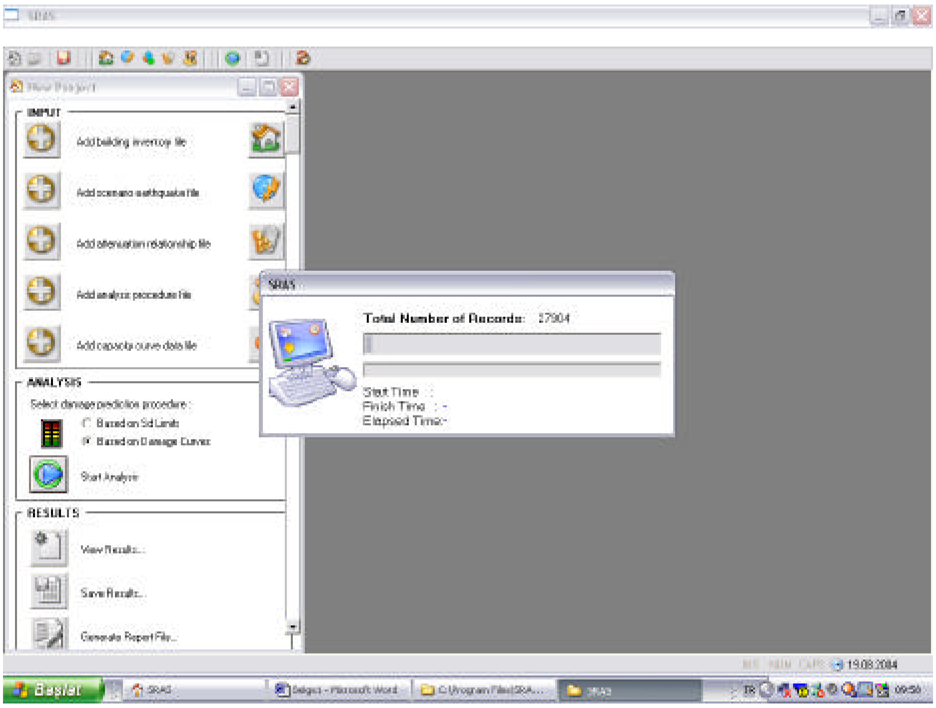

Figure 4. 30 Calculation of building damage

Results are given as damage percentage and sample result-data obtained from SRAS can be seen in Appendix C.

4.5 Pairwise Comparison

Having created standardized map for MCE evaluation criteria, the next task is to apply decision spatial rules based on these criteria to identify areas which has higher and lower vulnerability values. In the first run, it calculates vulnerability according to four criteria. Those are; population who live in building (POPULATION), building collapse vulnerability (BCV) which is calculated in section 4.4.1, nearest health center distance (HS_DISTANCE) and service road of building (SERVICE_ROAD). In the second and third run, BCV criteria changed with results of SRAS's three different earthquake scenario results. Pairwise comparison steps include one excel sheet (mcda_pcm_pcv_sras.xls) and also program application (MCE Software).

In the first step a ratio matrix is created and also the "intensity of importance" values (Table 4.20) are considered for each criteria.

Table 4. 20 Intensity of importance values

CRITERIA	BCV/SRAS	POPULATION	SERVICE ROAD	HS_DISTANCE
BCV/SRAS	1	1	3	4
POPULATION	1	1	3	4
SERVICE ROAD	1/3	1/3	1	5
HS_DISTANCE	¼	1/4	1/5	1
TOTAL	2.58	2.58	7.20	14

Second step is about computation of criterion weights (Table 4.21).

Table 4. 21 computation of criterion weights

CRITERIA	BCV/SRAS	POPULATION	SERVICE ROAD	HS_DISTANCE
BCV/SRAS	0.387	0.387	0.417	0.286
POPULATION	0.387	0.387	0.417	0.286
SERVICE ROAD	0.129	0.129	0.139	0.357
HS_DISTANCE	0.097	0.097	0.028	0.071
TOTAL	1.000	1.000	1.000	1.000

Estimation of the consistency ratio is done in the third step and in this step consistency of comparisons are determined (Table 4.22).

Table 4. 22 Estimation of the consistency ratio

CRITERIA	BCV/SRAS	POPULATION	SERVICE ROAD	HS_DISTANCE	TOTAL
BCV/SRAS	0.369	0.369	0.566	0.293	1.597
POPULATION	0.369	0.369	0.566	0.293	1.597
SERVICE ROAD	0.123	0.082	0.189	0.366	0.760
HS_DISTANCE	0.092	0.092	0.038	0.073	0.295

Consistency ratio indicates a reasonable level according to “Random Inconsistency Indicies”, therefore relative criteria weights can be determined (Table 4.23).

Table 4. 23 Relative criteria weights

CRITERIA	WEIGHT
MAXIMIZE COSTS FOR RECOVER OF BUILDINGS	0.369
MAXIMIZE DEMAND ON SHELTER	0.369
MINIMIZE FUNCTIONALITY OF ROADS	0.189
MINIMIZE ACCESIBILITY OF HOSPITALS	0.073
TOTAL	1.000

All those processes are done three times and the results from three different criteria weights are obtained. Than results are used as input parameter for MCE program application. However, different from chapter 4.3.1, *div values* are used for urban vulnerability evaluation.

Step-1: To find urban vulnerability according to criteria for social risk (population distrubution and building collapse) and criteria for systematic vulnerability (health center distance and accesibility), firstly database file(bina.mdb) and *master table* from that database (BUILDING) are selected. After that first *criter column* (population) is selected. Then *div value* *(maximum building populaiton)* is entered and finally *relative criteria weight* of selected criteria is written in text box. All that input parameters are added computation grid with *add* button. This process is repeated for all criteria. Important point is, if criteria has *code table*, user must select *code table*, if not, user must enter *div value*. Also results of *building collapse* are used as criteria (Figure 4.31).

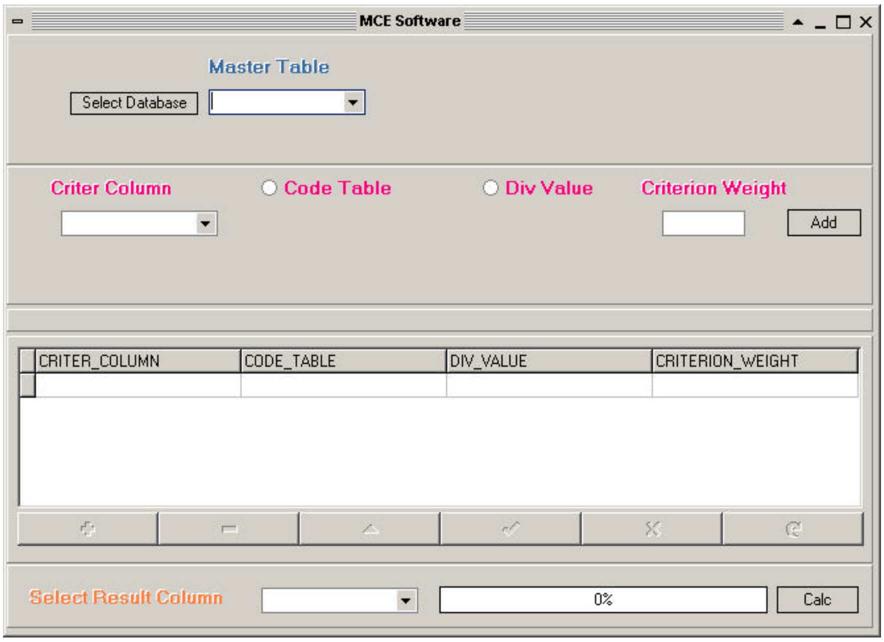

Figure 4. 31 MCE Step-1

Step-2: Before the calculation result column is selected. If user select building collapse vulnerability as a criteria, VULF_PCM column must be selected as result column. If user select a building damage percantage as a criteria VULF_SRAS column must be the result column. Then vulnerability calculation of buildings is finished with pressing *Calc* button (Figure 4.32). Result maps of each scenario are shown in Figure 4.33-4.36

