STRUCTURAL RISK MANAGEMENT OF DISASTERS

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STRUCTURAL RISK MANAGEMENT OF DISASTERS

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ABSTRACT

STRUCTURAL RISK MANAGEMENT OF DISASTERS

BATTAL, Fulya

In this thesis, an expert system that evaluates the risk of damage of buildings during an earthquake is studied. The system asks some critical questions about the ground type and structural properties of the buildings. The answers to these questions are evaluated to conclude on the risk of damage of the buildings and advise for the necessary precautions to decrease the damage of the building to the user.

The rules and parameters are determined due to a predefined knowledgebase and utilized in the expert system called, *Structural Risk Management of Disaster* prepared by the software Exsys Corvid. This expert system may be used in determining the risk of damage of buildings including government buildings, hospitals, residences etc. The determination of the risk of damage is important to get ready for any possible earthquake.

Keywords: Risk Management, Expert Systems

ÖZ

DOĞAL FELAKETLERİN YAPISAL RİSK YONETİMİ

BATTAL, Fulya

Bu tez çalışmasında yapıların olası bir depremde taşıdığı riski hesap eden bir uzman sistem geliştirilmiştir. Bu sistem kullanıcıya çeşitli sorular sorarak, binanın zemin ve yapısal özelliklerini sorgulayarak bir risk analizi yapmaktadır. Yapılan analiz doğrultusunda sistem bir uzman görüş belirtmekte, kullanıcıyı risk azaltmak adına yapılması gerekenlere yönlendirmektedir.

Önceden belirlenen bilgitabanları kullanılarak sistemin kuralları ve parametreleri belirlenmektedir. Exsys Corvid programı kullanılarak hazırlanan bu sisteme "Yapısal Risk Yönetimi" sistemi diyoruz. Bu uzman sistem sayesinde devletin onemli binalarının, hastanelerin, yaşam alanı olarak kullanılan binaların vs. olası bir deprem anında görebileceği hasarın riskinin belirlenmesinde kullanılabilir. Bu riskin belirlenmesi gerekli onlemlerin alınması açısından çok önemlidir.

Anahtar Kelimeler: Risk Yönetimi, Uzman Sistemler

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CHAPTER 1

INTRODUCTION

The thought processes of humans and representing these processes via machines are studied as artificial intelligence (AI). We understand model and solve problems in the real world domain with the advent of AI. The various branches of AI deal with natural language processing, computer vision, robotics, problem solving and planning, learning and Expert Systems. Many challenging problems can be solved successfully by Expert Systems which is a relatively new concept of AI present a prime example of the success of AI in solving challenging problems [1].

Expert Systems are knowledge-based systems that emulate expert thought to solve significant problems in a particular domain of expertise. They are built to have expert knowledge in a well-defined and sharply differentiated area i.e., they are not designed to solve all problems. They usually perform more symbolic processing than numerical calculations. Facts, observations and hypotheses are represented/manipulated as symbols.

The first expert system called DENDRAL was developed at Stanford in 1964 [2] . Its purpose was to provide aid in the prediction of possible set of structures of unknown compounds from spectroscopic and nuclear magnetic resonance data. Work on MYCIN, an expert system for treating blood infections, began at Stanford in 1972. MYCIN would attempt to identify the organism responsible for an infection from information concerning the patient's symptoms and test results. The program would request further information if necessary, asking questions such as "has the patient recently suffered burns?". Sometimes MYCIN would suggest additional laboratory tests. When the program had arrived at a diagnosis it would recommend a course of medication. If requested, MYCIN would explain the reasoning leading to the diagnosis and recommendation [3]. Medicine was an apt area for the application of Expert Systems since the human body has been a subject of research for a long time though we still don’t understand its functioning completely. SRI International developed the expert system called PROSPECTOR in 1978 for exploring ore deposits of commercial interest. In the same year, CMU and DEC developed R1/XCON to configure AX 11/780 computers. All of the above expert systems have been a fairly good success though some of them such as MYCIN were never used except for learning and training purposes due to political reasons.

An expert system may also interact with humans and have the capacity to explain itself. For example it may explain how conclusion *A* was reached and why conclusion *B* was discarded. This is a significant aspect since it allows users to relate to the system and better understand its workings. They also usually have the capability to justify why a particular piece of information is needed to derive an inference.

Nowadays with the decreasing costs and increasing power of computers, their usage raised enormously. Alongside, the applications of expert systems become widespread. The complexity of modern day plants/operations, makes them difficult to design and maintain. Data explosion (quantity and quality of sensor data) as a result of advanced and precise collection techniques have led to better ways to exploit the embedded information. Techniques based on inexact reasoning such as fuzzy logic are extensively being used for controller design. Expert system technologies based on machine learning such as neural networks and genetic algorithms have been used in design and control. Process safety analysis is another major area where expert systems have found good applications. Another area of expert system, which we will focus on is the risk management of earthquakes. In general the usage of expert systems in risk management would cut down on the labor and time required to solve problems and at the same time improving performance and accuracy.

In the next section some aspects of the theory behind expert systems are presented. Basic concepts of expert systems are explained dealing with knowledge acquisition, representation and validification/verification.

1.1 Theoretical foundations

Expert system is one of the prime branches of artificial intelligence. The other AI branch closely related to expert systems is learning. Expert systems emerged from symbolic manipulation approach with the aim to model human expertise in the background. Reasoning, explanation and intelligent data processing are some of the activities performed by knowledgeable human experts. Expert systems are designed to possess these characteristics. Expert system architecture and its main components are discussed below.

1.1.1 Expert system structure

Expert system architecture is shown in the Figure 1.1 [4]. The main components of an expert system are knowledge base, inference mechanism (engine) and user interface.

Domain knowledge is stored in some suitable form (for easy access for problem solving) in the knowledge base. There are mainly two types of knowledge - declarative knowledge and procedural knowledge. Declarative knowledge represents data and facts. Procedural knowledge represents the knowledge about using declarative knowledge.

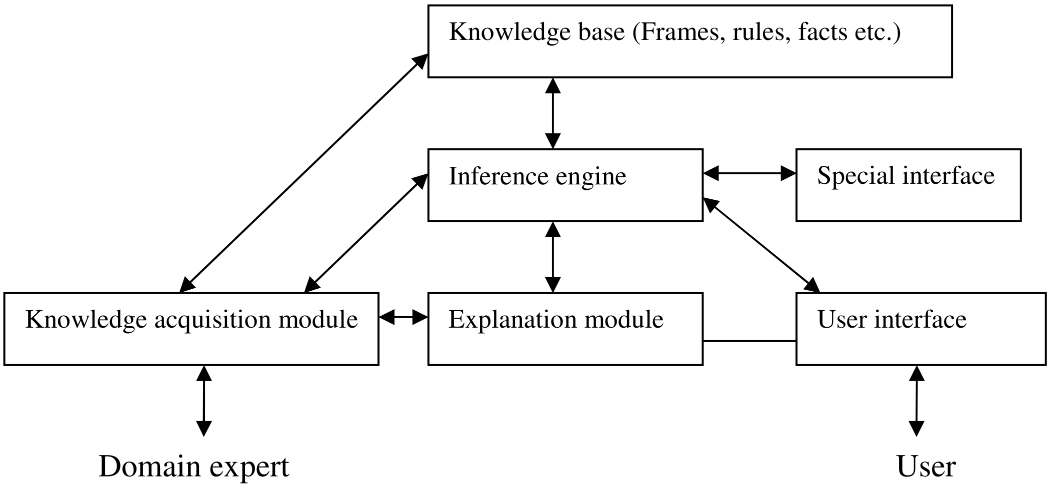


Figure 1.1. Structure of an expert system

The process of gaining knowledge from human experts (such as plant operators and engineers) and storing it in suitable form is called knowledge engineering. The process of knowledge engineering is schematically shown in Figure 1.2 [5]. The main subtasks of knowledge engineering are knowledge acquisition, knowledge representation and knowledge validation.

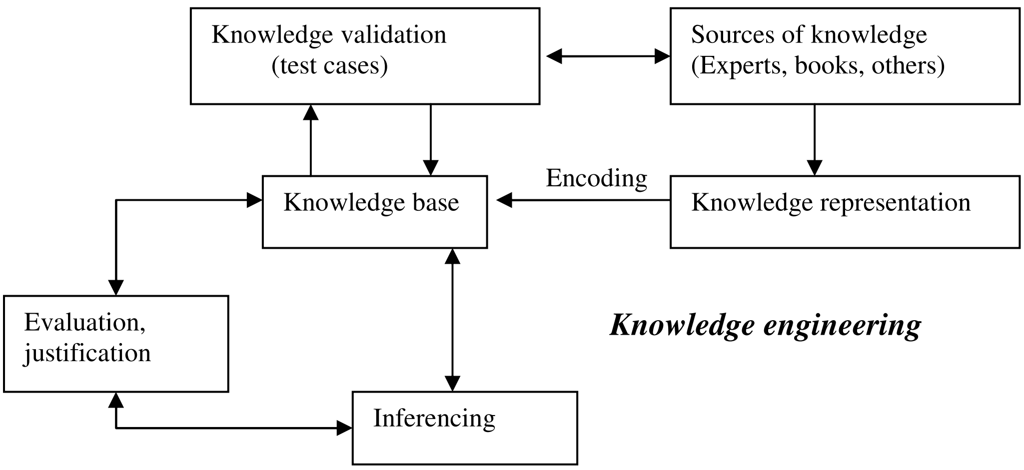


Figure 1.2. Knowledge engineering

The knowledge representation models in current literature are - logic, rules, semantic networks, frames, objects, scripts, O-A-V triplets, lists and decision trees, agents and hybrid systems. The most widely used ones are discussed below.

- *Rules* - Rules are in IF-THEN form and they show antecedent-consequent relationship.
- *Objects* - Objects have emerged from the object-oriented programming paradigm. The main features of object-oriented programming are data hiding, inheritance and late binding (operation binding at run time).
- *Agents* - Agents are used for distributed computing. What makes agent based programming somewhat different than all others is that agents are pro-active and procedures are application-independent.
- *Hybrid systems* - In order to overcome the drawbacks due to use of a single representation, more than one model (usually rules and objects) are used which is thus called hybrid representation.

1.1.2 Inference engine

The next component of an expert system is inferencing/reasoning and explanation. Expert systems can provide explanation on how certain conclusion was reached or why a certain piece of information is needed. Deductive reasoning, inductive reasoning, analogical reasoning, formal reasoning and metalevel reasoning are some of the commonly used reasoning techniques. The inference process is either *goal-driven* also known as *backward chaining* (starting from goal and looking for the premises or initial state leading to that conclusion iteratively) or *data-driven* also known as *forward-chaining* (start from the initial state and find the goal state in an iterative manner). A hybrid strategy which uses both of the above is called *means-ends analysis*. Reasoning often involves search.

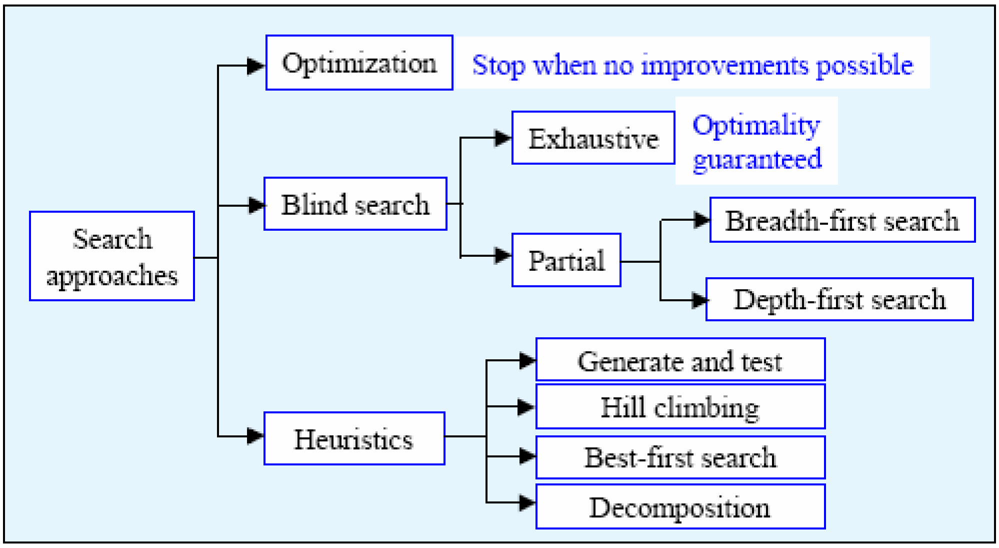


Figure 1.3. Search approaches.

Problem-solving process in AI involves search and evaluation. Search is either *datadriven*(*forward search*) or *goal-driven* (*backward search*). Various search techniques are listed in Figure 1.3 [5]. Search can be either a blind search or it can be based on some heuristic method. In blind search category, the most widely used ones are partial searches (in most of the real life problems, complete enumeration is impossible). The common search methods used are explained below.

1. *Breadth-first search (BFS)*- All the states at the current level are searched before going to a lower level. It comes up with the shortest-path.
2. *Depth-first search (DFS)*- Search goes on through deeper levels till it reaches the goal or dead-end is encountered.
3. *Best-first search*- Best-first search is based on some heuristic evaluation function.

One moves to the best node reachable in one step.

Incompleteness and vagueness associated with human knowledge provides motivation for inexact reasoning. Depending upon the way of capturing the uncertainty as a numeric, the main approaches to deal with uncertain knowledge are bayesian approach, fuzzy logic, certainty factors and theories of evidence. The most widely used approach is fuzzy logic.

1.1.3 Knowledge acquisition, validation, learning and update

Knowledge acquisition is the process of collecting the knowledge necessary for problem solving. The main methods used can be broadly classified as manual, semiautomatic and automatic. Manual methods usually involve interviews. Automatic methods are based on the principle of induction and machine learning. Neural networks (NN) and genetic algorithms (GA) have emerged from the machine leaning approach and the second generation expert systems use them extensively. Neural networks are capable of learning from their mistakes though they require a lot of training data. Genetic algorithms are based on the Darwinian approach of natural selection and genetics. They are basically a global search technique. Both NN and GA are suitable for parallel computing and they are widely used for pattern recognition and related tasks such as clustering and classification. Knowledge base is checked for completeness and correctness through validation and verification. Typical consistency checks involve identifying dead-end rules, conflicting rules etc. and correcting them. Knowledge base building is an iterative process. Expert system knowledge structure should be such that it's amenable to updates in the future. In Figure 1.4 a classical expert system is presented. In order to construct such expert systems, knowledge is elicited from domain experts or associated literature. Collecting knowledge and transforming it into a form that can be processed by a computer has proven to be the bottleneck of building expert system [6,7]. The term knowledge acquisition (KA) covers activities included in this process.

Knowledge systems have traditionally been constructed by knowledge engineers, who are people interviewing domain experts and formalizing their knowledge. Different phases of KA require different skills of the knowledge engineer [8]. Computerized tools for KA aim at supporting, or even automating, the work of a knowledge engineer. The ultimate goal is to construct more reliable expert systems in less time. KA as a separate field of research has been recognized in the mid-1980's. It has a wide range of subtopics, raising from a number of other disciplines, including humanistic research like psychology or linguistics, as well as research in different areas of computer science. Tools developed for KA may differ a lot, as the ideas, experience and methods come from a variety of sources, and different phases of KA require different support. Machine learning techniques have also been used in some KA tools, but they will not be considered in this thesis.

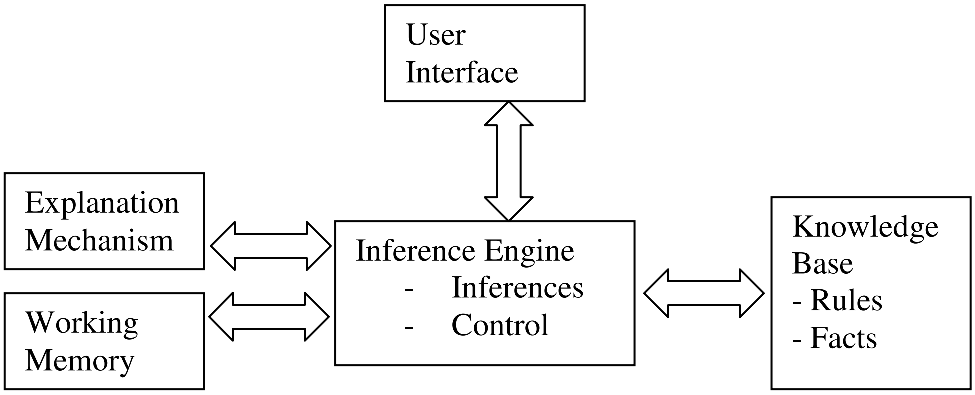


Figure 1.4. A classical expert system. The inference engine fires rules in the knowledge base and updates the state of the working memory. It communicates with the end user through the user interface, using the explanation mechanism, when necessary.

1.1.4 Traditional KA techniques

Judith Reitman Olson and Henry H. Rueter [9] describe expertise as a skill of recognising old patterns in a new problem. They mention there is evidence suggesting that experts see more richly encoded patterns (concepts are organised with much more depth and with more central associations) than novices. It also seems that experts use a variety of kinds of knowledge structures, e.g., lists, tables, flow diagrams, decision trees, hierarchies, networks, physical space or physical models. Olson and Rueter describe methods revealing what experts know. These techniques are classified into direct and indirect, according to whether they rely on the expert's ability to articulate his/her knowledge, or collect other behaviours. Indirect methods make different assumptions about the form of the underlying representation.

- Direct methods:
  - Interviews: Knowledge engineers elicit knowledge from experts in conversation. The process is best started with free-formed questions, narrowing in specificity. The expert is in control, which has some advantages, but makes interviews very time-consuming.
  - Questionnaires: Questionnaires are an efficient way to gather information, especially in discovering the objects of the domain. A questionnaire may consist of cards or pieces of paper, on which are printed some standard but open-ended questions: object definition templates, requests to draw graphs, pre-formatted response scales for eliciting probability estimates etc.
  - Observation of task performance: The expert's performance, while working at a real problem, may be recorded by simply watching or by videotaping the process.
  - Protocol analysis: In addition to the situation above, the expert is asked to 'think aloud', while performing the task. The objects, their relationships and the inferences are gained from a transcript of this session. There are, however, tasks for which protocol analysis is not appropriate. Tasks for which some idiosyncratic language is used, e.g., composing music, and non-verbalizable tasks, fall out of the scope.
  - Interruption analysis: The expert performs his/her task without thinking aloud, but is interrupted when the observer can no longer understand the expert's thought process. This procedure is most useful, when the expert's performance is compared to that of a prototype expert system.
  - Drawing closed curves: Drawing closed curves is a specialised method for indicating relationships among objects that can be assumed to be encoded in a physical space representation, e.g., a typeset formula, an x-ray scan or a position on a game board. The expert is asked to draw a closed curve around each group of objects that 'go together'.

- Inferential flow analysis: A kind of an interview with questions about causal relations is used to build up a causal network among concepts. Weights are attached to the links.

- Indirect methods:
  - Multidimensional scaling: The data is assumed to have come from stored representation of physical ndimensional space. The expert provides similarity judgements (assumed to be symmetric and graded and between 0 and 1) on all pairs of objects or concepts. The similarity judgements are arrayed in a half-matrix, and then analysed further to place the objects in space of user-specified dimensions. The expert may inspect and describe in further detail the diagram produced. Collecting the similarity judgements and finding the right dimensionality axes and axis names is difficult.
  - Johnson hierarchical clustering: A half-matrix of similarities is again formed, but it is only assumed that an item is or is not a member of a cluster. Judgements are assumed to be a function of the nested clusters that two items have in common, or the 'height' at which two items become members of the same superordinate category. The most similar pair is joined as a cluster, and the half-matrix drawn again with the cluster as a new item. A hierarchical representation is produced by continuing in the same way. Different joining functions can produce very different hierarchies, so if there is no theoretical justification for choosing a certain one, the analysis is somewhat subjective. Johnson hierarchical clustering is used to cluster objects of the grid, as well as its dimensions. The distance of two objects is the sum of absolute differences on various dimensions. Distances among dimensions are defined in a more complex way. As directions of scaling within dimensions have not been judged, differences according to both original and flipped directions are considered. The smaller of these values is taken into the half-matrix.
  - General weighted network: The expert gives symmetric distance judgements, expected to arise from primary paths in a network of

associations. A minimal connected network is formed from the distance matrix. A minimal elaborated network is produced by adding links, if and only if the new links are shorter than the ones currently in the network between the two nodes. The two structures are examined to identify dominating concepts (having a large number of connections) and members of cycles. Structures created by experts differ clearly from ones created by novices (simplicity, integration of larger conceptual structures, identification of link relations), so this technique might reveal significant aspects of expertise.

- Ordered trees from recall: Ordered trees begin with recall trials. Objects are assumed to belong to a cluster or not, and the technique assumes that people recall all items from a stored cluster before recalling items from other clusters. Regularities found in the orders of repetitive recalls (from many starting points) are drawn in the form of an ordered tree. Experts show much more organisation than novices and different experts have fairly similar structures, whereas those of novices differ widely.
- Repertory grid analysis: Repertory grid analysis is based on personal construct theory in clinical psychology. It includes
    - an initial dialogue with the expert,
    - a rating session and
    - analysis resulting in clusters of both objects and dimensions of rating.

The analysis begins with an open interview, in which some objects in the domain are named. The analyst then picks triples of objects, and asks the expert to give a trait distinguishing two of the objects from the third. The analyst records the dimension and scale values of the three concepts on it. After the major dimensions have been uncovered, all objects have to be rated on all dimensions. A grid with objects at the top and dimensions on the left is given to an expert, who fills in missing values. For instance the tool ETS by Boose [10] uses repertory grid analysis. It is particularly applicable to classification type problems.

In this thesis we used a kind of “Questionnaires” method which is a direct way of gathering information.

1.1.5 Building expert systems

Expert systems can be either written in AI based languages such as LISP and PROLOG or general languages such as C/C++ etc. They can also be built using shells such as KEE, G2 but the user might lose some flexibility in that the person would be bound to use the structure/representation provided by the shell environment. However they are extensively used to build rapid prototypes to analyze the feasibility and practical issues. The use of general programming languages removes all restrictions but is in general time consuming and labor intensive.

1.2 The Aim Of the Thesis

Catastrophic earthquakes every year takes heavy toll on human lives and widespread destruction of property in all over the world. Turkey is on a very active seismic belt that would cause severe earthquakes (Figure 1.5).

In the past several earthquakes resulted in much damage of both human health and property (Figure 1.6 and 1.7). For the present, there is no way to prevent a possible earthquake to occur. Therefore the best thing to protect human life is to construct safe buildings. However, in our country many of the buildings are not constructed by obeying the rules that are necessary to make buildings safe for humans during a earthquake. To reduce the damage of such weak buildings in the future, the risk of destruction of these buildings during an earthquake should be investigated. In this thesis we propose a risk managing expert system that would determine the risk of damage of buildings.

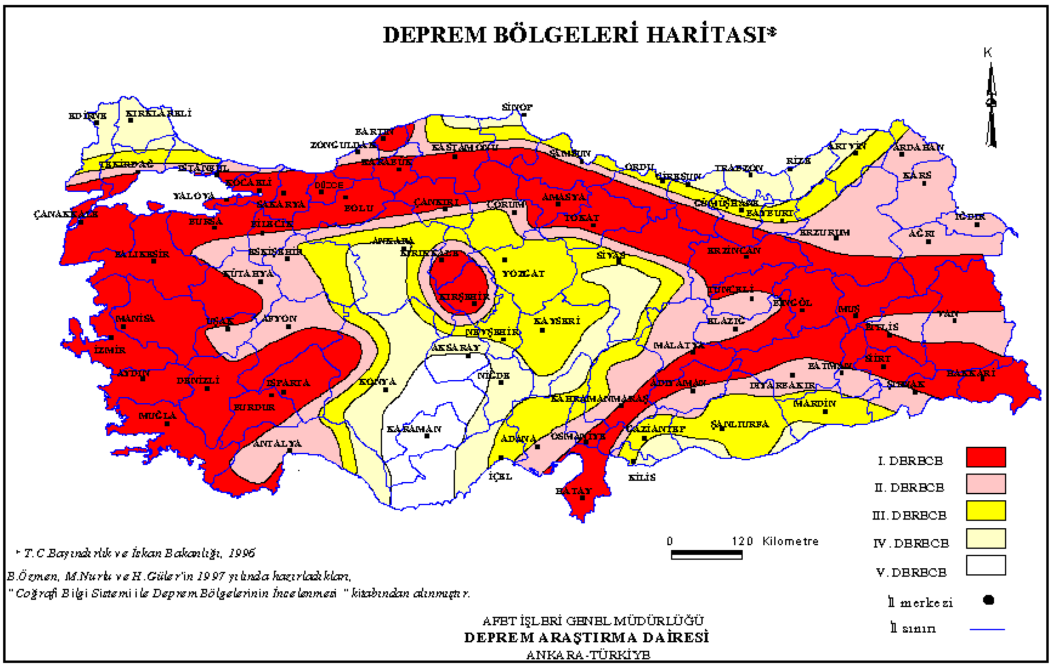


Figure 1.5. Map of Turkey colored according to the harshness of possible earthquakes. The regions are colored with red, purple, yellow, light yellow and white with the order of harshness (from most dangerous to least dangerous ones).

Figure 1.6. A completely destructed building.

Figure 1.7. A completely destructed building in front of a healty building.

1.3 Literature Survey

There are many earthquake prediction studies especially in countries that frequently faces with earthquakes. A study that summarizes the current status of earthquake prediction research in China is [11].

Shengkui et al. studied on an Intelligent Decision Support System for Earthquake Prediction (ID-SSEP) which has several databases and subsystems [12,13]. The essence of model system in the paper [14] is establishing knowledge base on earthquake prediction and countermeasure which is concerning with many aspects and domains such as geology,geophysics, geodesy and geochemistry. In [15,16], a method called FUMCE (Fuzzy User Model based Customized Explanation) is proposed.. FUM-CE can provide different and suitable explanation for the different users with different domain knowledge, by which the understandability and acceptability of the expert system for earthquake prediction are improved. In [17] the authors develop an Expert System, to measure the polarisations and time-delays of seismic shear-wave splitting in three-component seismograms above small earthquakes. The study of Berrais [18] is concerned with the description of a knowledge-based expert system for the earthquake resistant design of reinforced concrete buildings. The system is considered as an interactive analysis/design tool in which the structural engineer is guided from the preliminary earthquake design to the final detailed design including non-linear dynamic analysis.

The branch of artificial intelligence represented by Expert Systems has evolved to be a very useful approach for real world problem solving [19]. Expert Systems are knowledgebased systems that emulate expert thought to solve significant problems in a particular domain of expertise. Expert system is a novel area of artificial intelligence. There are many studies utilizing expert systems in various subjects. In [20] a practical way to make a reactive (dynamic) expert system is proposed and its limitations and problems are studied.

CHAPTER 2

STRUCTURAL RISC MANEGEMENT OF DISASTER

Turkey is a country which frequently faces with earthquakes some of which are very drastic. Therefore, to prevent the loss of human life and damage of capital, the quality of construction have to be improved and the regulations and standards should be followed. In Turkey many of the finished and incomplete buildings do not satisfy the government regulations about construction. The main reason for the huge losses of human and capital during the previous earthquakes in Turkey is the disobeying of building contractors to the regulations.

2.1 What is Risk?

The term "risk" is about the probability of occurrence of a dangerous event and the results of this event. The errors in the construction of buildings make them have high risk of damage in a possible earthquake. In Figure 2.1, we see a discontinuity on one of the columns of the building. This huge error in the construction makes the building very risky. If the outer side of building was plastered then the determination of the discontinuity would be very hard. In such cases the building should be investigated by engineering techniques.

2.2 Behaviors of Buildings During Earthquakes

Constructing buildings that do not get any harm in an earthquake is very hard and expensive. However, buildings may get some amount of damage with still protecting human health. Therefore, in many countries the buildings are expected to get damage during a violent earthquake without loss of human life. This case is also valid for Turkey.

Figure 2.1. A building in İstanbul that has discontinuity in one of its columns

During light but frequent earthquakes the frameworks of the buildings should not get harm. However, the remaining parts like cell walls that do not take role in resisting the load may be damaged. For the stronger but less frequent earthquakes, it is acceptable that the frameworks are damaged. This damage should de repairable. For very strong and rare earthquakes the damage of framework which can not be repaired is acceptable but this damage should never lead to loss of human life. The buildings should be unpartitioned and awake in such huge earthquakes.

These damage criteria is valid for ordinary residence buildings but not for hospitals, fire departments and such buildings that are required while natural disasters. The damage level in these buildings should not prevent their service after the disasters. However, in Turkey these buildings are not enough strong to get rid of severe earthquakes. Therefore, an urgent investigation of possible damage during an earthquake and maintanace/repairment process should start for these first order important buildings and other important buildings.

2.3 Structural Risks

Risk of damage of buildings in earthquakes can be classified into 2 main topics. First is the risk due to the damage of the structure of the buildings. The second group of risk factors is the ones that are not related with the structural damages. Second group contains things, cabinets, shelves etc. that may fall during an earthquake as seen in Figure 2.2.

Figure 2.2. The materials that fell during an earthquake.

These risk factors may be eliminated as following. The cabinets, shelves and other objects that may fall can be fixed on the walls. Furthermore, the home machines like washer, dishwasher, refrigerator should be fixed to prevent them to harm people during an earthquake. With these precautions the risk levels would be lowered.

The structural risks can be classified into 2 topics. The first one is the risk of damage of parts that do not carry load. The destruction of room walls, fall out of plaster, broken glasses, are in this first group of structural risks. The second group contains the damage of the framework of the building. The damage of the building is the most dangerous risk factor. It may lead to collapse of the building.

As the the framework elements -columns, rows, curtain, base, floor- are stronger, the buildings are safer and risk of damage is less. The acceleration (Figure 2.3) resulted in the huge destruction of buildings with weak frameworks in Figure 2.4.

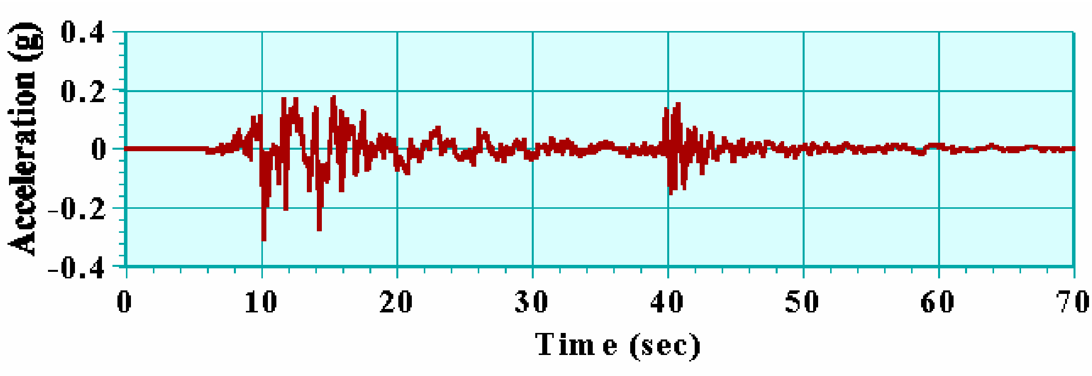


Figure 2.3. Acceleration record during an earthquake.

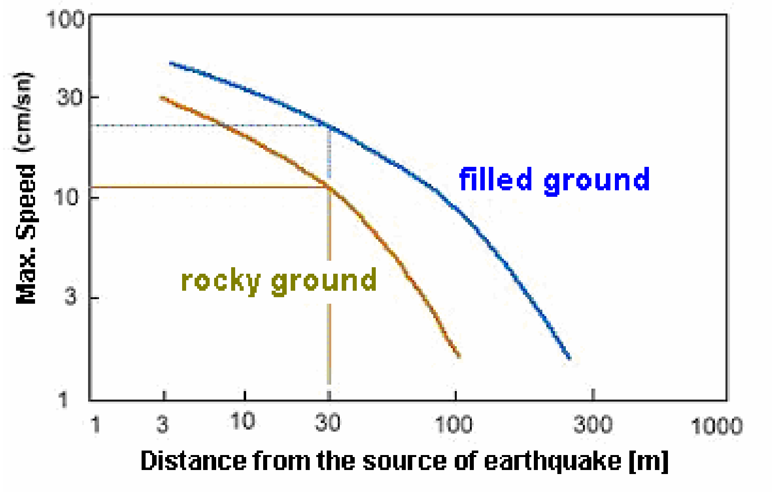
Figure 2.4. Buildings that are completely collapsed during an earthquake.

In this thesis study, in addition to the structural risk factors, the type of ground is investigated.