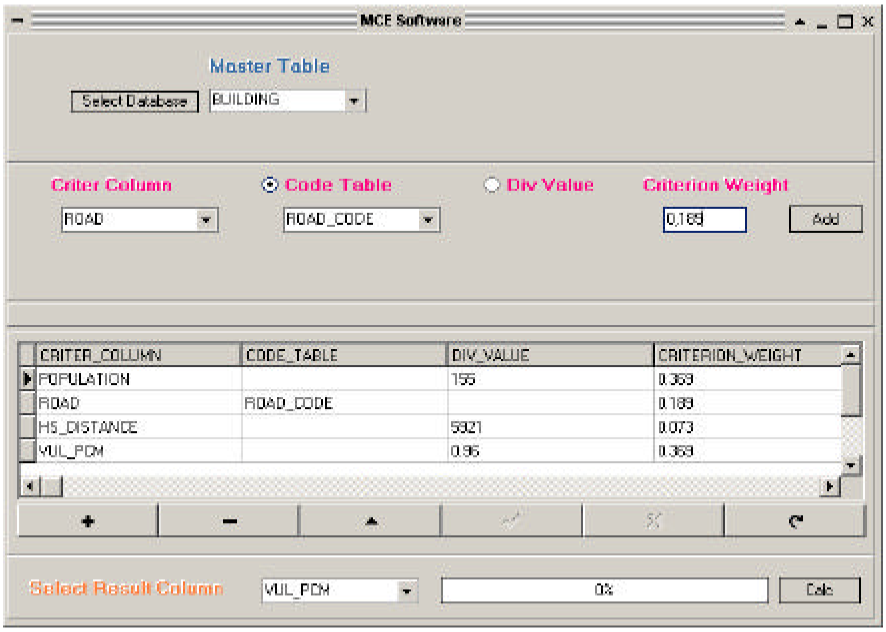

Figure 4. 32 MCE Step-2

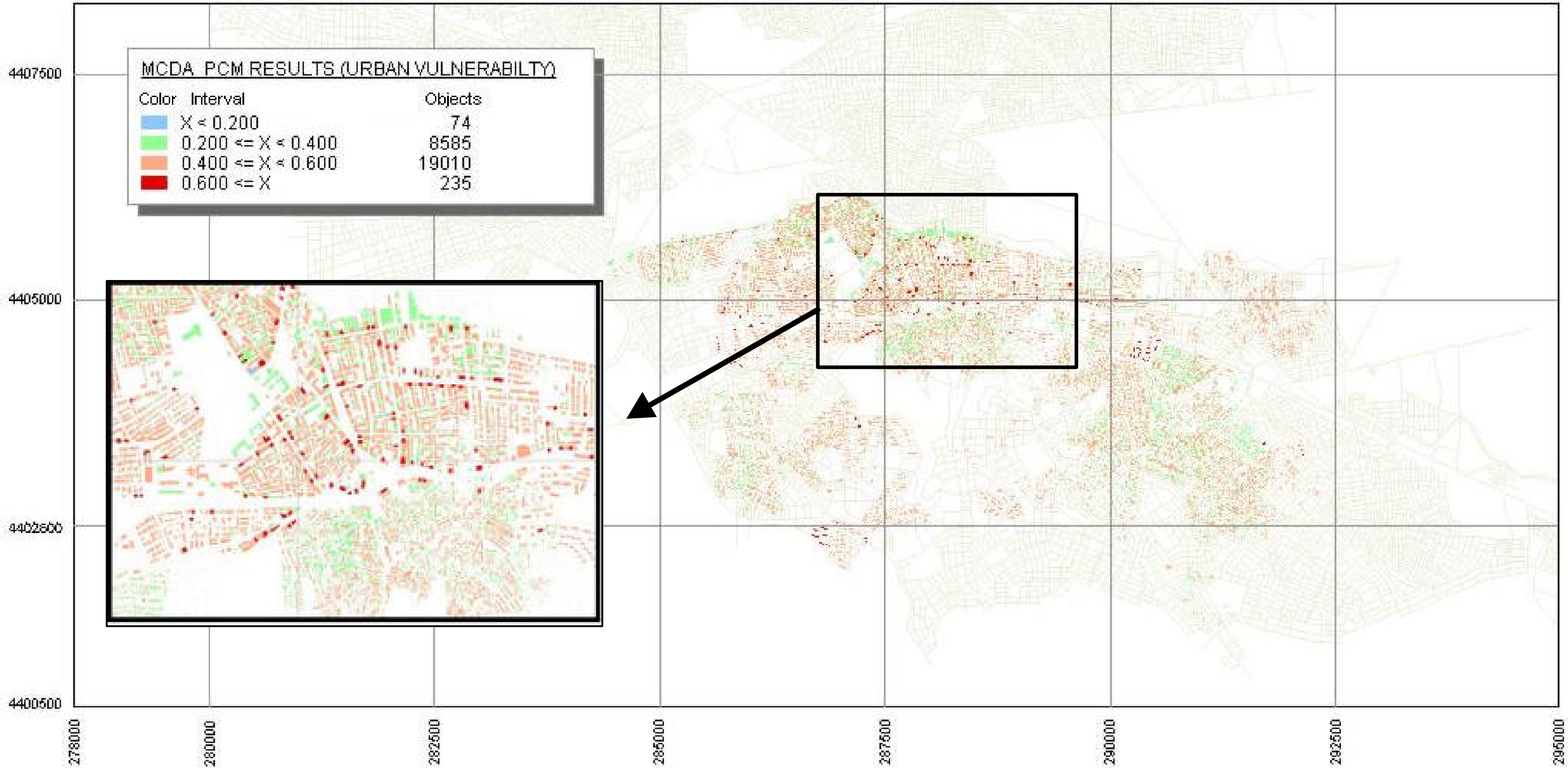

Figure 4. 33 MCE CRITERIAS: Building Collapse, Population, Distance of Nearest Health Center, Accessibility

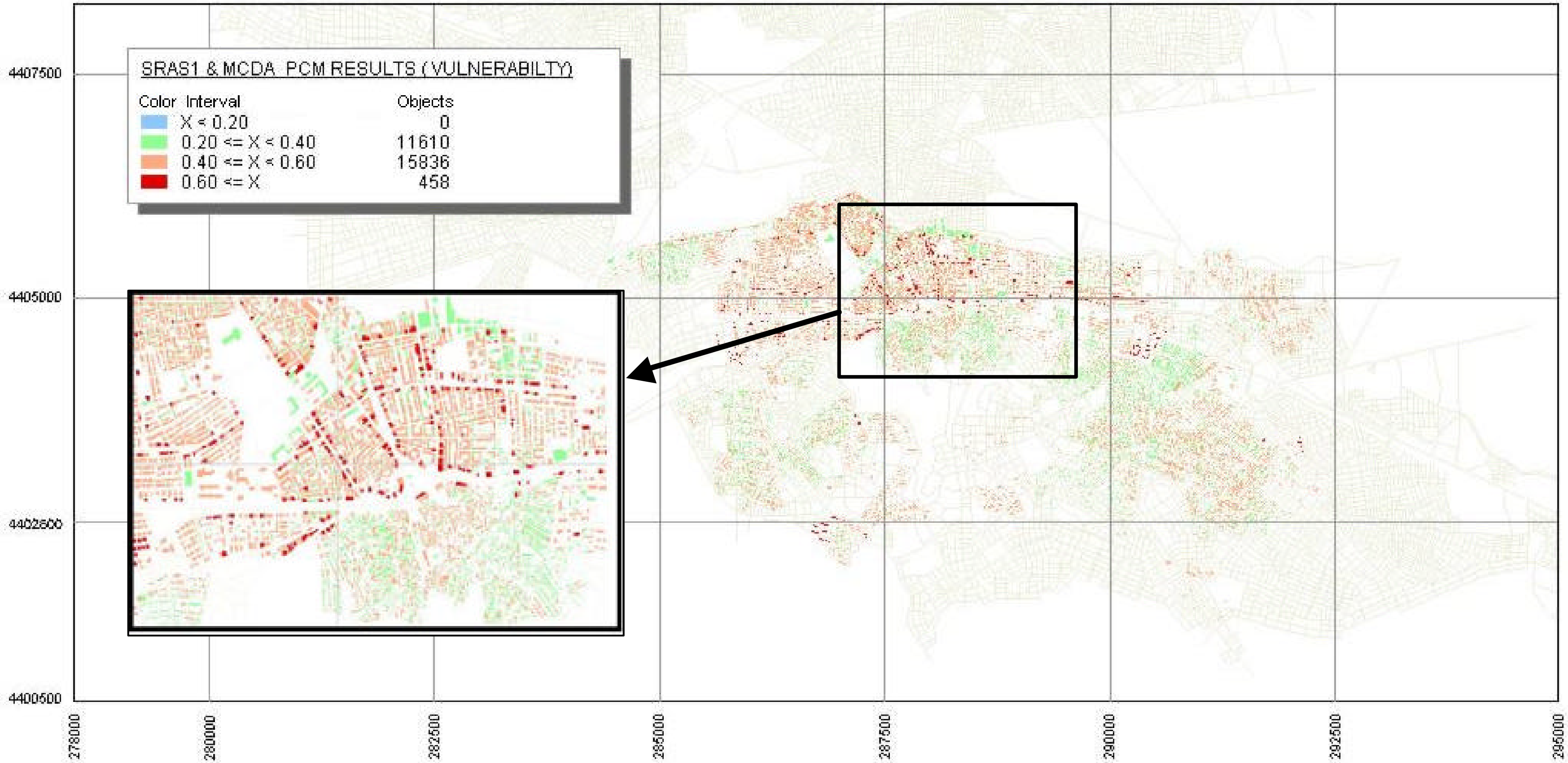

Figure 4. 34 SRAS Scenario1

CRITERIAS: Building Damage, Population, Distance of Nearest Health Center, Accessibility.