The experiences from 17 August Marmara earthquake says that as the structural risk factors, the risk of damage of buildings due to ground type is important issue to be considered. The buildings constructed on rocky ground had less damage during the earthquake. In figure 2.5, a building that fall over the right side is shown. The framework of the building is healthy but it is unusable now. Therefore if the ground a building constructed on is not safe then despite its strong framework it may get severe damages.

Figure 2.5. A building in Adapazarı that fall over in the 1999 earthquake due to soft ground it is constructed on.

Comparing the soft and hard grounds we can look at the velocities of ground plotted with respect to the distance from the source of earthquake in Figure 2.6. As seen the soft ground (filled with soil) has higher speed than the rocky ground for all distances from the source. For example, at the 30km far away from the source the speed of ground is 12cm/s for rocky groundand 20cm/s for soft ground (filled ground). Speed of ground is less for hard grounds and high for soft ones. Therefore, the buildings on the hard grounds faces with lower speeds and be safer.



. **Figure 2.6.** Speed-distance curve for ground types: rocky ground (red) and filled of soil ground (blue).

CHAPTER 3

EXPERT SYSTEM DEVELOPMENT TOOL: EXSYS CORVID AND IMPLEMANTATION FOR RISK MANEGEMENT OF DISASTER

3.1 EXPERT SYSTEM DEVELOPMENT TOOL: EXSYS CORVID

Exsys CORVID is a very powerful expert system development tool capable of handling a wide range of problems [21]. The program has many options and controls that are used for advanced systems and special situations. In this section some controls that are used in this thesis are presented.

3.1.1 Selecting an Appropriate Problem

Exsys CORVID helps to describe the logical steps in a decisionmaking process in a way that allows the knowledge to be delivered to others as if they were interacting with a human expert. This is actually very similar to the way you would explain how to solve a problem to a person. The first step in building a CORVID application is to select a problem that can be broken into logical steps or pieces. The problem should be able to be solved using logic that can be explained to a person using statements in the form: "IF …. THEN…", or "SINCE …. I KNEW THAT……". The "IF", or "SINCE", part may involve several conditions that are combined. For example:

IF the place your building is constructed on rock ground THEN

There is no risk for your building

Describing a problem in this way puts it in the correct form for input into CORVID.

3.1.2 Heuristics and Rules

In expert system terminology, each of the expert's “rules of thumb” is a heuristic [21]. That is a specific small fact that tells how to make a part of a decision. The combination of all the heuristics allows the overall decisionmaking problem to be solved. A large part of building an expert system is identifying the individual decision steps and converting them into a form that a computer can use. There are many ways of describing the heuristics for a decision-making process, but the one that has proven the most effective and efficient is the IF/THEN rule. This is a rule where there is an IF part that can be tested to be true or false based on the data for a specific case or situation. When the IF part is true, the statements in the THEN part are also considered true.

3.1.3 Backward Chaining / Forward Chaining

The way in which the Inference Engine combines the rules is called backward chaining. Backward chaining is “goal driven”. Setting appropriate goals is part of the expert system development process, but typically the top-level goals are the possible answers to the problem or potential recommendations. The Inference Engine can determine what it needs to meet a particular goal, including determining when that goal is met or that a goal can not be met. The Inference Engine analyses what data is needed to determine if the first possible goal is appropriate for the user. To make this determination, the system requires data on the specific situation being analyzed. This data can come from other rules, external sources such as databases and spreadsheets, and asking the user additional questions.

The Inference Engine checks the rules to find one that would be relevant to making this decision:

IF

You want less damage during an earthquake

THEN

Build your house on rocky ground

The Inference Engine has found a potentially useful rule, but without more data it cannot determine if this rule should be used. To make a further determination, it needs to know if “You want less damage during an earthquake”. Determining if this statement is true becomes the new goal of the Inference Engine. The original goal is not forgotten, but it is temporarily superseded by the new goal. The Inference Engine now looks for a rule that can tell it something about less damage. It finds:

IF

Your house is on rocky ground

THEN

Your building would get less damage during on earthquake

The Inference Engine would determine where and how to get the needed data. This process of having one goal requiring data, which leads to another goal, can be repeated many times. This “chain” of goals going backwards from the highest level to the lowest level is what gives backward chaining its name. As data becomes available, lower level goals are met and are dropped off the chain until the Inference Engine is able to determine which of the conditions for the initial top-level goal are met, and the recommendation is presented to the user. A typical one-on-one consultation with an expert takes several paths before reaching a conclusion, but without asking redundant questions. Backward chaining in expert systems emulates this process. The CORVID Inference Engine also supports another way to run the Inference Engine - forward chaining. Forward chaining is data driven, rather than goal driven. Running the Inference Engine in this mode is done when there is a body of data already available and you just want to use the logic in the rules to analyze it. In this case the rules are tested sequentially to see what conclusions result. Forward chaining is somewhat faster for some problems, but the questions are not as focused and it is not as good an emulation of a session with a human expert.

3.1.4 Confidence

Another powerful feature of Exsys CORVID is that the rules can include a “confidence factor” for a particular answer. This enables expert systems to make multiple recommendations with differing degrees of confidence to reach a "best fit" in its conclusion. While in some cases, it is possible to give a specific recommendation with absolute precision; the real world is not often so clear-cut. Often multiple recommendations are simultaneously possible and the system ranks them and presents them to the user.

The ability to handle confidence factors in expert systems provides a much more effective way to build systems that emulate the real world and give the type of recommendations that human experts would. Exsys provides many different ways to handle and utilize confidence values.

3.1.5 CORVID Variables

Variables are the building blocks that are used to build expert systems with CORVID [21]. They are the elements that would be needed to incorporate into a decision-making process. For instance, if a system will use temperature to help make the decision, there will need to be a Variable [RİSK] defined and used when you build the logic.

Variables are used:

- To define the logic in Logic Blocks and Command Blocks
- To hold data during the execution of the system
- To define the goals of how the system will run

3.1.6 Variable Types

There are 7 types of Variables in Exsys CORVID: Static list, dynamic list, numeric, string, Date, Collection, confidence. In this study, the variables static and confidence are used in implementation. The variable Static List is a mutiple choice list with the values defined during development of the system. Examples - day of the week, on/off, high/medium/low.

3.1.6.1 Static List

Multiple choice list with the values defined during development of the system. Examples – the place ; rock / ground containing water. As seen in Figure 3.1. "The_place" variable is defined as static list variable.

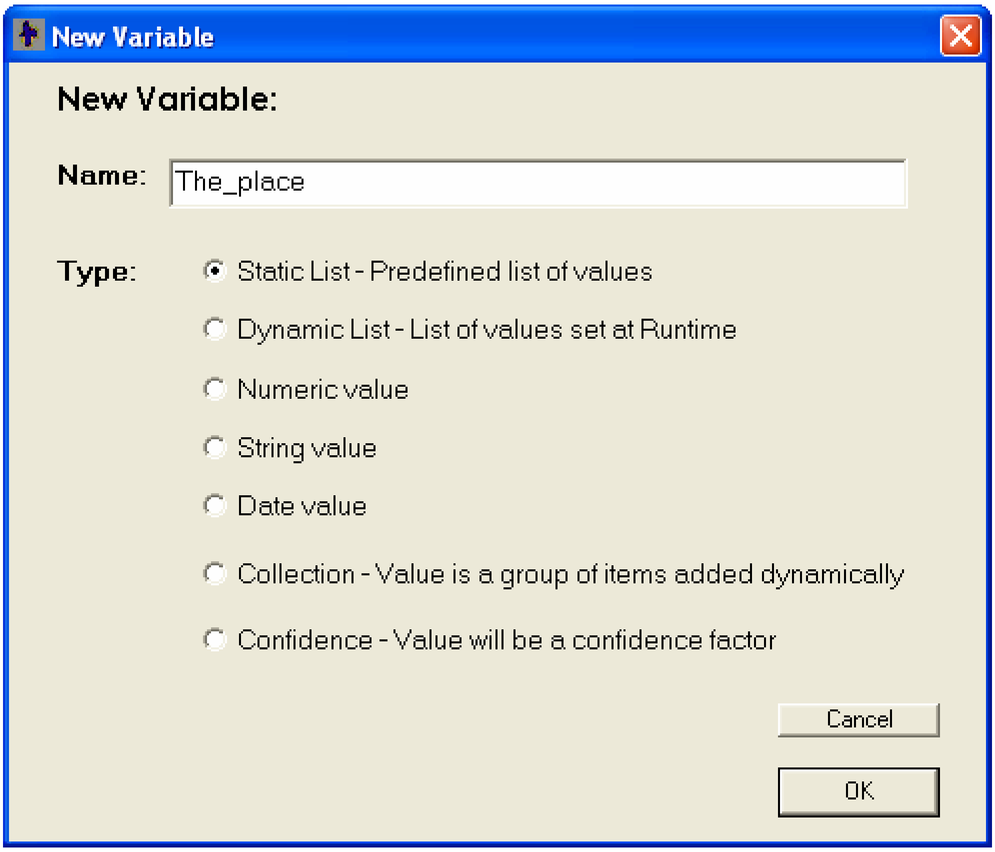


Figure 3.1. Adding the static variable

In Figure 3.2 values like *Rock ground* are assigned for the static variable The_place which was created as shown in Figure 3.1.

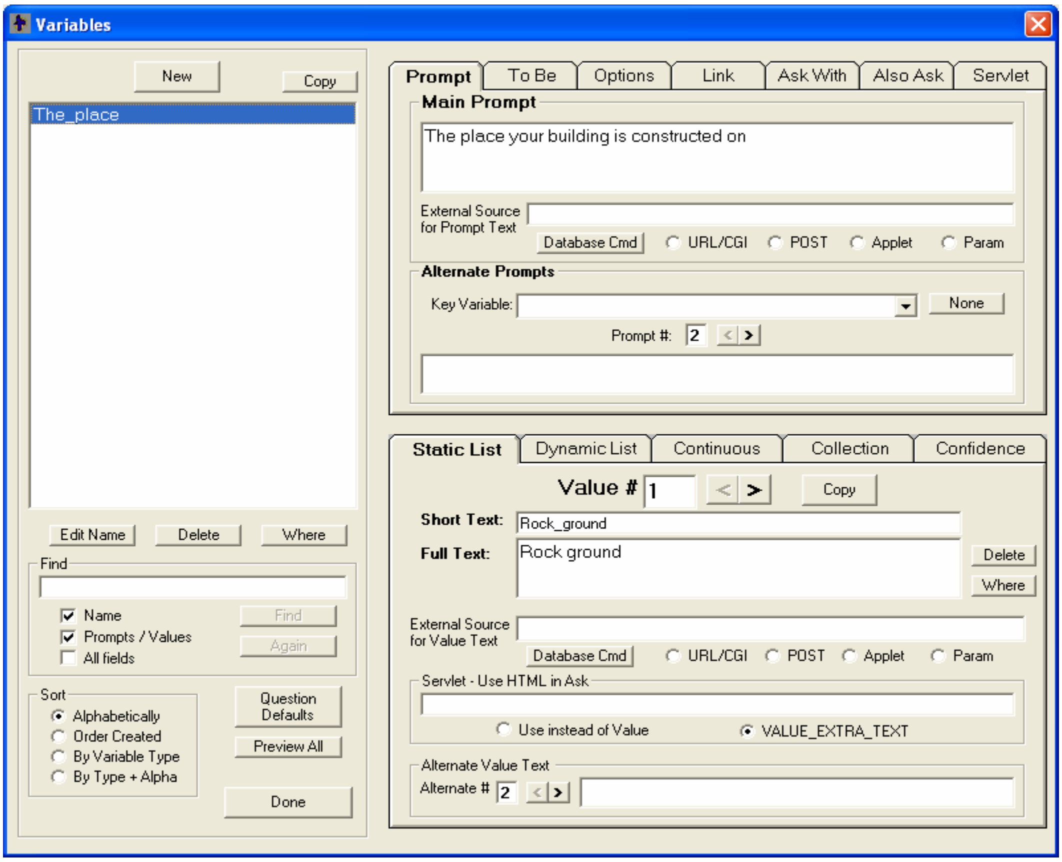


Figure 3.2. Assigning values for static variable, *The_place*

3.1.6.2 Confidence Variable

The confidence variable is a variable that can be assigned confidence value that reflects a degree of certainty [21]. Various formulas can be used to combine the values assigned to an overall confidence for the Variable. In Figure 3.3. a confidence variable called as “Risk” is defined in new variable window.

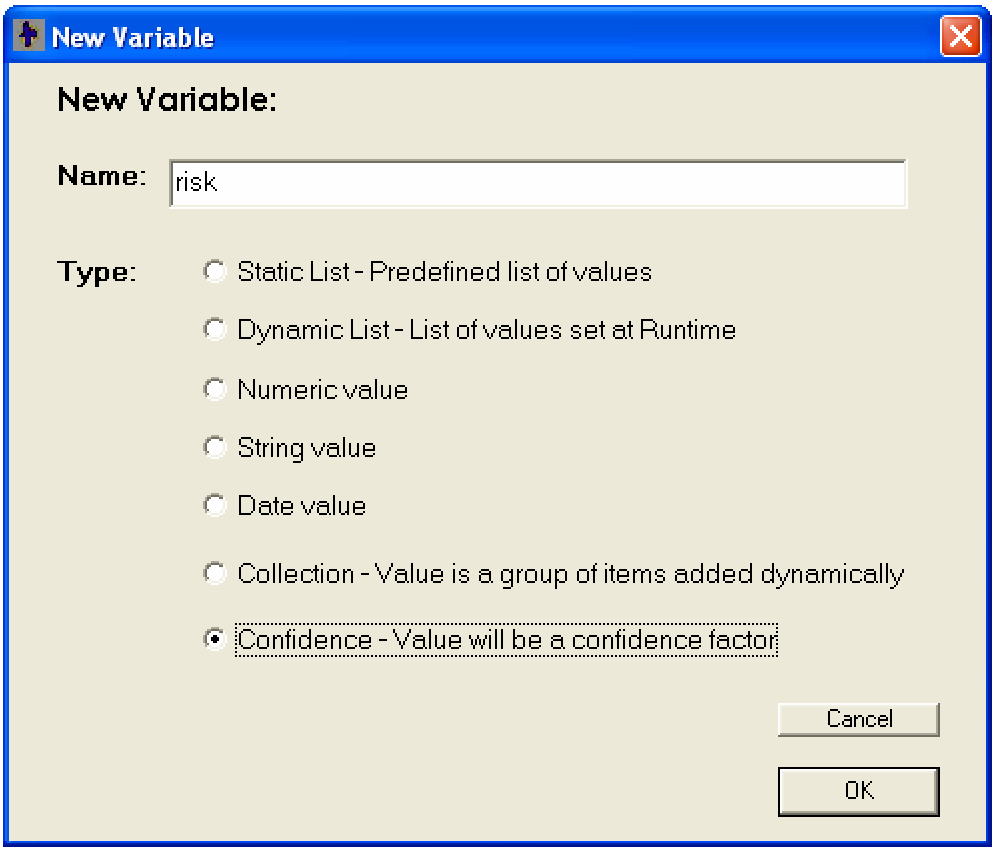


Figure 3.3. Adding the confidence variable

In Figure 3.4. a confidence variable called *risk* to assign risk values for each static variables.

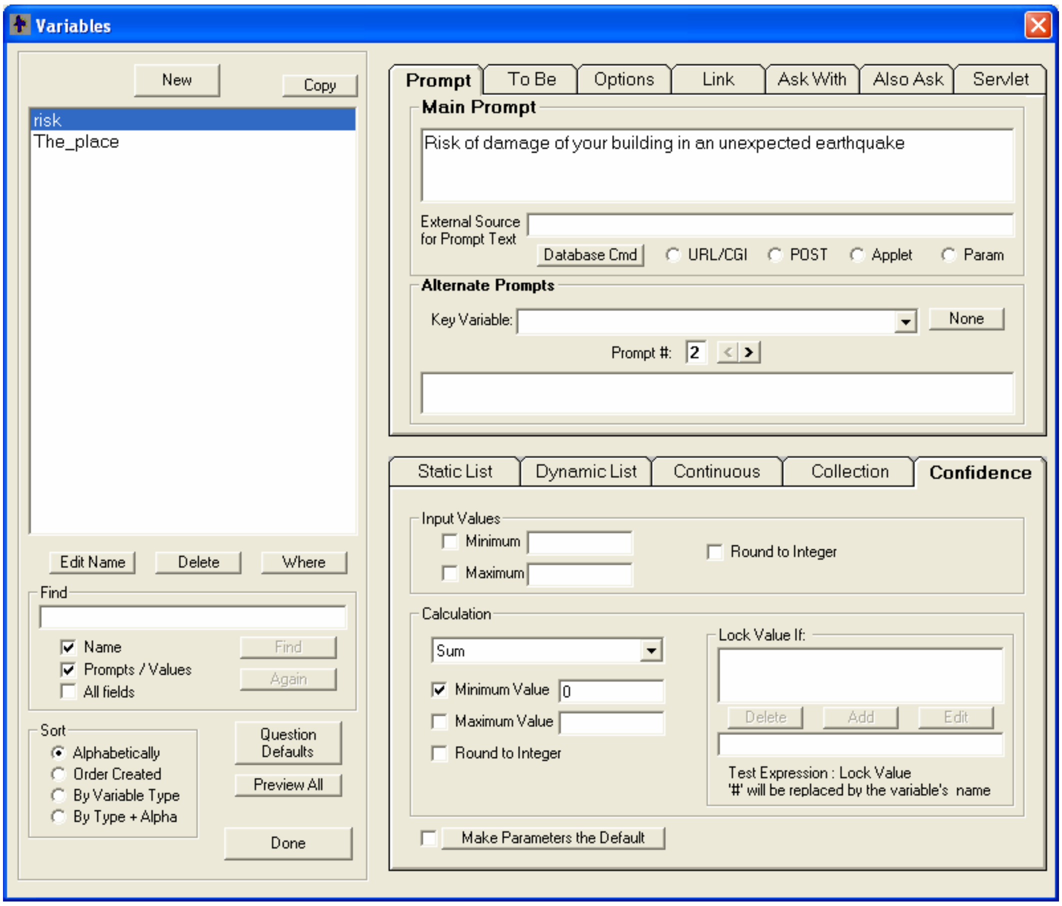


Figure 3.4. Assigning values for confidence variable, *Risk*

3.1.7 System User Interface of How Variables are Asked

When the logic of a system requires that the value for a Variable is asked by the system user. There are a range of options in how a question is asked (radio button, check box, edit field, drop-down list, etc.), how these are formatted, what questions are asked together, and enables other text or graphics to be added to the question. In this study, radio button is used in implementation.

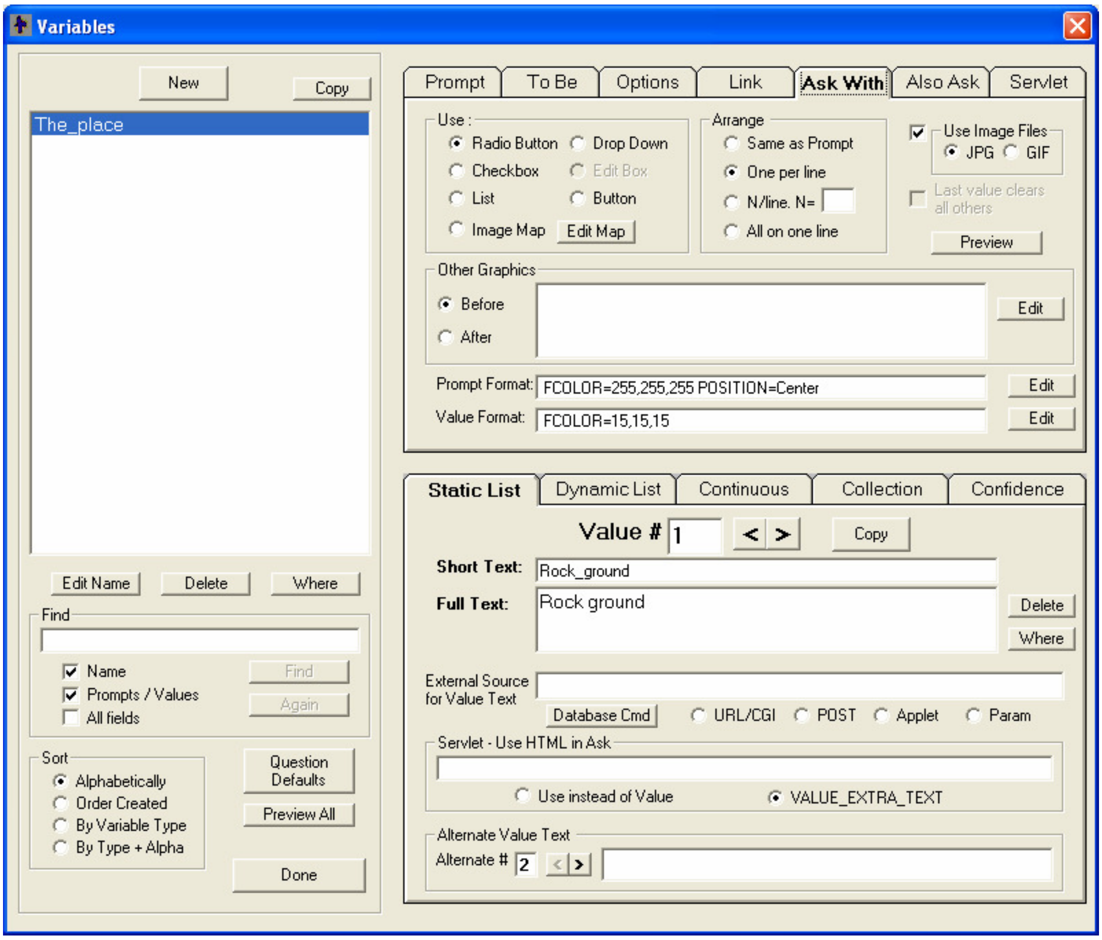


Figure 3.5. Defining variable

In Figure 3.5 we see the value of variables and prompt properties of radio button on the user interface. Additionally the text format and setup options can be changed on this interface.

3.1.8 CORVID Logic Blocks

Exsys CORVID introduces a unique new way to define, organize and structure rules into logically related blocks. These Logic Blocks are blocks made up of rules that can be defined by tree diagrams or stated as individual rules. Each block may contain many rules or only a single one. Logic Blocks provide a convenient way to use a group of related rules from within the expert system. Blocks are created and edited in the CORVID Logic Block window.

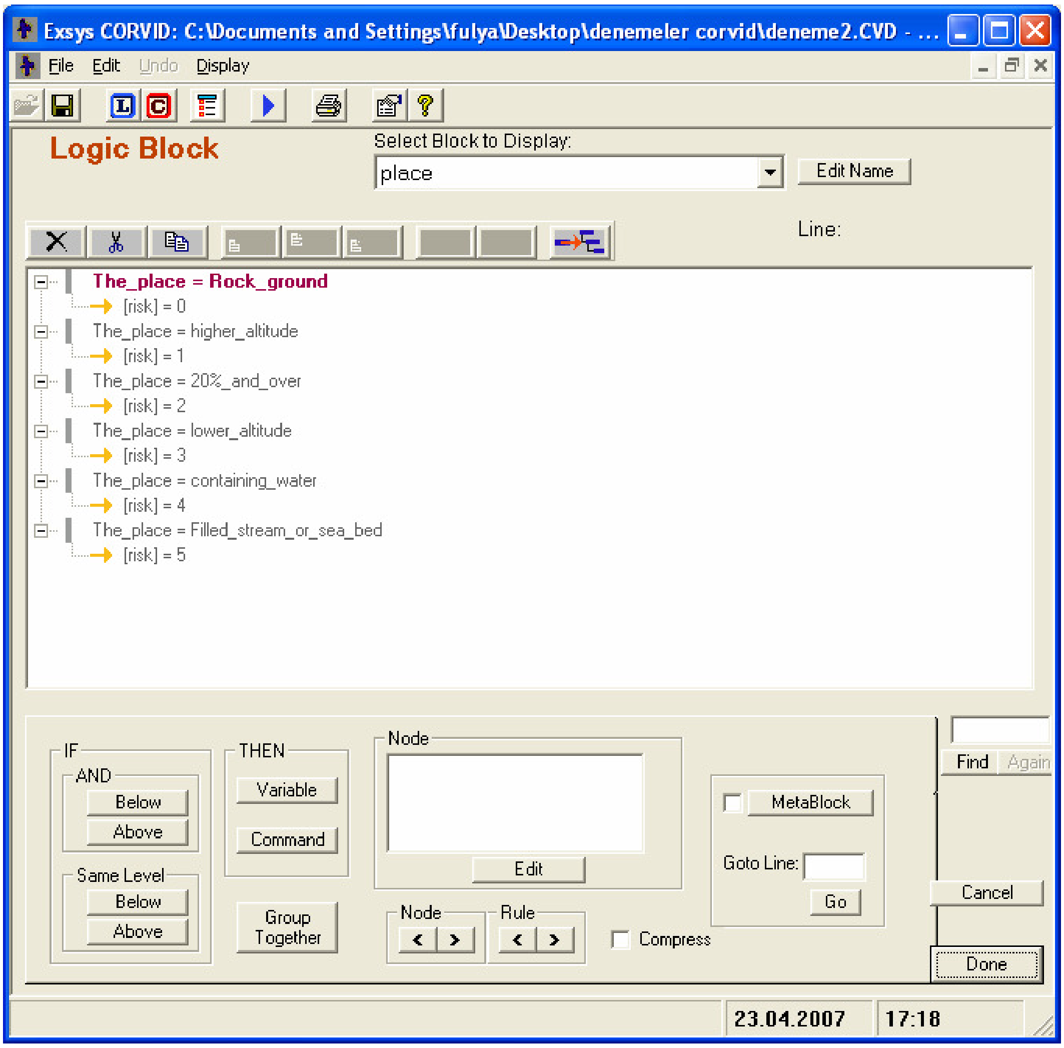


Figure 3.6. Logic block window

The indentation in a block indicates the level of the IF condition in a rule. For example, expressing the single rule:

IF

The place your building constructed on is rock ground

THEN

Risk of damage = 0

One would look like this in a Logic Block as in figure 3.7.

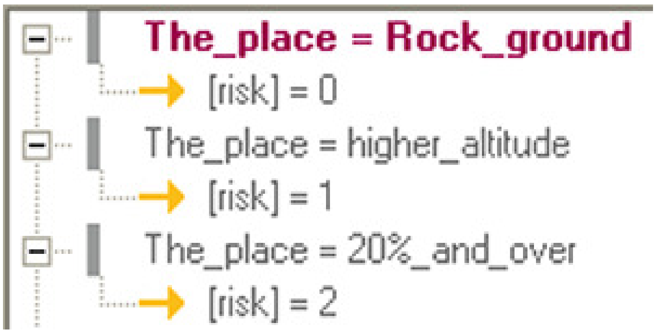


Figure 3.7. Rules displayed on logic block

3.1.9 CORVID Command Blocks

Command Blocks control how a system operates, what actions to take and what order to perform actions. The Logic Blocks in a system have the detailed logic of how to make a decision, but these must be invoked from a Command Block. Most fundamentally Command Blocks control what Variables the system will try to derive values for, and what Logic Blocks will be used to do that.

Command Blocks control the procedural flow of the system including how the system chains, executes the Logic Blocks, loops, and displays results. Command Blocks can be a single command that starts backward chaining on all Confidence Variables; up to more complex systems that involve While and For loops, conditional branching, forward chaining, displaying intermediate results, etc.

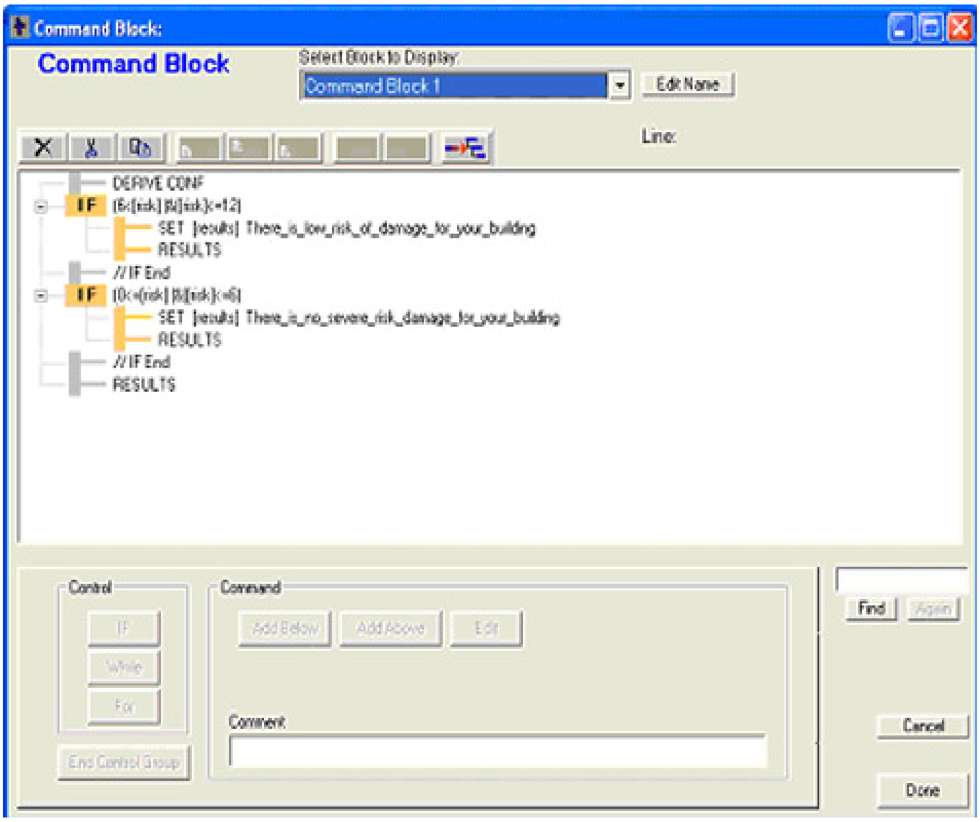


Figure 3.8. Building command block

The Command Block provides a graphical development interface to describe the procedural operations, no matter how complex they get. Command Blocks are built and edited in the CORVID Command Block window. This window displays the command structure in a visual interface.

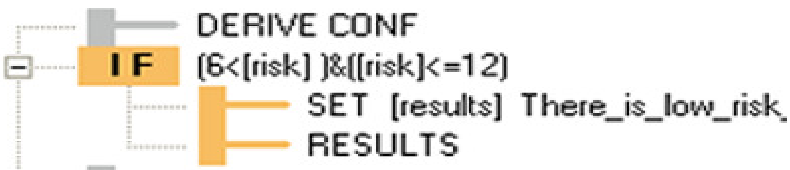


Figure 3.9. Rule displayed on command block

On command block the below tabs (properties) are present.

Variables Tab - Builds commands that set or drive the value for a Variable, or force the Variable to be asked of the user.

Blocks Tab - Builds commands that run a Logic Block in forward chaining mode or as a Command Block.

Reset Tab - Allows data or blocks to be cleared for reuse. This is usually only required in Command Blocks that use WHILE or FOR loops.

External Tab - Allows commands to be added that call other applets.

Control Tab - Provides ways to control the flow of execution and include/exclude blocks from the backward chaining.

Results Tab - Provides two ways to display the results of a system - a default results screen or a file display.

Title Tab - Allows the Interface Commands to be added that can be called to display a title at the start of a system run session.