Assumed Earthquake: Gölcük, Mag: 7,4, Dept: 40 km, Dist: 140 Km

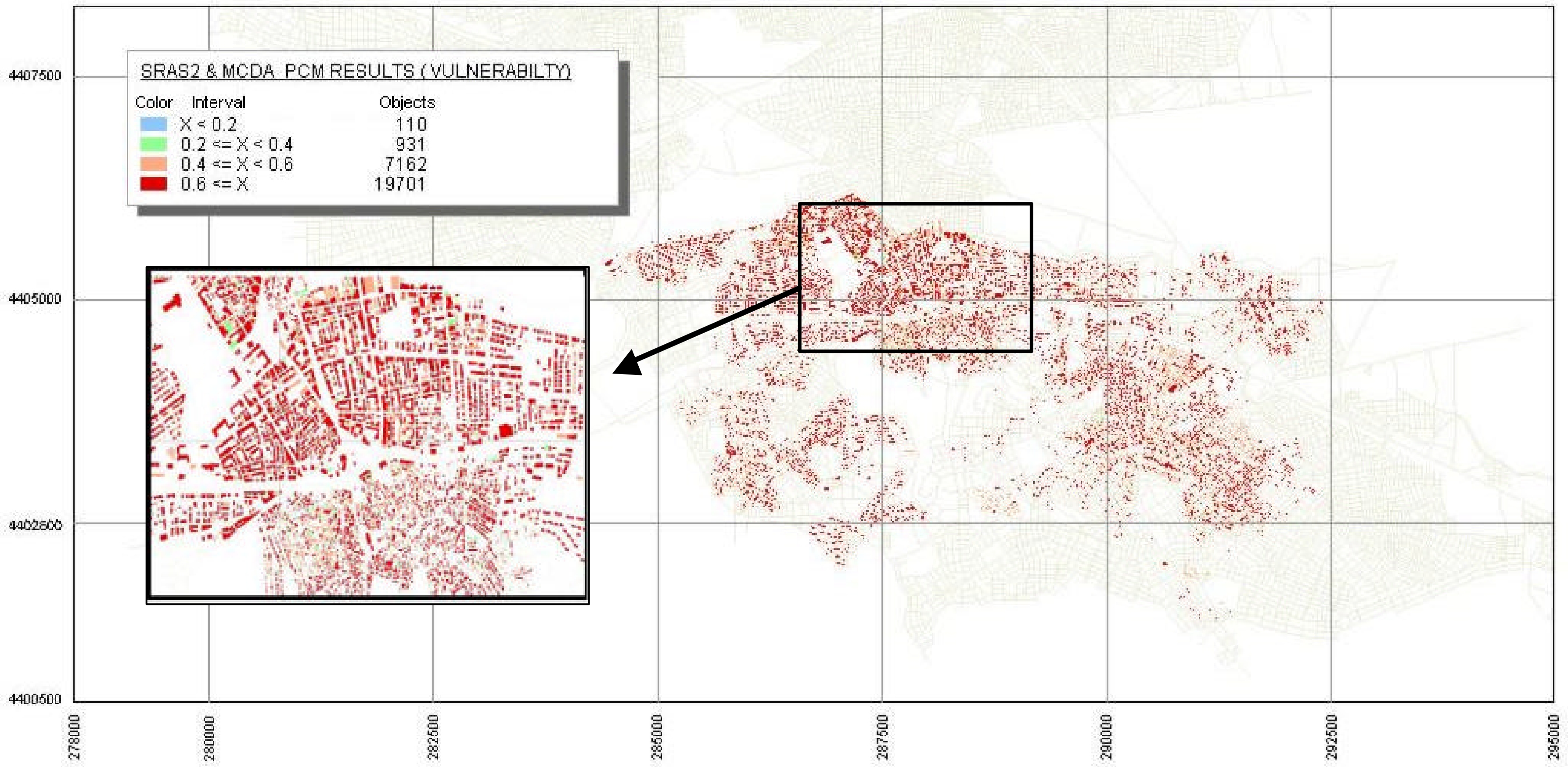

Figure 4. 35 SRAS Scenario2

CRITERIAS: Building Damage, Population, Distance of Nearest Health Center, Accessibility.

Assumed Earthquake: Eskisehir Fault Zone, Mag: 6,4, Dept: 30 km, Dist: 8 Km

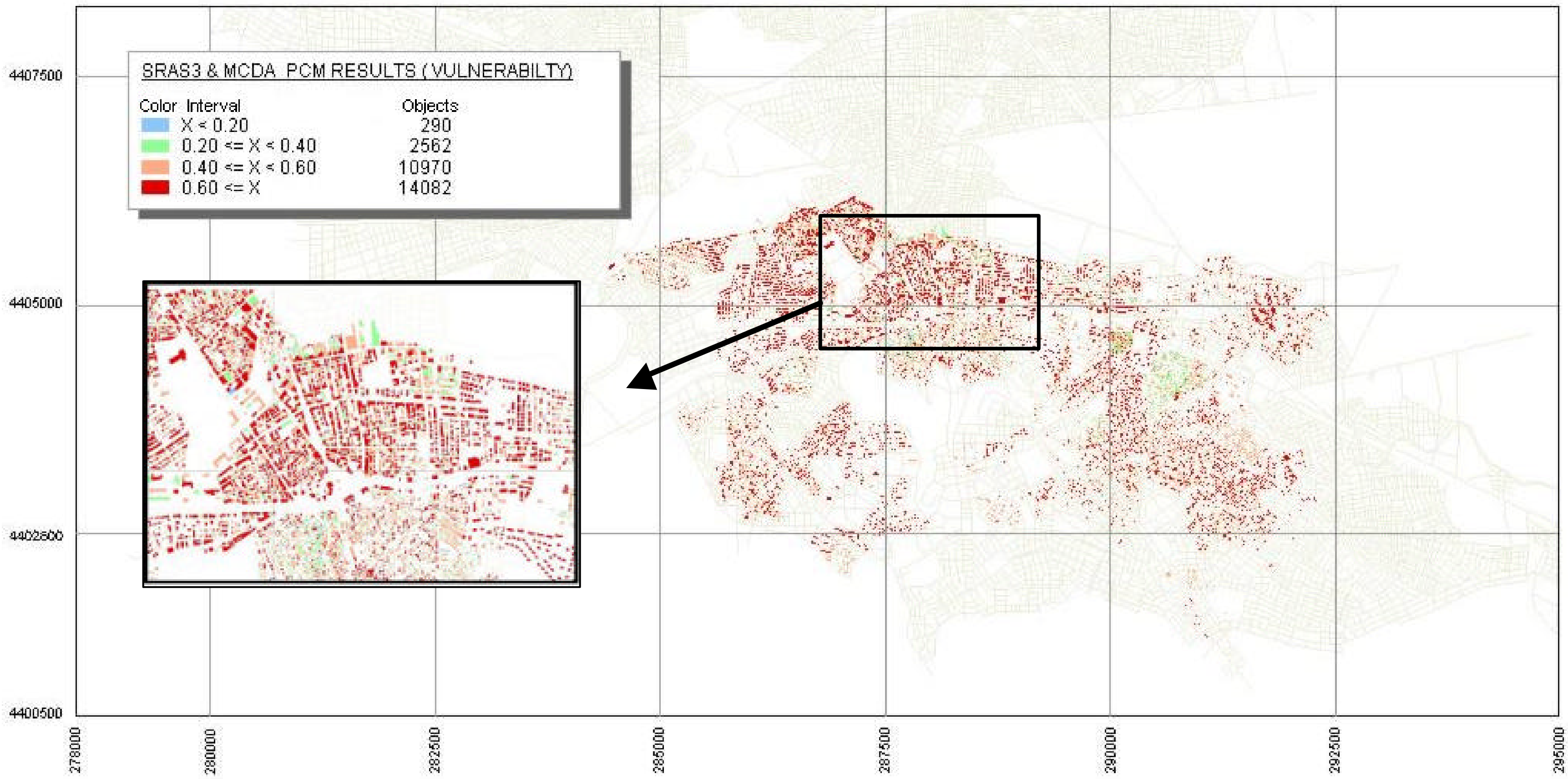

Figure 4. 36 SRAS Scenario 3

CRITERIAS: Building Damage, Population, Distance of Nearest Health Center, Accessibility.