Let explain the usage of these commands in our thesis study. First, variables that will be used in the output of the system, are selected (Figure 3.10)

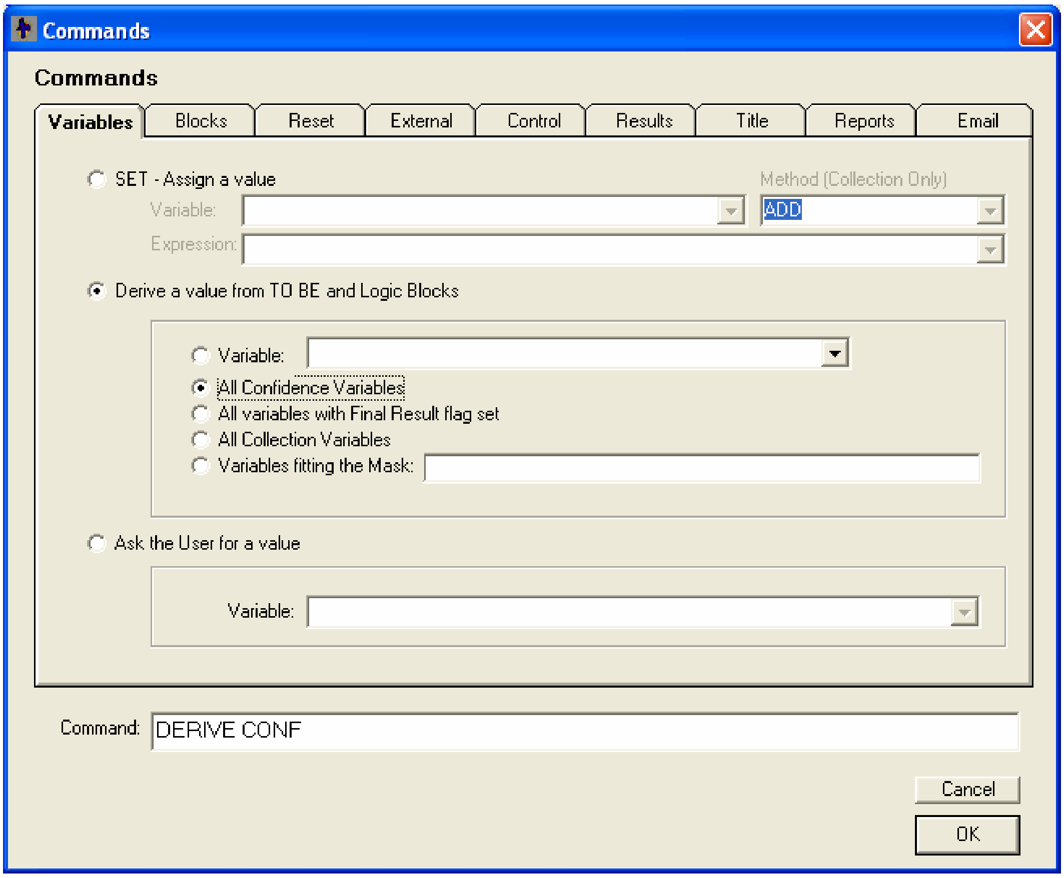


Figure 3.10. Command block with tabs

Second, the value setting is performed due to the total of risk that will effect the output. The "Add To Block" window in Figure 3.11 is used to determine the interval of risk that will imply an output. After the determination of risk interval an output should be assigned to this interval. This wil be performed at the third step. In figure 3.12 we see the third step that will assign an output for the given interval. After this assignment, the next thing to be done is to tell the program to make these outputs readable by the users. The "Results" tab in figure 3.13 is used for this action.

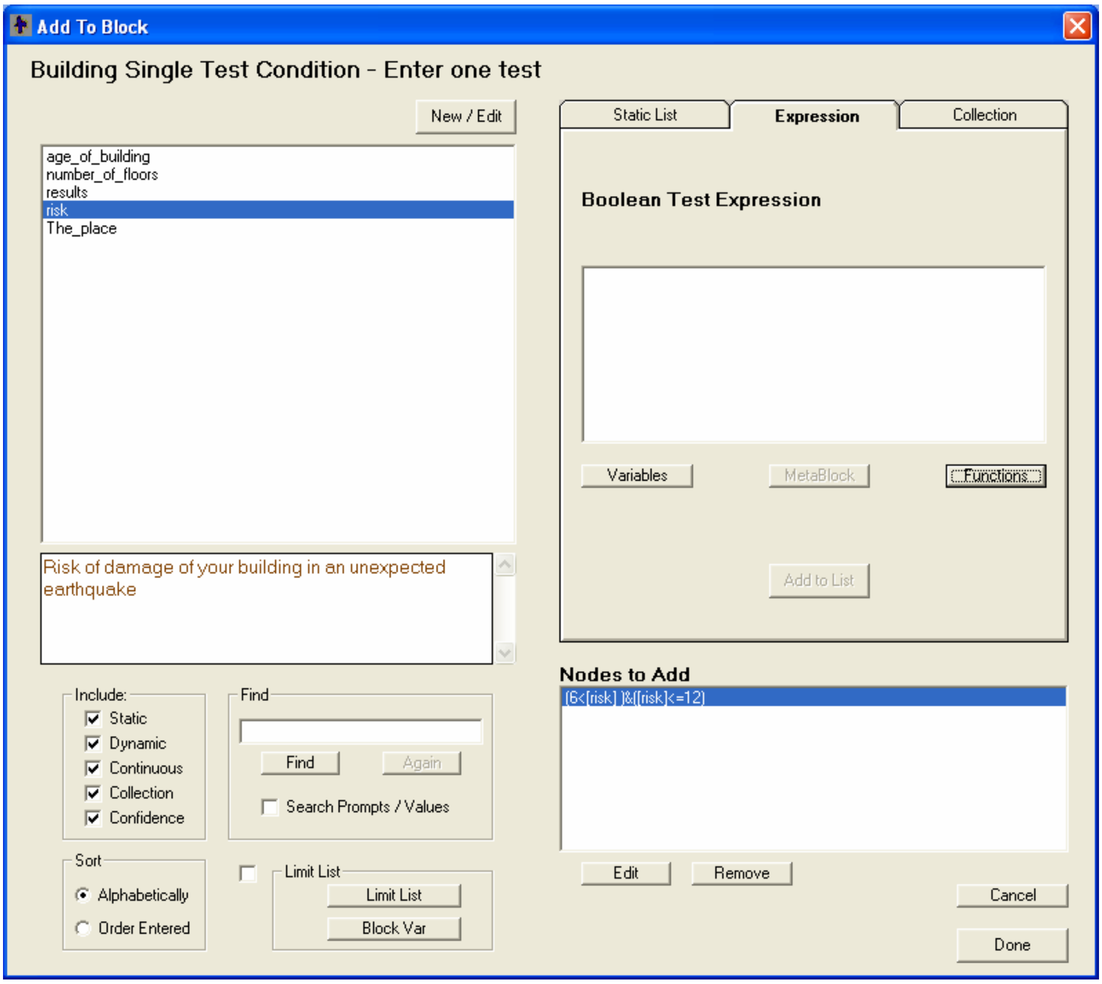


Figure 3.11. Building single test condition

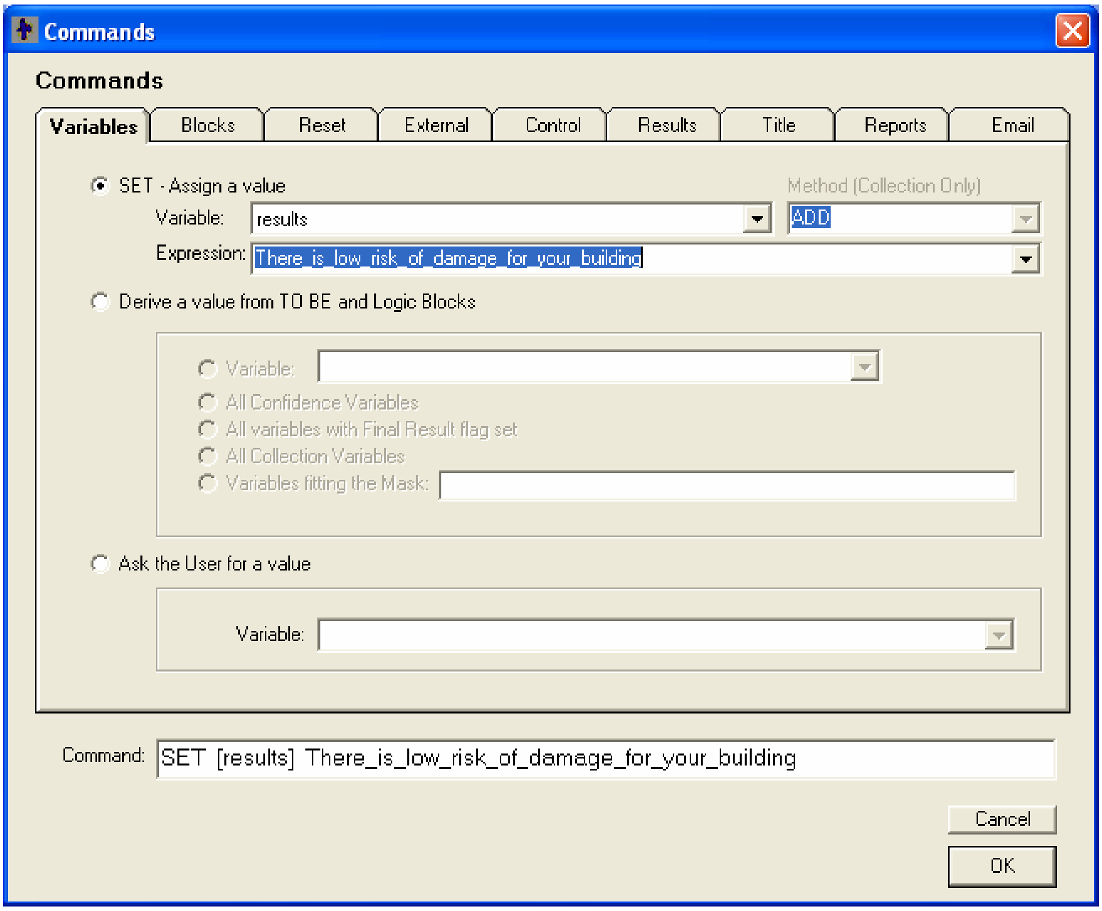


Figure 3.12. Assigning value to the variable *results*

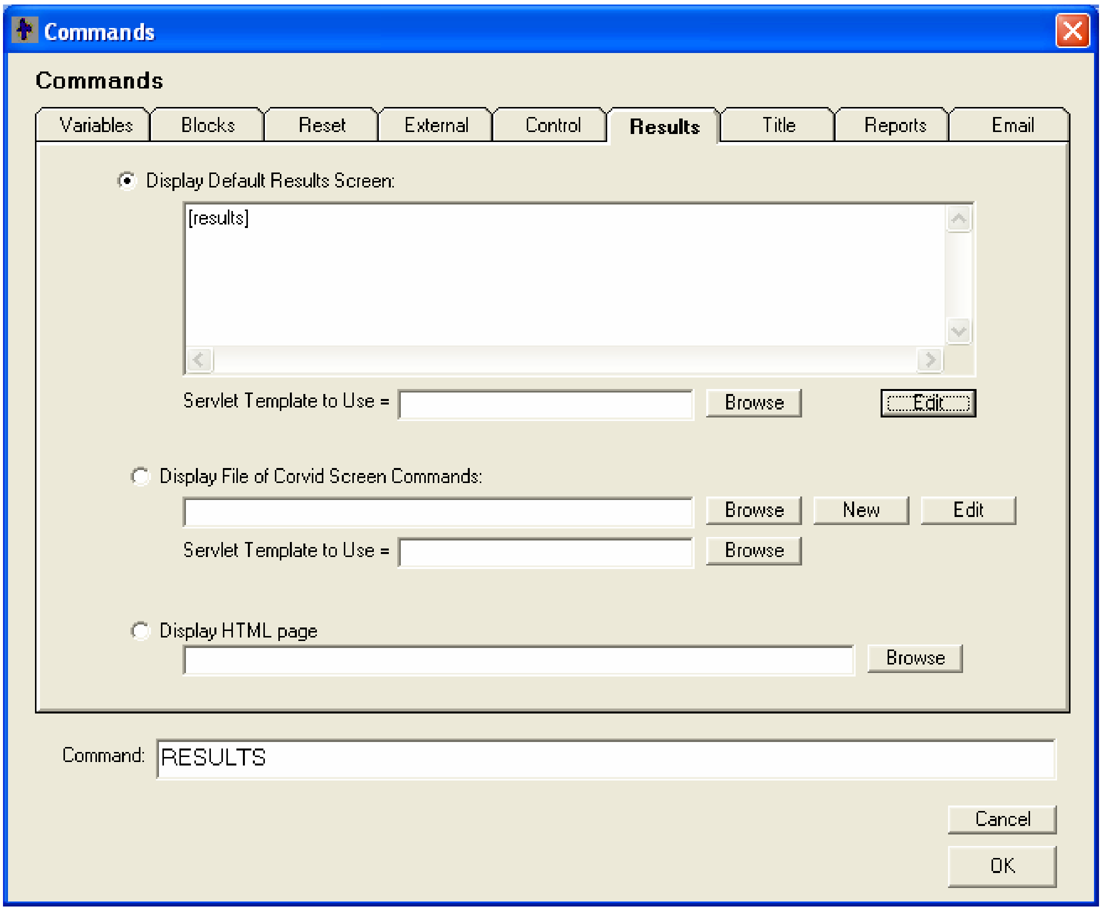


Figure 3.13. Results tab on command block

After all required settings are performed the resulting "command block" diagram is seen in figure 3.14. Now this basic corvid system is ready for users.

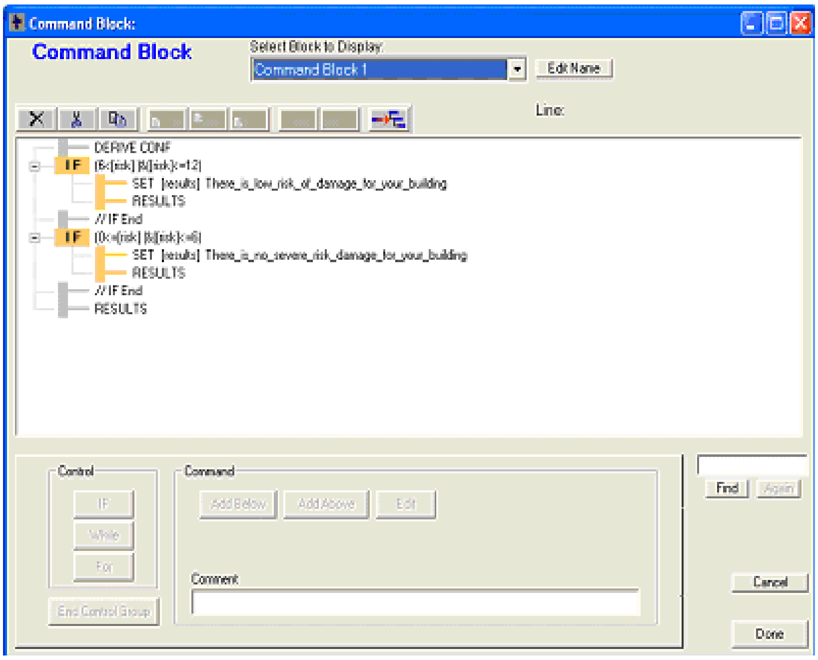


Figure 3.14. The display of command block after all settings

3.2 Implemantation For Risk Manegement of Disaster

In Turkey, especially before 1999 many buildings are constructed breaking the construction regulations. Therefore, the possibility of damage of such buildings is high. The determination of the amount of damage of these buildings would lead to the preparation of disaster management and required maintenance processes. The expert system developed for this purpose askes some critical questions [22] to the users to determines the risk of damage and would propose some comments.

3.2.1 User interface

As shown in Figure 3.15, the first screen consists of the definition of the goal of the system.