Assumed Earthquake: Inönü Fault Zone, Mag: 5, Dept: 30 km, Dist: 18 Km

4.6 Urban Vulnerability Maps

After creating the indices of higher risk from all the scenarios, the final task is to derive the final set that represents higher vulnerability. In order to locate the hot spots of vulnerability, the accumulating fuzzy evidence (AFE) method suggested by Cox (1999) is used. This method simply formulated as:

(Vul. Value of SRAS1 + Vul. Value of SRAS2 + Vul. Value of SRAS3) x 1000

The result is given in Figure 4.37.

Finally the hot spots of vulnerability at building scale is aggregated to neighbourhood scale (Figure 4.38).

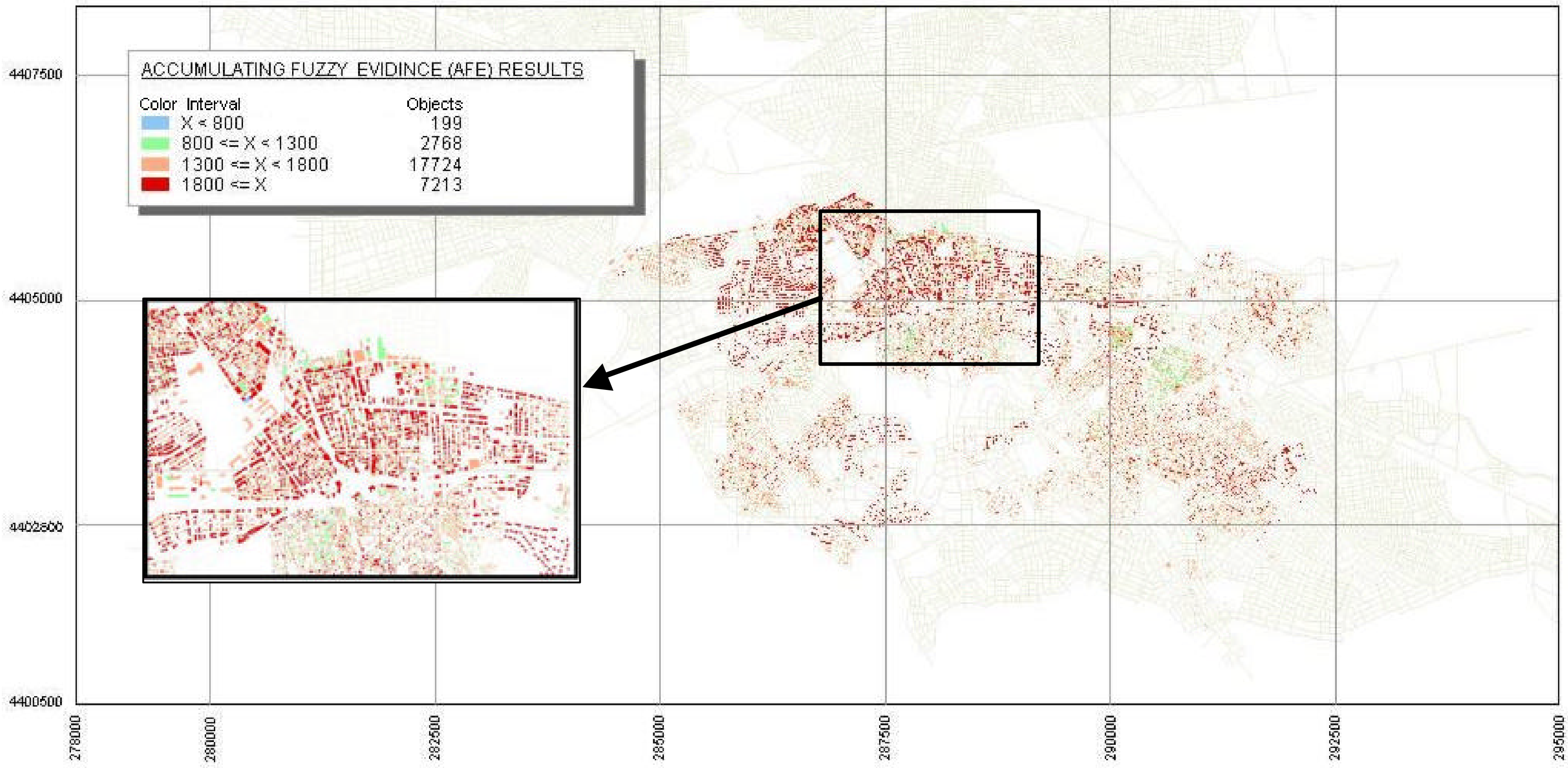

Figure 4. 37 The result of Accumulating Fuzzy Evidence (AFE)