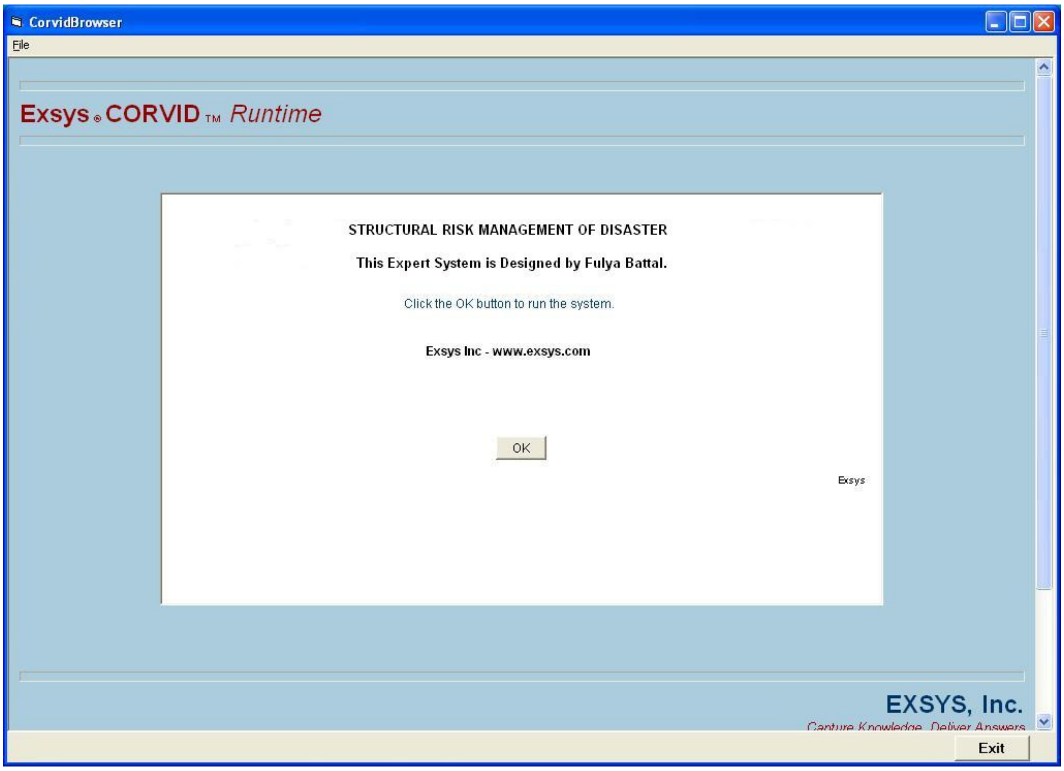


Figure 3.15 First Window in Run Time

Then the first question after clicking “OK” button is as seen in Figure 3.16

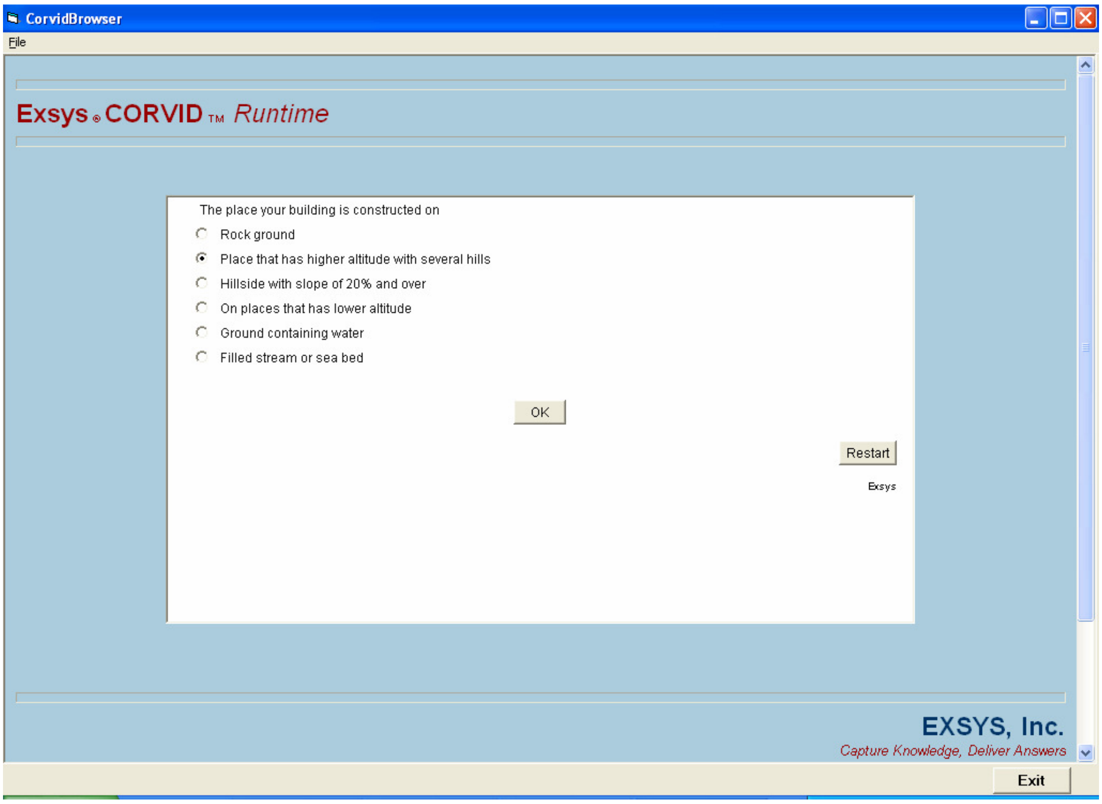


Figure 3.16. First question in the system.

This question askes the type of the ground on which the building is constructed. The choices are ordered from *a* (most safe) to *f* (least safe). The most safe ground type is rocky groud. As the groud gets softer the safety factors are decreasing and therefore the risk of damage is increasing.

Furthermore, the user cannot select more than one choice. System gets only one risk value for each question to use for commenting on the result. Note that if the selection is sandy ground then the resulting comment is not strictly “the building will get damage during an earthquake”. Instead the system will take other risk fators into account. For example if the building is constructed considering the sandy ground and all the safety requirements for the sandy ground are met then the building would probably donot get any damage during an earthquake. The expert system is capable of determining this result evaluating the answers to the other questions.

Figure 3.17 is the second question that is asked to the users. The age of the building is asked to the user. When the buildings get older the roof and outer plaster of the building get weaker and may result in oxidation in the skeleton. If there had been no maintenance of these parts the rain and moisture in air will reach the steel skeleton and lead to oxidation. The question for the age of building is asked to decide whether this oxidation worsens the strength of building and therefore increase the risk of damage.

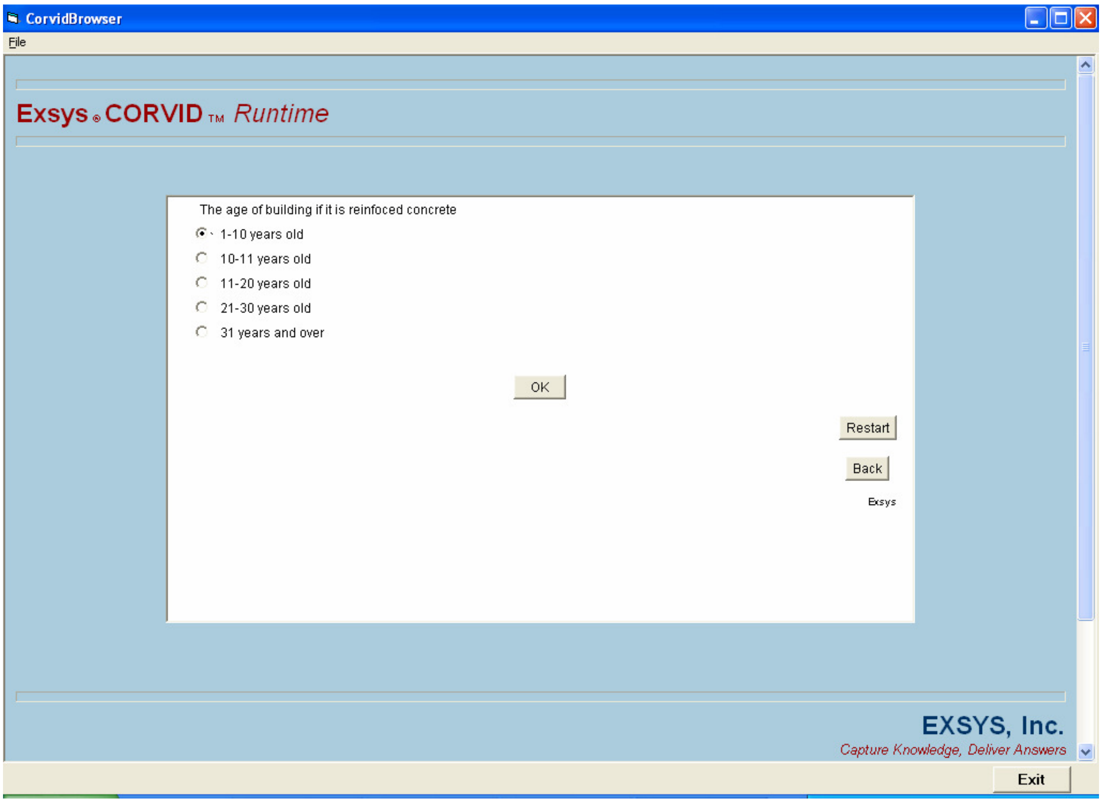


Figure 3.17. Second question.

In the third question (Figure 3.18) the type of the framework of the building is asked.

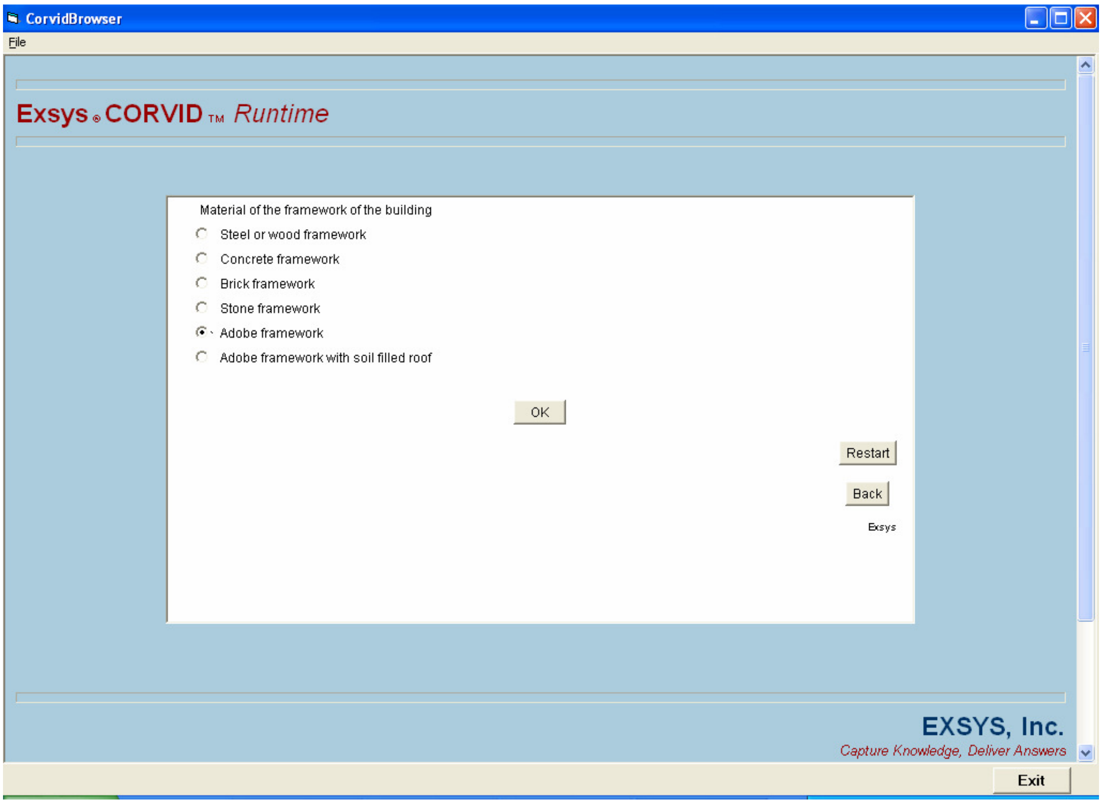


Figure 3.18. Third question.

After the installation of framework, the choices in Figure 3.18 are used as the wall material. Steel and wood are more safe with respect to other materials since they have the required elasticity. In concrete buildings iron is the part that carries the main load. However, iron is not as strong as the steel. Note that buldings made of wood do not have as much mass as the concrete buildings. Therefore buildings made of wood are safer than the concrete buildings during an earthquake. The other wall materials brick, stone and adobe are softer or harder than the required elasticity and hence less safer than the steel, wood and concrete.

In Figure 3.19 (question 4) the basement and the moisture level are asked. The existence of the basement increases the strength of the building since the it can hold the base better. However, if the moisture in the basement harms the framework than the strength of the building weakens. Additionally, if there exist water accumulation in the basement then liquefaction of the base would be observed and therefore the danger of damage would increase.

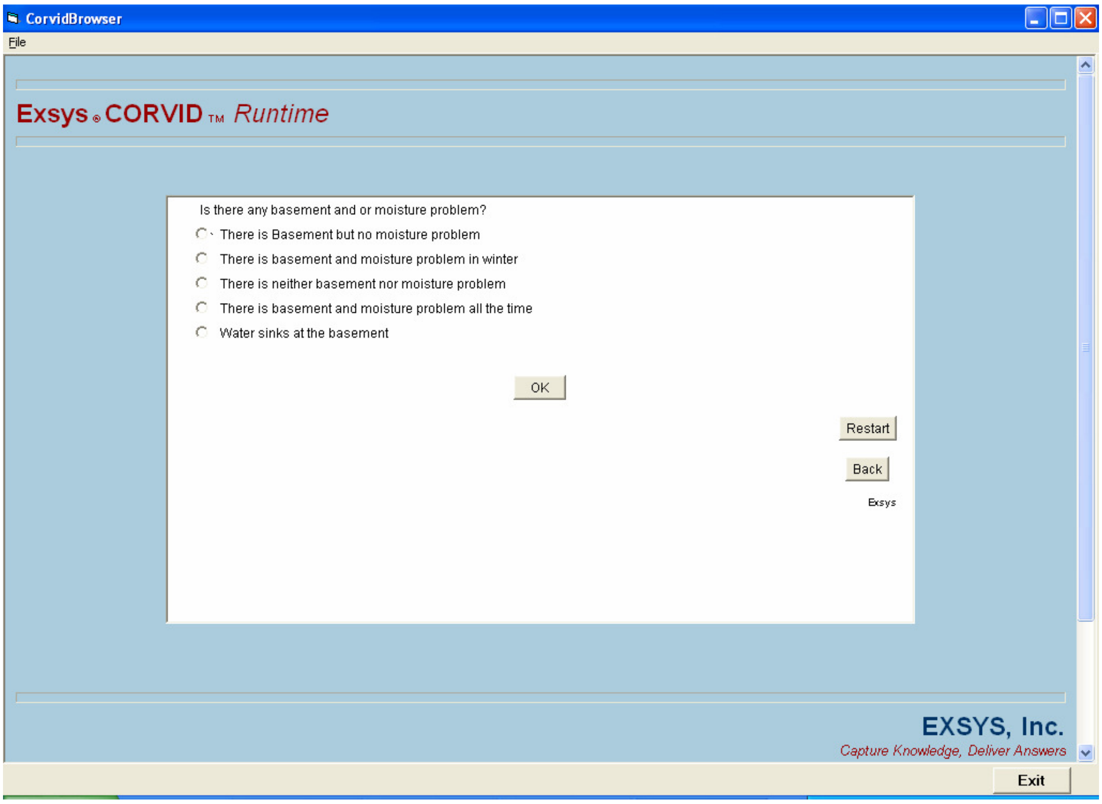


Figure 3.19 Fourth question

The fifth question is the number of floors including basement (Figure 3.20)

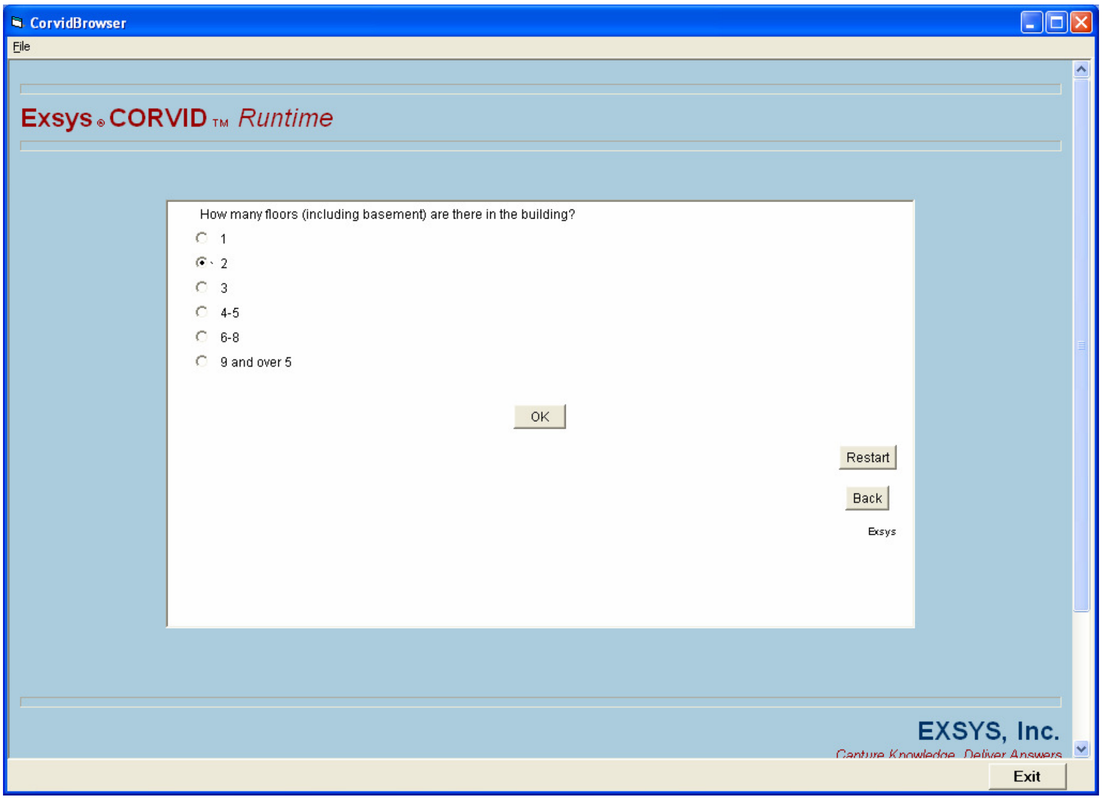


Figure 3.20 Fifth question

As the number of floors increase the load on which the buliding should carry incerases. If there exists faults and defectives in the project of building than the load on the building would lead to damage during an earthquake. Therfore as the number of floors increase the risk of damage of the building would increase.