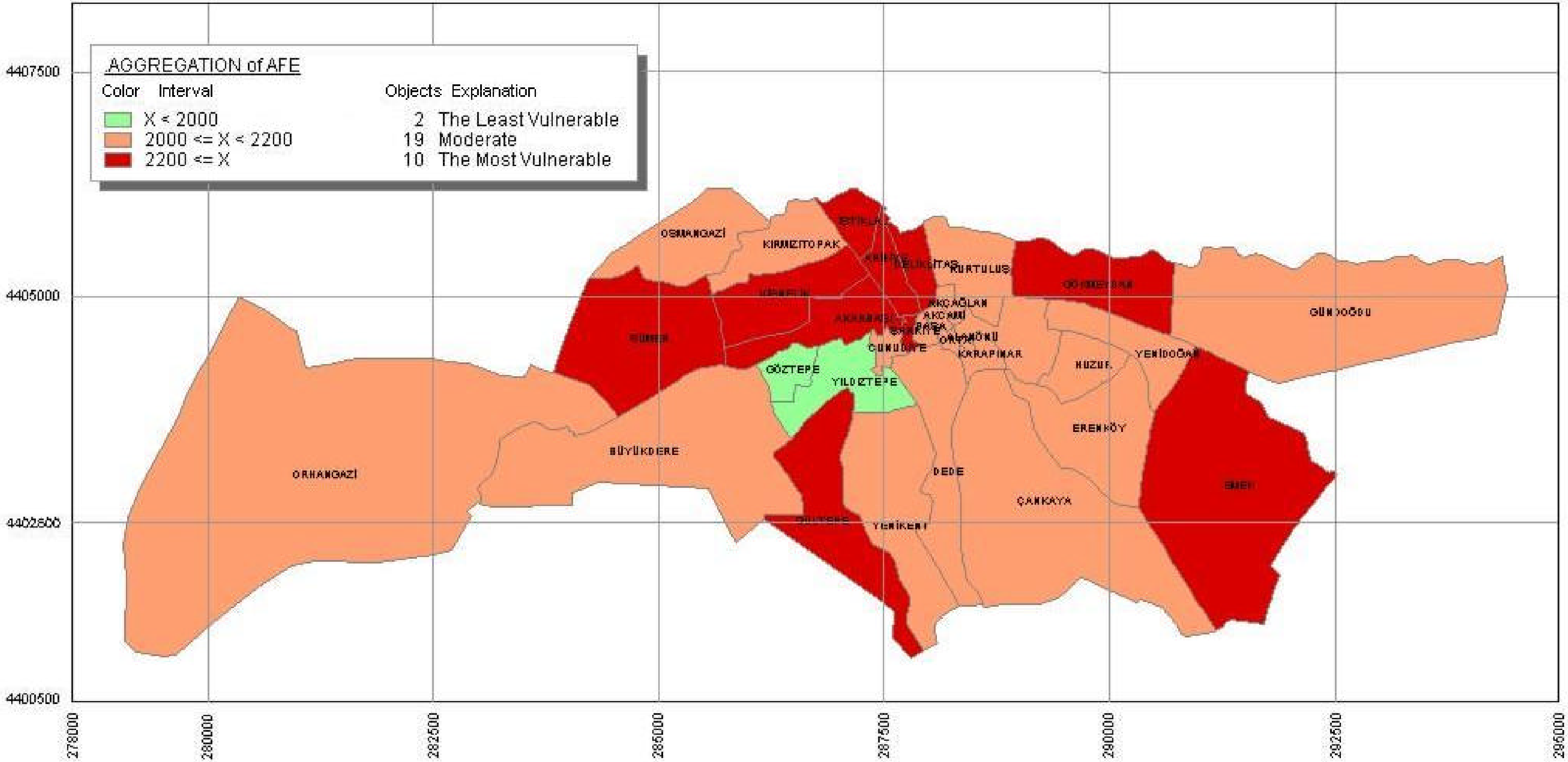

Figure 4. 38 The result of aggregation of AFE into neighbourhood scale

5.DISCUSSIONS and CONCLUSIONS

5.1 Discussion

In the case study, three different earthquake scenarios (tested with SRAS) and expert knowledge based vulnerability analysis results were processed. These processes also gave different urban vulnerability values for buildings. After creating the indices of higher-risk from all the scenarios, in order to locate the hot spots of vulnerability accumulating fuzzy evidence (AFE) method was used. Since AFE method is more risk-taking, it is suitable in such decisions as establishing mititgation strategies and emergency plans, where worst case scenarios should be taken into account.

In the first scenario, Gölcük earthquake (about 140 km from Eskisehir) was accepted as sample earthquake. Its magnitude was 7.4 and depth was 18 km. SRAS was used to calculate building damage and results were used as criteria to find urban vulnerability. As a result of that, there are no buildings in the first interval (0-0,199), and there were 11610 buildings in the second interval (0,2-0,399) also the most of the buildings are in the third interval (0,4-0,599) and finally there are also some buildings (458) in the fourth interval (0,6-1). That means the most of the buildings (Table 5.1) are not so much vulnerable and Eskisehir-Odunpazari can be named as safe-city against earthquake like Gölcük.

Table 5. 1 SRAS Scenario1 Results-Buildings

Vulnerability Interval	Number of Building	Percentage
0-0.199	0	0.00
0.2-0.399	11610	41.61
0.4-0.599	15836	56.75
0.6-0.849	458	1.64

In the second scenario, earthquake, which had the biggest magnitude on Eskisehir fault zone (about 8 km from Eskisehir), was accepted as sample earthquake. Its magnitude was 6.4 and depth was 40 km. Also, SRAS was used to calculate building damage and results were used as criteria to find urban vulnerability. Results indicated that, there are only 110 buildings in the first interval (0-0,199), and there are 936 buildings in the second interval (0,2-0,399) also there are more buildings (7162) in the third interval (0,4-0,599) and finally the most of the buildings (19701) are in the fourth interval (0,6-1). That means the most of the buildings (Table 5.2) are vulnerable and Eskisehir-Odunpazari has vulnerable situation against earthquake in Eskisehir fault zone.

Table 5. 2SRAS Scenario2 Results-Buildings

Vulnerability Interval	Number of Building	Percentage
0.076-0.199	110	0.39
0.2-0.399	931	3.34
0.4-0.599	7162	25.67
0.6-0.959	19701	70.6

In the third scenario, earthquake, which had the biggest magnitude on Inönü fault zone (about 18 km from Eskisehir), was accepted as sample earthquake. Its magnitude was 5 and depth was 30 km. SRAS was used to calculate building damage and results are used as criteria to find urban vulnerability. Results indicated that, there are only 290 buildings in the first interval (0-0,199), and there are 2536 buildings in the second interval (0,2-

0,399) also there are more buildings (10970) in the third interval (0,4-0,599) and finally the most of the buildings (14082) are in the fourth interval (0,6-1). Similarly the second scenario, the most of the buildings (Table 5.3) are vulnerable and also Eskisehir-Odunpazari has vulnerable situation against earthquake in Inönü fault zone.

Table 5. 3 SRAS Scenario3 Results-Buildings

Vulnerability Interval	Number of Building	Percentage
0.088-0.199	290	1.04
0.2-0.399	2562	9.18
0.4-0.599	10970	39.31
0.6-0.862	14082	50.47

In the fourth vulnerability evaluation, physical criteria of the buildings were assumed to be effective in estimating the vulnerability of buildings. According to this scenario, firstly, building collapse vulnerability was evaluated and than it was taken as criteria for urban vulnerability evaluation.

It is seen that, there are only 79 buildings in the first interval (0-0,199), and there are more buildings (8595) in the second interval (0,2-0,399) also the most of the buildings (19010) are in the third interval (0,4-0,599) and finally some of the buildings (235) are in the fourth interval (0,6-1). The first SRAS scenario gave similar results, the most of the buildings (Table 5.4) were obtained as less or moderate vulnerable. It can be said that, earthquake location and magnitude are too much effective on estimating the urban vulnerability and also Odunpazari structural condition of the buildings is not ready for a serious earthquake, which may happen near Eskisehir.

Table 5. 4 Building Collapse Results (expert knowledge) - Buildings

Vulnerability Interval	Number of Building	Percentage
0.129-0.199	74	0.27
0.2-0.399	8585	30.77
0.4-0.599	19010	68.13
0.6-0.785	235	0.84

The spatial distribution of vulnerability scores resulted from AFE methods indicate that, there are only 199 buildings in the first interval (297-799), and there are more buildings (2768) in the second interval (800-1299) also the most of the buildings (17724) are in the third interval (1300-1799) and finally some of the buildings (7213) are in the fourth interval (1800-2320). The higher vulnerability result based on AFE shows, that the most of the buildings in Eskisehir (Table 5.5) are vulnerable to earthquake hazard, according to proposed methodology.

Table 5. 5 Accumulating Fuzzy Evidence (AFE)- Buildings

Vulnerability Interval	Number of Building	Percentage
297-799	199	0.71
800-1299	2768	9.92
1300-1799	17724	63.52
1800-2320	7213	25.85

The results were aggregated from building to neighbourhood scale and it was seen that (Table 5.6), there are 2 neighborhoods in the least vulnerable interval, also 19 neighborhoods have moderate vulnerability scores and 8 neighborhoods are in the most vulnerable interval.

Table 5. 6 The vulnerability scores based on AFE method

Vulnerability Interval	Number of Neighbourhood	Percentage
1850-1999	2	6.45
2000-2199	19	61.29
2200-2320	10	32.26

After the aggregation, there were two neighborhoods, which have the lowest vulnerability values. The reason for that is less number of buildings and people are living in these neighborhoods. However, there are ten neighborhoods, which have high vulnerability scores. Some of these neighborhoods include high buildings or they are located far from health services, also their accessibility can be considered as poor because of narrow roads. Therefore those neighborhoods have priority to reduce vulnerability and also mitigation process.

The term "**mitigation**" describes actions which can help reduce or eliminate your long-term risk from natural disasters. With mitigation, you can avoid losses and reduce your risk of becoming a disaster victim. There are many low-cost mitigation measures you can take to protect yourself, your home, or your business from losses. Natural hazard issues are usually given low priority on local government agendas. Low priority, however, is not necessarily due to a lack of awareness (Berke, 1998).

Frame of case study's results, local authority should take some precaution to reduce urban vulnerability. Despite, there are four main criteria, some other urban database element can be used in the proposed methodology. Fire sensitivity of buildings, infrastructure information, bridges, information about debris flow and capacity of health center can be criterias related to urban vulnerability. For example, dormitories in those ten neighborhoods (39% of dormitories in Eskisehir) should be used as shelter after earthquake scenario.

In disaster cases transportation facilities and their liability and sustainability has a crucial importance. As almost every type of crisis services necessitates transportation facilities, we need to give special importance to transportation sustainability. In this context, vulnerability assessment of transportation facilities has the potential to be a base for transport crisis risk mitigation. If the local government has a knowledge on the weak parts of the cities' and the region's transport risks, the authority can put mitigative countermeasures beforehand, which the decrease of potential losses.

Conditions of the factors considered to be effective in assessing the urban vulnerability must be improved by local authority. For example, cul-de-sac type roads should be modified as a normal street and also narrow streets should be modified as main road. Furthermore, physical condition of buildings should be improved.

Respectively, health facilities (42% of all health facilities in Eskisehir are in those ten neighborhoods) have a considerable importance in crisis cases. As in transportation case, the local government has the potential to be ready for a situation when access to urgent health services is impossible. Possible inter-municipal vulnerability analyses may lead to crisis partnerships, which can formulate a health-secure crisis prone region.

In this study, analysis was done in building scale and neighbourhood scale. However, it seems that, medium scale mapping between building and neighbourhood is necessary. Because, in some situation, buildings may have low vulnerability scores but only one building may have very high vulnerability score. After the aggregation to neighbourhood scale, that one building causes neighbourhood vulnerability scores is shown in highest vulnerability interval.

5.2 Conclusion

Turkey experienced a fast population growth at urban settlements during the last four decades as a result of internal social dynamics, which was accompanied by heavy construction activity in urbanized neighborhoods.

Importance of vulnerability assessment with regards to this analysis significant effect on the success of pre-disaster mitigation activities. Any city having the vulnerability distribution data has the ability and the potential to enact loss decreasing countermeasures.

An appreciation of contingency-related possibilities is one of a political actor's important skills. For administrative and organizational actors alike, however, contingency stemming from adverse or complex situations has not yet been fully recognized as a critical element in decision-making strategy.

The secret of a good mitigation program is the planning process that developed it. It is not the resulting paper document, but rather the process of planning that is important. Because each community is different, each hazard mitigation plan will be different. However, the process followed should be similar.

Vulnerability analysis can be described as a part of mitigation process. Also GIS technologies offer many methods to do vulnerability analysis. With the help of this technology, local authorities have a chance to try different scenarios about earthquake. Therefore local authorites acquire flexible situation against earthquake occurence and they produce more realistic mitigation plans to reduce risk. Also vulnerability analysis enables proper city planning. Urban planners can use results of vulnerability analysis to design safe city against earthquake disaster. Also optimum resource management can be achieved by the help of vulnerability assesessement's results.

Spatial analythical approach can be incorparated into a GIS in order to provide measures of urban vulnerability. A successful replication of this methodology depends on the existence of variety of spatial and aspatial data that can be utilized in a damage simulation tool. Therefore the accessibility of loss estimation methods by non-earthquake experts such as emergency planers and urban planners represents a major achievement in providing a powerful tool for risk assessement and mitigation to practitioners in the disaster management fields. These tools must be developed covering the damage assessement fire and debris flow following an earthquake.

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APPENDICIES

A. Software Codes

Nearest Health Service Script, Service Road Script and Multicriteria Evaluation (MCE) Software Codes

I-Nearest Health Service Script Codes

```
sub Main
 dim BD,conn,RS,SQL, RS2, SQL2, YOL, RS3, SQL1,i,cnt, sttime,endtime, maxHast, SQLYAPIYOL,Yapi_yol_cnt
 dim ary(40,5)
 dim numS
 dim ind(5)
 sttime=time()
 set conn=createobject("adodb.connection")
 Conn.Open "Provider=Microsoft.Jet.OLEDB.4.0;Data Source=D:\mehmet\TEZ\bina.mdb;Persist Security Info=False"
 SQL2="Select * from SAGLIK"
 SQL="Select * from YAPI"
 set BD=netcad.NewBDialog("Tablo Islemleri")
```

```
  BD.GetRadio "ITEM1", "YAPI_YOL Tablosu Bosaltilsin mi?", "Evet|Hayir",1
  if BD.Showmodal then
    if BD.ValueByName("ITEM1")=0 then
      SQLYAPIYOL="Delete From YAPI_YOL"
      set rs=conn.execute(SQLYAPIYOL)
      Yapi_yol_cnt=0
    else
      SQLYAPIYOL="Select * From YAPI_YOL"
      set rs=conn.execute(SQLYAPIYOL)
      Yapi_yol_cnt=0
      DO WHILE NOT RS.EOF
       Yapi_yol_cnt=Yapi_yol_cnt+1
       Rs.movenext
      loop
    End if
    Set BD=nothing
  else exit sub
  End if
SET RS=conn.execute(SQL)
SET RS2=conn.execute(SQL2)
maxHast=3
numS=0
cnt=0
DO WHILE NOT RS2.EOF     'tüm hastaneleri tara ve ary listesine merkez koordinatlarini ve id'lerini al
  ary(numS,0)=RS2("MERKEZY")
  ary(numS,1)=RS2("MERKEZX")
  ary(numS,2)=RS2("HASTANE_ID")
  ary(numS,3)=0  'kusuçusu
  ary(numS,4)=0 'Kisayol
  RS2.MOVENEXT
  numS=numS+1
```

```
 LOOP
 RS.move Yapi_yol_cnt
 DO WHILE NOT RS.EOF   'her bir bina için en yakin hastaneyi bulmak için bina kayitlarini bastan sona tara
    sort RS("MERKEZY"),RS("MERKEZX"), nums,ary,3  'aktif kayittaki binanin tüm hastanelere kus uçusu mesafesine göre hastaneleri siraya sok
    cnt=0
    for i=0 to nums-1  'tüm hastanelere olan sirali kayitlarda gez
        ary(i,4)=hesap(RS("MERKEZY"),RS("MERKEZX"),ary(i,0),ary(i,1))
        if ary(i,4)>0 then  '0'dan farkli bulunan ilk üç kisayolu ind array'ine al
          ind(cnt)=i
          cnt=cnt+1
        end if
        if cnt=maxHast then exit for
    next
    if cnt>0 then      'bu binadan en az bir hastaneye kisayol var ise YAPI_YOL tablosuna yaz
       sortind ind,ary,cnt  'bulunan üç kisayol arasinda enkisasini bul
         SQL1= "INSERT INTO YAPI_YOL (BINAID, HASTANE_ID, MESAFE) VALUES ('"& RS("BINAID") &"','"& ary(ind(0),2) &"',"& ary(ind(0),4) &")"
       SET RS3=conn.execute(SQL1)
    else
       SQL1= "INSERT INTO YAPI_YOL (BINAID, HASTANE_ID, MESAFE) VALUES ('"& RS("BINAID") &"','Yok',"& ary(ind(0),4) &")"
      SET RS3=conn.execute(SQL1)
    end if
    exit do
    RS.MOVENEXT
 LOOP
 endTime=time()
 msgbox (sttime&"-"&endtime )
end sub
function Hesap(C1Y, C1X, C2Y, C2X)
```

```
 dim Sbs
 dim cn, P, i, o, snapc
 dim CY, CX, s
 dim MARKNO
 hesap=0
  set Sbs = createobject("SbsMod.SbsCOM")
  Sbs.StartKisaYolBul      ' Kisayol bulma islemlerini baslat
  with Netcad
     set P = .NewPoly         ' Sonucu tutmak icin poly objesi yarat
         ' Simdi Kisayol buldur
         if Sbs.KisayolBul(C1Y, C1X, C2Y, C2X) then
           ' sonuclar Sbs objesinde duruyor.
           ' once sonuc Cokludogrunun noktalari alalim
           P.Clear
           for i = 0 to Sbs.PolyNum-1  ' sonuc yol noktasi sayisi
             CY = Sbs.GetPolyCY(i)
             CX = Sbs.GetPolyCX(i)
             set cn = .newc(CY,CX,0)
             P.AddCoor(cn)                ' P ye ekle
           next
          ' simdi sonuc P yi Cokludogru olarak Projeye ekle
           'set o= .MakePline("KISAYOL", 0, 0, 0, 0, 0, P)  ' 0. tabakaya ekle
           Hesap= P.perim(false,false)
      end if               ' of bitis sec
  set P = nothing
  end with
  Sbs.StopKisaYolBul       ' Kisayol bulma islemlerini bitir
  set Sbs = nothing
end function
sub sort(Y,X, numS,ary,sk)
Dim i,j,t1,t2,t3,t4,t5
for i=0 to numS-1
    ary(i,3)=sqr((Y-ary(i,0))^2+(X-ary(i,1))^2)
```

```
next
For  i=0 to numS-2
    For j=0 to numS-2
        if ary(j,sk)>ary(j+1,sk) then
         t1=ary(j,0)
         t2=ary(j,1)
         t3=ary(j,2)
         t4=ary(j,3)
         t5=ary(j,4)
         ary(j,0)=ary(j+1,0)
         ary(j,1)=ary(j+1,1)
         ary(j,2)=ary(j+1,2)
         ary(j,3)=ary(j+1,3)
         ary(j,4)=ary(j+1,4)
         ary(j+1,0)=t1
         ary(j+1,1)=t2
         ary(j+1,2)=t3
         ary(j+1,3)=t4
         ary(j+1,4)=t5
        end if
    Next
Next
End sub
sub sortind(ind,ary,cnt)
Dim i,j,t1
For  i=0 to cnt-2
    For j=0 to cnt-2
        if ary(ind(j),4)>ary(ind(j+1),4) then
         t1=ind(j)
```

```
  ind(j)=ind(j+1)
       ind(j+1)=t1
      end if
   Next
Next
End sub
```