In table 3.1 and Figure 3.21 we see the number of buildings that had damage during the 1999 Duzce earthquake ordered with respect to the number of floors.

Table 3.1 The number of buldings that had been damaged during Düzce Earthquake classifed with respect to their number of floors.

	Number of Floors							
	1	2	3	4	5	6	7	**Total**
Not Damaged	25	38	21	17	13	2	1	117
Less Damaged	24	73	59	32	22	6	0	216
Intermediate Damaged	3	10	18	26	21	4	0	82
Very Damaged	10	5	9	22	26	2	2	76
Some destructed	2	5	3	14	4	2	1	31
Debris	4	14	15	47	56	16	2	154
Total	68	145	125	158	142	32	6	676

After this earthquake the maximum number of floors is set to 3 by local regulators.

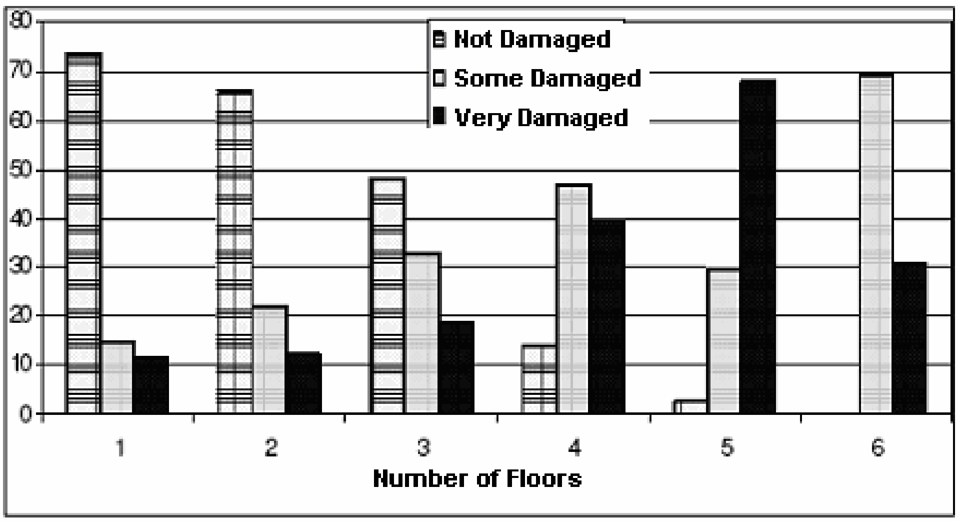


Figure 3.21 The number of buldings that had been damaged during Düzce Earthquake classifed with respect to their number of floors.

In the sixth queston the properties of the basement is asked (Figure 3.22).

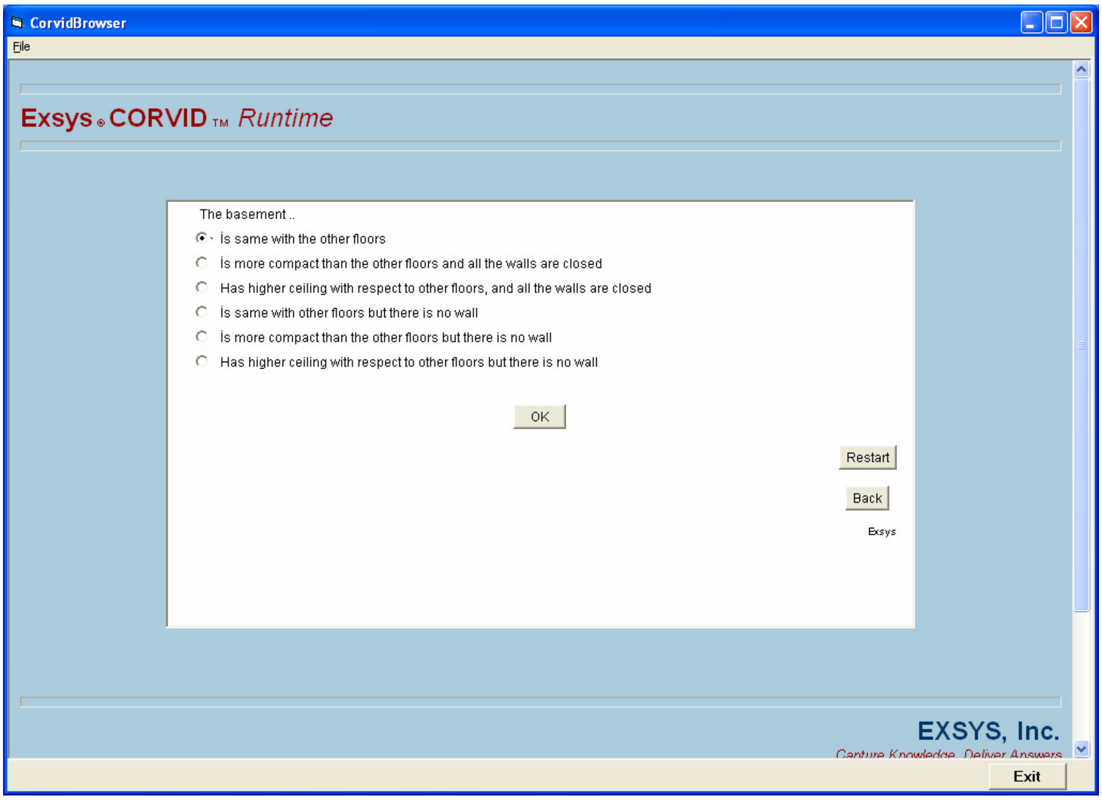


Figure 3.22. Sixth question

The basement should be as wide as or wider than the other floors in a healty building. In the case of narrower basements the stability of the building worsens and the basement may not carry the floors above it. Therefore the risk of damage would increase in the case of narrower basements.

The overhangings are investigated in the seventh question. (Figure 3.23)

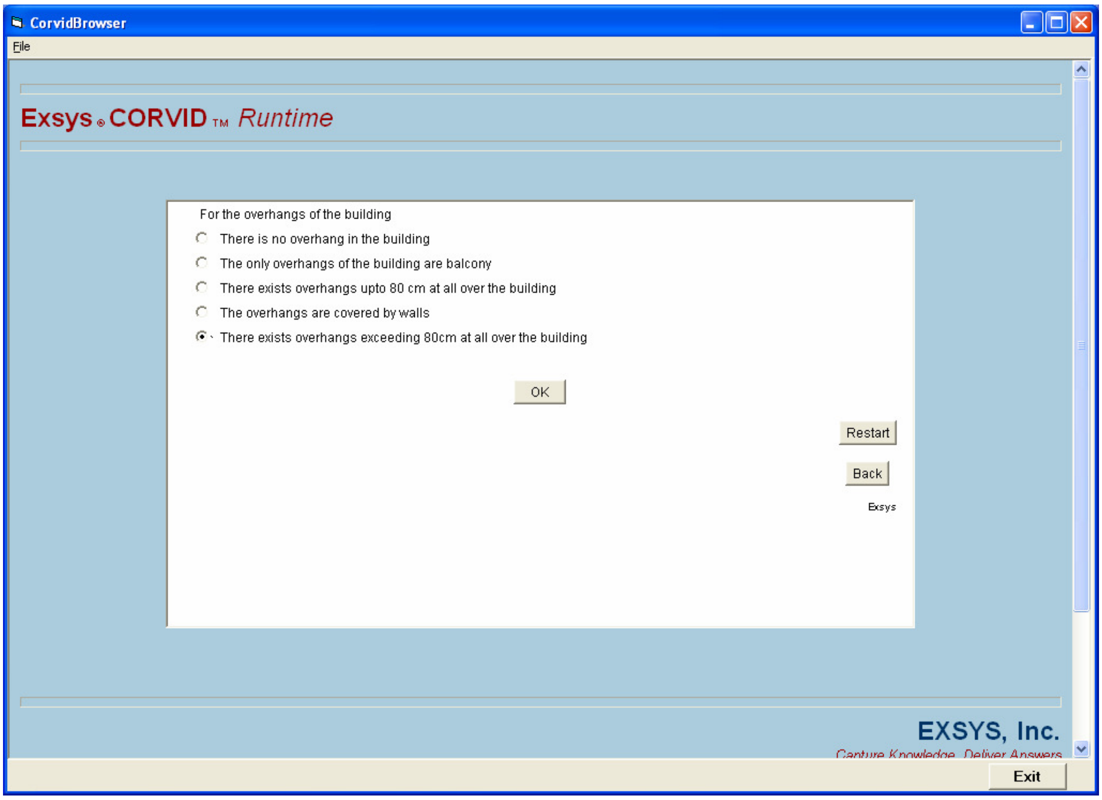


Figure 3.23 Seventh question

In multiple-floored concrete buildings the balconies out of the original framework would worsen the stability. If the balcony is constructed with heavy concrete parapets then the mass center will heighten and therefore, the stability would worsen. In the previous earthquakes the buldings with heavier overhangings had more damage with respect to the buildings with lighter overhangings.

In figure 3.24 we see the eighth question.

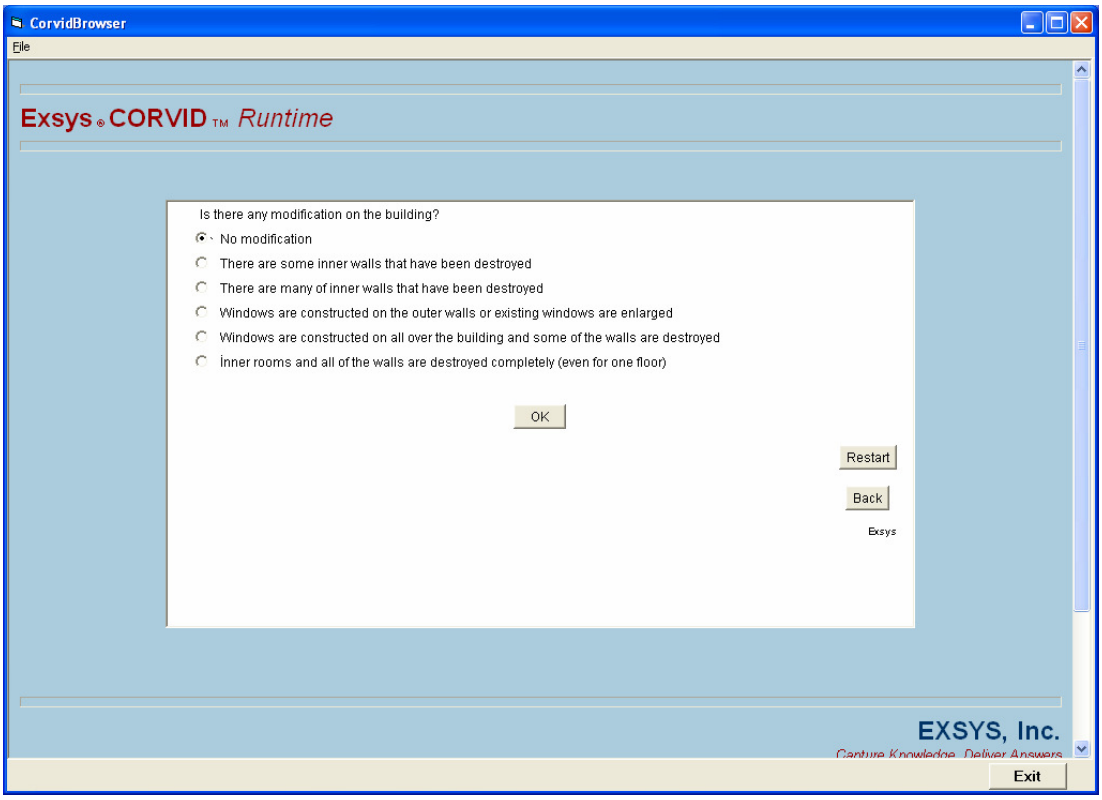


Figure 3.24 Eighth question

In some buildings the columns and rows may be destroyed due to requirements for wider usage area (i.e. stores, galleries). These would lead worse static equilibrium in the carrier system of building and therefore cause more risk o damage.

The usage type of the building is asked in Figure 3.25 (quesion 9).

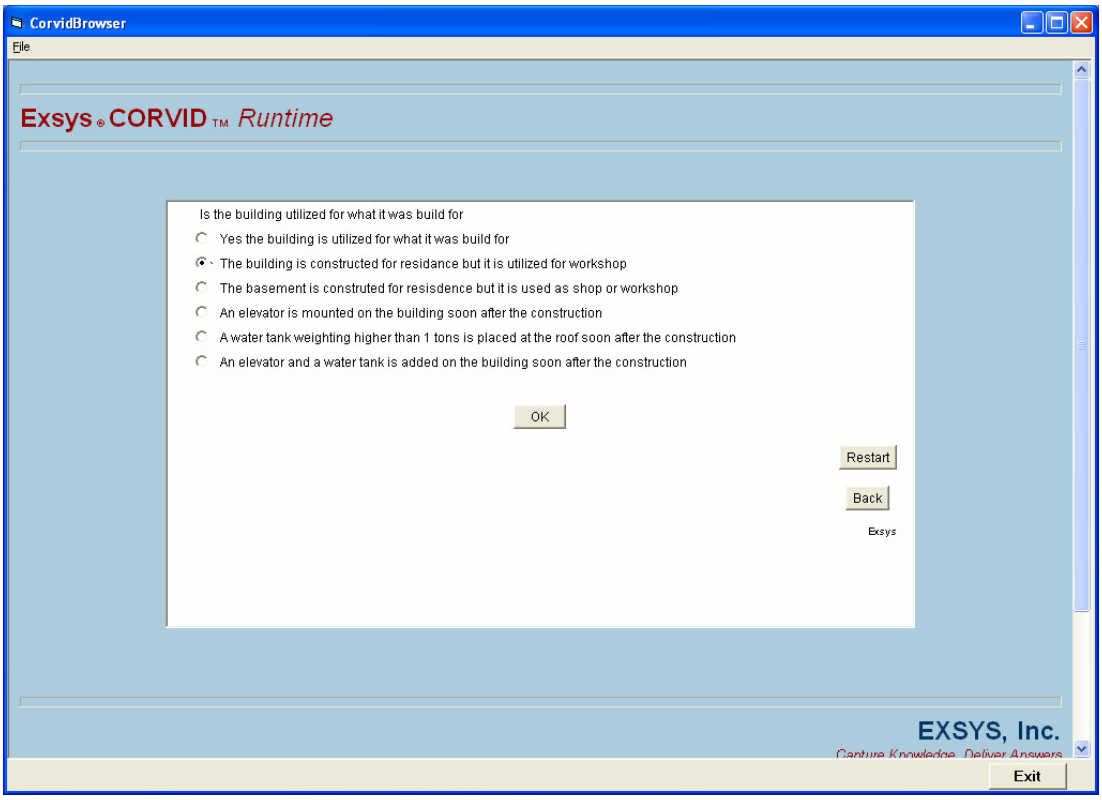


Figure 3.25 Ninth question

Due to the usage purposes the design of buildings differ and these differences lead to different vertical and horizontal stresses on the framework. For example if the building is constructed fror residance and it is used as store or gallery than probably much more stresses will occur on the framework. So the static stability of the building worsens and result in risk of damage during an earthquake. The original framework should be kept unchanged and the usage purposes of the building should not change.

As seen in Figure 3.26 the basement of the buildings which are used as shop are destroyed while the other floors are undamaged. Since the basements of these buildings are weak, most of the energy absorbtion is performed by the basement and so it collapsed.