II-Service Road Script

```
sub Main
 dim conn,RS,RS2,SQL, SQL1,sttime,endtime,k
 dim ary(40,5)
 dim ind(500,2)
 dim i,w,p,o,oc,j,c,u,t,d,bi,mint,icnt
 with netcad
 sttime=time()
 set conn=createobject("adodb.connection")
 Conn.Open "Provider=Microsoft.Jet.OLEDB.4.0;Data Source=D:\mehmet\TEZ\bina.mdb;Persist Security Info=False"
 SQL="Select * from YAPI"
 SET RS=conn.execute(SQL)
 DO WHILE NOT RS.EOF
   k=1
   set c=.Newc(RS("MERKEZY"), RS("MERKEZX"),0)
   set oc=.NewCollection
   set o=.NewObject
   set p=.NewPoly
   do while oc.NE=0
     getroad RS("CLLY"),RS("CLLX"),RS("CURY"),RS("CURX"),k,oc
     k=k*2
     if k=64 then exit do
   loop
   icnt=0
   for i=0 to oc.NE-1 'her bir yol için dik mesafe
     oc.GetObject i, o, p
     bi=-1
     mint=0
     for j=0 to p.num-2 'yolun segmentleri içinde en yakin olani
        u=ncmath.INV_Side_Length(c, p.cor(j), p.cor(j+1))
        d=ncmath.Distance(p.cor(j), p.cor(j+1), false)
        if ((u>0) and (u<d)) then
```

```
          t=ncmath.INV_Side_Tail(c, p.cor(j), p.cor(j+1))
          if t<0 then t=-t
          if ((bi=-1) or (t<mint)) then
            bi=j
            mint=t
          end if
        end if
      next
      if bi>-1 then
        ind(icnt,0)=mint 'uzunlugunu al
        ind(icnt,1)=o.objname 'vtkodunu al
        icnt=icnt+1
      end if
    next
    if icnt>0 then
      sort icnt,ind
      SQL1= "INSERT INTO YOL_BINA (BINA_ID, YOL_ID) VALUES ('"& RS("BINAID") &"','"& ind(0,1) &"')"
      SET RS2=conn.execute(SQL1)
    else
      SQL1= "INSERT INTO YOL_BINA (BINA_ID, YOL_ID) VALUES ('"& RS("BINAID") &"','Yok')"
      SET RS2=conn.execute(SQL1)
    end if
    RS.MOVENEXT
    set c=nothing
    set oc=nothing
    set o=nothing
    set p=nothing
  LOOP
  endTime=time()
  msgbox (sttime&"-"&endtime )
  end with
```

```
end sub
sub getroad(ly,lx,ry,rx,k,oc)
dim ww,oo,cc,ii,p
  with netcad
    set oo=.Newobject
    set ww=.newworld(ly,lx,ry,rx)
    ww.expand (ry-ly)*k,(rx-lx)*k
    .SetFilter ww, array(),array()
      while .GetNextObject2(oo)
          set p = .getplineext(oo)
          oc.AddObject oo, -1, p
      wend
    .resetfilter
  end with
    set oo=nothing
    set ww=nothing
end sub
'SORT KOD
sub sort(numS,ary)
Dim i,j,t1,t2
For  i=0 to numS-2
     For j=0 to numS-2
         if ary(j,0)>ary(j+1,0) then
          t1=ary(j,0)
          t2=ary(j,1)
          ary(j,0)=ary(j+1,0)
          ary(j,1)=ary(j+1,1)
          ary(j+1,0)=t1
          ary(j+1,1)=t2
         end if
     Next
Next
End sub
```

III- Multicriteria Evaluation (MCE) Software Codes

```
unit Unit_mcda;
interface
uses
  Windows, Messages, SysUtils, Variants, Classes, Graphics, Controls, Forms,
  Dialogs, cxGrid, cxStyles, cxControls, cxContainer, cxEdit, cxTextEdit,
  cxMaskEdit, cxDropDownEdit, BusinessSkinForm, cxLookAndFeelPainters,
  cxLookAndFeels, StdCtrls, cxButtons, RXCtrls, ADODB, DB, ExtCtrls,
  cxRadioGroup, DBCtrls, Grids, DBGrids, RXDBCtrl, Gauges,IB;
type
  TForm1 = class(TForm)
    bsBusinessSkinForm1: TbsBusinessSkinForm;
    cxStyleRepository1: TcxStyleRepository;
    cxGridViewRepository1: TcxGridViewRepository;
    cxLookAndFeelController1: TcxLookAndFeelController;
    Open_mdb: TOpenDialog;
    Conn1: TADOConnection;
    MasterTable: TADOTable;
    DataSource1: TDataSource;
    CalcTable: TADOTable;
    DataSource3: TDataSource;
    FilterQ: TADOQuery;
    DataSource4: TDataSource;
    FltTbl: TADOTable;
    DataSource5: TDataSource;
    CrtTable: TADOTable;
    DataSource2: TDataSource;
    Panel1: TPanel;
    RxLabel1: TRxLabel;
    TableCombo: TcxComboBox;
    cxButton1: TcxButton;
    Panel2: TPanel;
```

```
  RxLabel2: TRxLabel;
  FieldList: TcxComboBox;
  Rb1: TcxRadioButton;
  ComboBox1: TcxComboBox;
  Rb2: TcxRadioButton;
  RxLabel3: TRxLabel;
  Edit1: TcxTextEdit;
  Edit2: TcxTextEdit;
  cxButton2: TcxButton;
  Panel3: TPanel;
  Panel4: TPanel;
  DBGrid1: TRxDBGrid;
  DBNavigator1: TDBNavigator;
  Panel5: TPanel;
  RxLabel4: TRxLabel;
  ComboBox2: TcxComboBox;
  Gauge1: TGauge;
  cxButton3: TcxButton;
  CrtTableCRITER_COLUMN: TWideStringField;
  CrtTableDIV_VALUE: TWideStringField;
  CrtTableCRITERION_WEIGHT: TWideStringField;
  CrtTableCODE_TABLE: TWideStringField;
  procedure cxButton1Click(Sender: TObject);
  procedure Rb1Click(Sender: TObject);
  procedure Rb2Click(Sender: TObject);
  procedure cxButton2Click(Sender: TObject);
  procedure cxButton3Click(Sender: TObject);
  procedure TableComboPropertiesChange(Sender: TObject);
private
  { Private declarations }
  function fltkod(TblName: string; fvalue: integer): double;
  function fltkod1(TblName: string; fvalue: integer): double;
public
```

```
  { Public declarations }
 end;
var
 Form1: TForm1;
implementation
{$R *.dfm}
procedure TForm1.cxButton1Click(Sender: TObject);
begin
open_mdb.Execute;
if open_mdb.FileName='' then
 Begin
  showmessage('Please Select Database!!!');
  open_mdb.Execute;
  if open_mdb.FileName='' then form1.Close;
 End
 else
  Begin
    conn1.ConnectionString:='Provider=Microsoft.Jet.OLEDB.4.0;Data
Source='+open_mdb.FileName+';Persist Security Info=False';
    conn1.Connected:=true;
    conn1.Open;
    conn1.GetTableNames(TableCombo.Properties.Items);
    CrtTable.Tablename:='CRITER_TABLE';
    CrtTable.Active:=True;
  End;
end;
procedure TForm1.Rb1Click(Sender: TObject);
begin
 if Rb1.Checked then
   Begin
    ComboBox1.Visible:=true;
    Edit1.Visible:=false;
    conn1.GetTableNames(ComboBox1.Properties.Items)
```

```
  End
 else
  Begin
   ComboBox1.Visible:=false;
   Edit1.Visible:=true;
  End;
end;
procedure TForm1.Rb2Click(Sender: TObject);
begin
  if Rb2.Checked then
    Begin
      ComboBox1.Visible:=false;
      Edit1.Visible:=true;
    End
  else
    Begin
      ComboBox1.Visible:=true;
      Edit1.Visible:=false;
      conn1.GetTableNames(ComboBox1.Properties.Items);
    End;
end;
procedure TForm1.cxButton2Click(Sender: TObject);
var
i:integer;
begin
 Crttable.Insert;
 CrtTable.FieldByName('CRITER_COLUMN').Value:=FieldList.Text;
 if Rb1.Checked then
CrtTable.FieldByName('CODE_TABLE').Value:=Combobox1.Text
 else  CrtTable.FieldByName('DIV_VALUE').Value:=Edit1.Text;
 CrtTable.FieldByName('CRITERION_WEIGHT').Value:=Edit2.Text;
 crttable.post;
end;-
```

```
procedure TForm1.cxButton3Click(Sender: TObject);
var
i,j:integer;
crtval: array of double;
vul: double;
vul2:double;
vul3:double;
vul4:double;
begin
gauge1.MaxValue:=MasterTable.RecordCount-1;
Crttable.First;
setlength(crtval,CrtTable.RecordCount-1);
MasterTable.First;
 For i:=0 to MasterTable.RecordCount-1 do
    Begin
            // kod tablolarini master tabloya göre filtrele
        vul:=0;
        Crttable.First;
        for j:=0 to CrtTable.RecordCount-1 do
         try
          Begin
           if Crttable.FieldByName('CODE_TABLE').asstring='' then
              Begin
               //showmessage(Crttable.FieldByName('COD_TABLE').asstring);
                vul2:=Crttable.FieldByName('CRITERION_WEIGHT').Value;
vul3:=mastertable.FieldByName(Crttable.FieldByName('CRITER_COLUMN').
Value).Value/(Crttable.FieldByName('DIV_VALUE').Value);
               vul4:=(vul3*vul2);
              End
           else
             Begin
              //showmessage(Crttable.FieldByName('COD_TABLE').asstring);
```

```
                  vul2:=Crttable.FieldByName('CRITERION_WEIGHT').Value;
vul3:=fltkod1(Crttable.FieldByName('CODE_TABLE').Value,mastertable.Field
ByName(Crttable.FieldByName('CRITER_COLUMN').Value).Value);
                  vul4:=vul2*vul3;
                 // crtval[j]:= 1;
                End;
              vul:=vul+vul4;
             // vul:=vul+crtval[j];
              CrtTable.Next;
               end;
             except
         //ShowMessage(Crttable.FieldByName('CRITERION_WEIGHT').Value);
                //ShowMessage(Crttable.FieldByName('CODE_TABLE').Value);
//showmessage(mastertable.FieldByName(Crttable.FieldByName('CRITER_
COLUMN').Value));
             //end;
             End;
         // agirligi hesapla ve tabloya yaz
         MasterTable.Edit;
         MasterTable.FieldByName(ComboBox2.Text).Value:=vul;
         MasterTable.post;
         MasterTable.Next;
         gauge1.AddProgress(1);
    End;
end;
function TForm1.fltkod(TblName:string;fvalue:integer):double;
Begin
  FilterQ.Active:=false;
  FilterQ.Sql.Clear;
  FilterQ.SQL.add('Select DEGER from '+TblName+' where KOD=
'+inttostr(fvalue));
  FilterQ.Open;
  result:=filterQ.fieldByName('DEGER').Value;
```

```
End;
function TForm1.fltkod1(TblName:string;fvalue:integer):double;
Begin
    flttbl.Close;
    flttbl.TableName:=tblName;
    flttbl.Active:=true;
    flttbl.Open;
    flttbl.Filtered:=false;
    flttbl.filter:='CODE = '+inttostr(fvalue);
    flttbl.Filtered:=true;
    result:=flttbl.fieldbyname('VALUE').Value;
End;
procedure TForm1.TableComboPropertiesChange(Sender: TObject);
begin
Mastertable.Close;
mastertable.TableName:=Tablecombo.Text;
mastertable.Active:=true;
mastertable.Open;
mastertable.GetFieldNames(Fieldlist.Properties.Items);
mastertable.GetFieldNames(ComboBox2.Properties.Items);
end;
end.
```

B. MCE Results

BUILDING : Table

BUILDING_ID	POPULATION	ROAD	HS_DISTANCE	VUL_PCM	VULF_PCM
B034504016	13	4	1196.462493332	0.71959752	0.464044868108
B034504017	14	4	1205.408811508	0.71959752	0.466535812413
B034504018	16	4	1225.217687866	0.54391352	0.404012788842
B034504020	7	4	1184.095585434	0.67826584	0.433721661052
B034504021	3	4	1176.191692848	0.66442208	0.418780438077
B034504022	3	4	1158.587476883	0.31358008	0.283708501975
B034504023	15	4	1149.125113952	0.73170789	0.472877459421
B034505002	17	4	1318.184622956	0.71959752	0.475068160705
B034505003	37	4	1341.995819733	0.71959752	0.522974632139
B034505004	37	4	1374.685311931	0.71959752	0.523377660839
B034505005	23	4	1317.139375030	0.71959752	0.489339144812
B034505006	34	4	1370.090382773	0.71959752	0.516179074481
B034505007	32	4	1576.604434225	0.73170789	0.518618819053
B034505012	13	4	997.8931419686	0.71104205	0.458308198096
B034505014	87	4	1203.515183	0.74026336	0.648242994894
B034505015	0	4	1219.191575873	0.71959752	0.433376707836
B034505018	52	4	1016.431835785	0.73170789	0.559325355164
B034505019	66	4	1060.615493622	0.73170789	0.593199127673
B034505020	29	4	1035.460508366	0.73170789	0.50480512093
B034505021	33	4	1070.231314352	0.75237373	0.522699823039
B034505022	25	4	1102.022578502	0.73170789	0.496103183946
B034505023	33	4	1087.625995149	0.73170789	0.514970849782
B034505024	58	4	1135.593259665	0.73170789	0.575078367146
B034505025	9	4	1130.583770067	0.73642074	0.460176493972
B034505026	7	4	1097.203470775	0.7157549	0.44706022574
B034505027	3	4	1087.996554735	0.64375624	0.409749648103
B034505029	6	4	1051.238917309	0.67297755	0.427670339763
B034505030	19	4	1126.898914292	0.73170789	0.482126013285
B034505031	22	4	996.023196704	0.71959752	0.482999458777
B034505032	10	4	1035.087454605	0.69037621	0.443681398986
B034505033	4	4	1055.588071966	0.52796053	0.367221753099
B034505034	10	4	1055.391260791	0.56929221	0.397390062082
B034505035	3	4	1068.646220850	0.46807224	341982540366379
B034505036	3	4	1080.565815378	0.46807224	0.342129497029
B034505038	3	4	999.7964841931	0.74026336	0.445757153818
B034505039	3	4	987.7681183970	0.66442208	0.416457364114
B034505040	3	4	978.7172776413	0.66442208	0.416345776312

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Figure B. 1 Urban Vulnerability Evaluation (VULF_PCM) Results According to Building Collapse Vulnerability (VUL_PCM)

C. SRAS Results

SRAS : Table

Build_Label	Building_Type	Site_Class	Storey_Number	Condition	Damage
B034491028	RC	2	2	2	24.02548
B034491029	RC	2	2	3	24.02306
B034491030	RC	2	1	2	22.49247
B034491031	RC	2	1	1	22.49532
B034491032	RC	2	1	4	22.50334
B034491033	RC	2	2	1	24.01916
B034491037	RC	2	3	1	24.61877
B034491040	RC	2	1	1	22.4979
B034491047	RC	2	6	1	29.91776
B034492001	RC	3	6	1	30.707
B034492003	RC	3	9	1	36.43426
B034492004	RC	3	5	1	30.62163
B034492005	RC	3	5	1	30.62538
B034493003	RC	3	8	1	34.16103
B034493004	RC	3	8	1	34.16228
B034493005	RC	3	5	1	30.61973
B034493006	RC	3	5	1	30.61901
B034493007	RC	3	5	1	30.61821
B034493008	RC	3	5	1	30.61712
B034493009	RC	2	6	1	29.96824
B034493010	RC	3	5	1	30.61512
B034493012	RC	3	6	1	30.69393
B034493013	RC	3	6	1	30.69678
B034493014	RC	3	6	1	30.69549
B034493015	RC	3	9	1	36.42964
B034493017	RC	3	5	1	30.60298
B034493018	RC	3	5	1	30.60322
B034493019	RC	3	5	1	30.60361
B034493020	RC	3	5	1	30.6038
B034493021	RC	3	5	1	30.60412
B034493022	RC	3	3	1	25.54051
B034493023	RC	3	3	1	25.54106

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Figure C. 1   SRAS Analysis Results