Figure 3.26 The basements are collapsed while the other floors are healty

In Figure 3.27 the question is about some of the modifications performed on the building

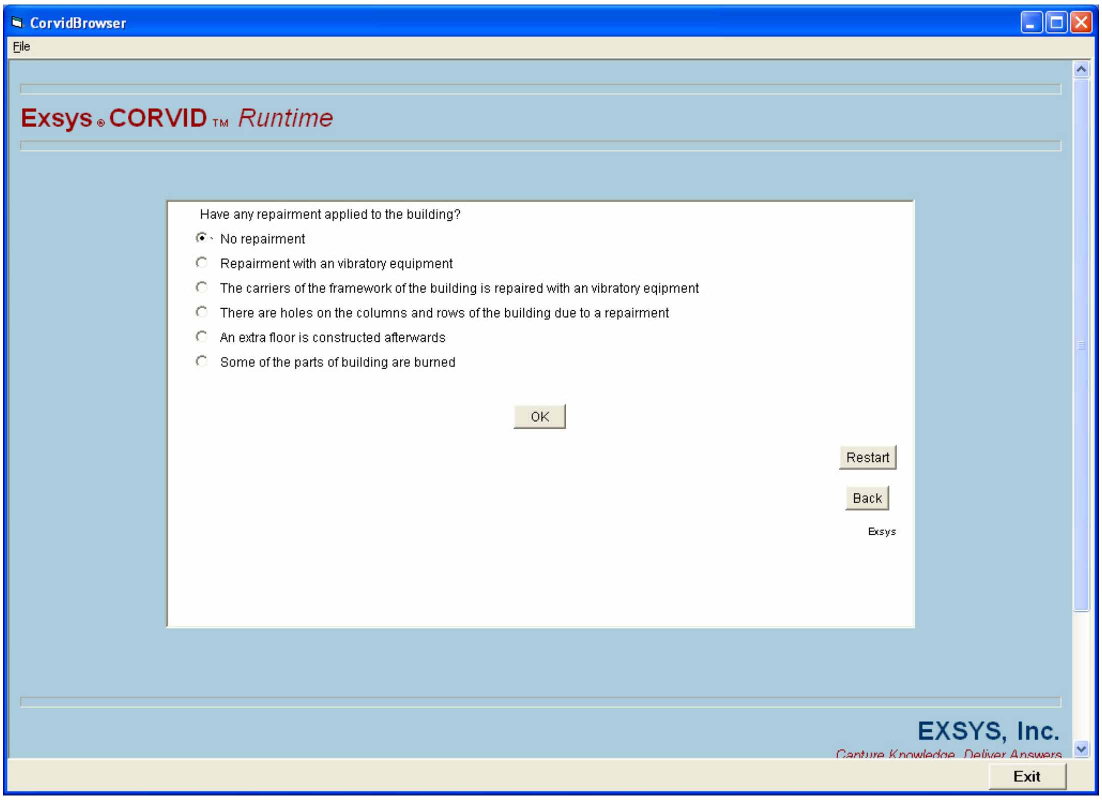


Figure 3.27 Tenth question

Some of the modifications on the framework and/or remaning parts of the building will result in insatbility of the buildings. Adding one more flor on the buildings will result in additional load on the framework and therefore corrupt the static stability of the building. So the dynamic strength of the building during an earthquake will worsen.

On other stability worsening event is the occurence of a fire in the building. During a fire the huge heat transfer to the metal parts of the building would result in melting of these parts and therefore lead to weakened strength of these parts.

Question 11 (Figure 3.28) is about the damage of the building occured during a previous disaster.

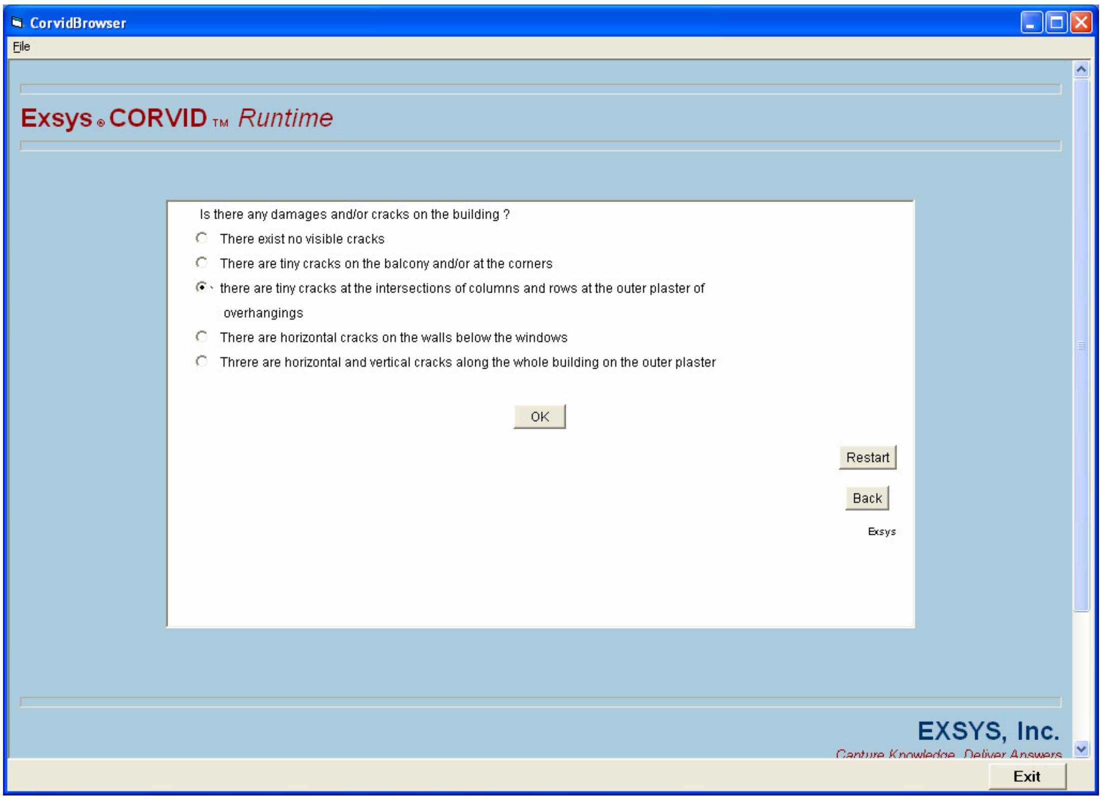


Figure 3.28 Eleventh question.

During the natural disasters some damage may occur on the buildings (Figure 3.29). These damages may lead to danger of harm during the next disaster/earthquake. Therefore, the damaged parts should definetly be repaired. If repairment/strengthening of these parts are not performed then the rain water leaking in the cracks would result in oxidation and worsen the strength of framework. To prevent such situations building owners should perform repairments as soon as possible with the help of expert if required.

Figure 3.29 Very dangerous crackes on the columns of building.

The outline and shape of the building is investigated in the 12th question (Figure 3.30).

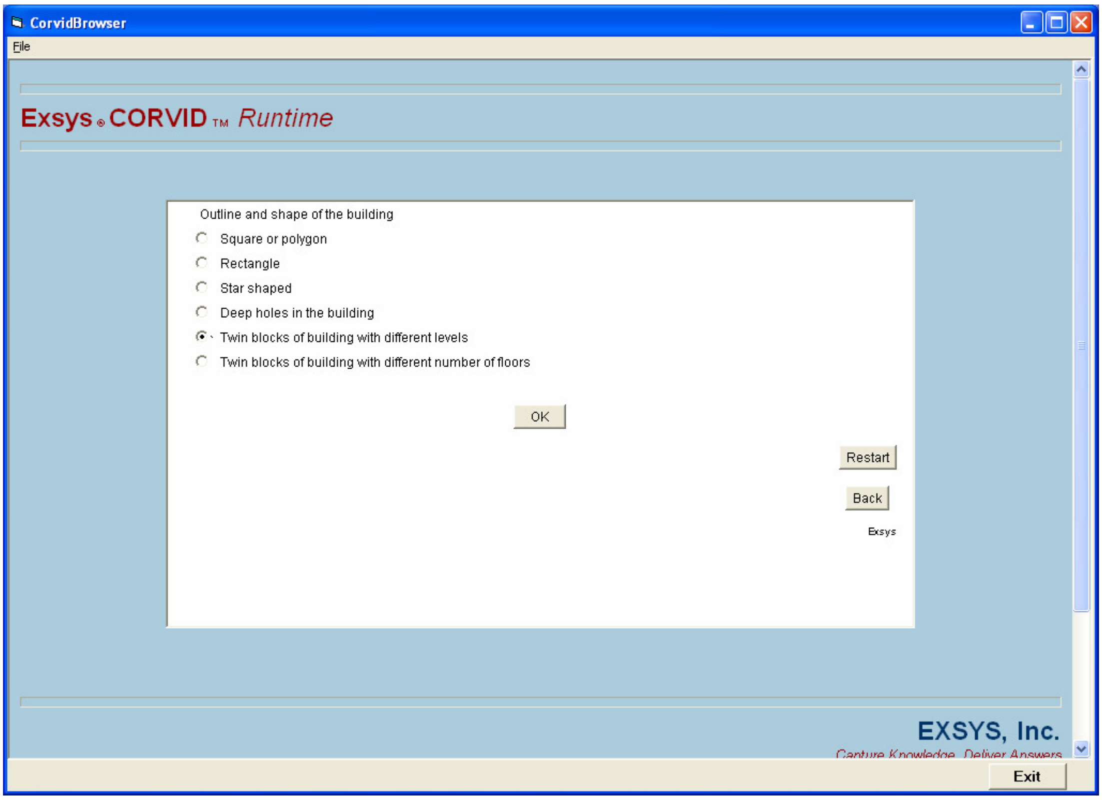


Figure 3.30. Twelfth question

For square shaped buildings the vertical and horizontal load are stable during any acceleration due to an earthquake. However, the rectangle and star shaped buildings are not as stable as the square shaped ones. Therefore the rectangle or star shaped buildings are more risky during earthquakes. On the other hand, large holes in the building would result in non-homogen distribution of the load and by the way higher risk of damage.

If the level of the floors of the twin buildings are not exactly same then during an earthquake due to different accelerations of the buildings will lead to hammer effect between buildings. If the levels were same the crashes of the columns and rows would happen face to face and so the resulting accelerations would be less damaging. Therefore, the level difference should be in a safe interval for twin buildings.

After the last -12th - question the system calculates the total risks and states a comment about the risk level as seen in Figure 3.31.

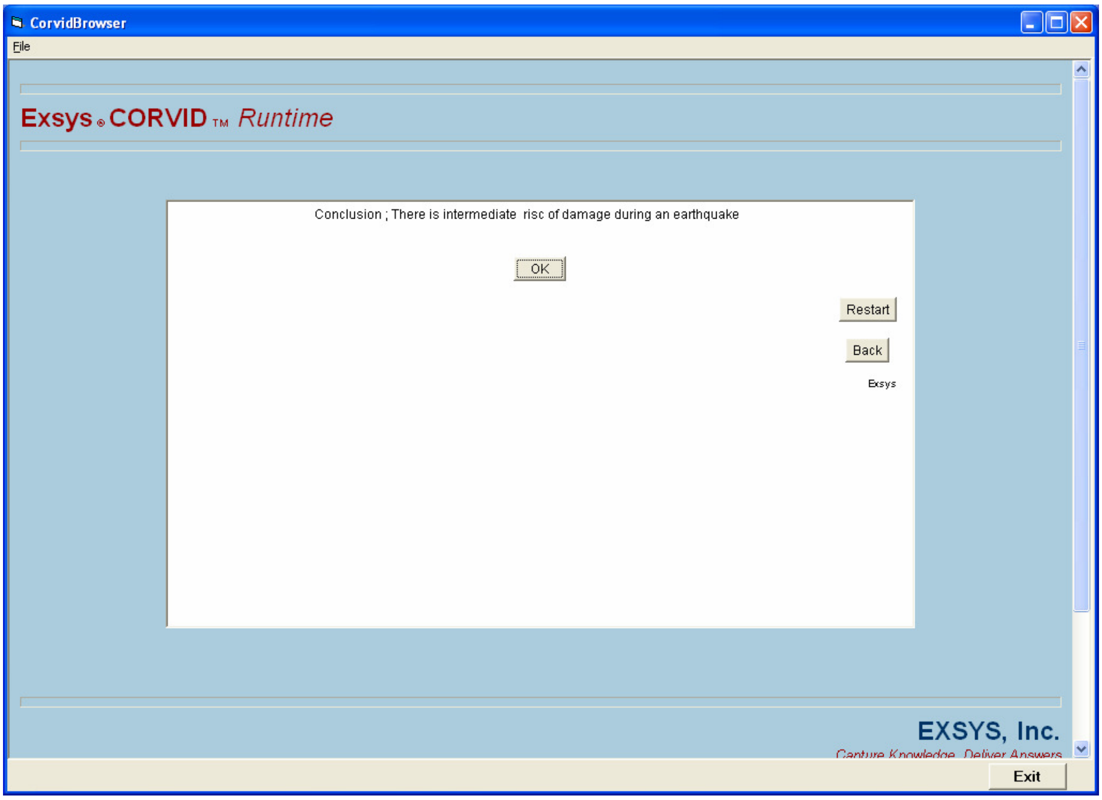


Figure 3.31 Command window

As seen in the comment window, the user would get the risk of damage level during an earthquake. The system offers some precautions due the results. All of the questions and the decision procedure are in Appendix A.

After the commenting and stating precautions the system finishes its work. The user may exit from the program. If the user need to use system again she/he should restart the program.

CONCLUSION

In this thesis, an expert system that evaluates the risk of damage of buildings during an earthquake is studied. The system asks some critical questions to the user. The questions are about the ground type the building is constructed on and structural properties of the buildings. The answers to these questions are evaluated to conclude on the risk of damage of the buildings and advise for the necessary precautions to decrease the damage of the building to the user.

The damage of the buildings during the earthquake occurred in Marmara in 1999 showed that most of the damages were due to the invalid structures of the buildings. To determine the risk of damage of buildings, first the possibilities of damages of buildings under different structural deficiencies are determined. Then a knowledge base is constructed with the facts, heuristics and decisions about the risk of damage of buildings.

The rules and parameters are determined due to the knowledgebase and utilized in the expert system called, *Structural Risk Management and Disaster*. This expert system may be used in determining the risk of damage of buildings including government buildings, hospitals, residences etc. The determination of the risk of damage is important to get ready for any possible earthquake. The precautions in such a risky case would be guiding to engineering experts for strengthening the building.

In addition to this study, the questions may be more detailed to develop the abilities of the expert system. Furthermore, the addition of remote sensing to this study would result in an expert system with immediate problem diagnosis. Utilization of satellite images for determining the changes on the structures of buildings can be used in such a system. The developments of this thesis study may be used in city and regional planning by defining daily changes and immediate risk determination.

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APPENDIX-A

The Questions Asked to the User

1- The place your building is constructed on

Rock (rocky) place (The risk faktor = 0)
Places that has higher altitude with several hills (The risk faktor =1)
Surfaces with slope of 20% and over (The risk faktor =2)
On places that has lover altitude (The risk faktor =3)
Ground containing water (The risk faktor =4)
Filled stream or sea bed (The risk faktor =5)

2- The age of building if it's concrete

1-10 years old (The risk faktor = 0)
10-11 years old (The risk faktor = 1)
11-20 years old (The risk faktor = 3)
21-30 years old (The risk faktor = 4)
31 years and over (The risk faktor = 5)

3- Material of the framework of the building

Steel or wood framework (The risk faktor = 0)
concrete framework (The risk faktor = 1)
brick framework (The risk faktor = 2)
stone framework (The risk faktor = 3)
adobe framework (The risk faktor = 4)
adobe framework with soil filled roof (The risk faktor = 5)

4- Is there any basement and/or mositure problem

There is Basement but no moisture problem (The risk faktor = 0)
There is basement and moisture problem in winter (The risk faktor = 1)
There is neither basement nor moisture problem (The risk faktor = 2)
There is basement and moisture problem all the time (The risk faktor = 3)
Water sinks at the basement (The risk faktor = 5)

5- How many floors (including basement) are there in the building?

1 (The risk faktor = 0)
2 (The risk faktor = 1)
3 (The risk faktor = 2)
4-5 (The risk faktor = 3)
6-8 (The risk faktor = 4)
9 and over (The risk faktor = 5)

7- For the overhangs of the building

There is no overhang in the building (The risk faktor = 0)
The only overhangs of the building are balcony (The risk faktor = 1)
There exists overhangs upto 80 cm at all over the building (The risk faktor = 3)
The overhangs are covered by walls (The risk faktor = 4)
There exists overhangs exceeding 80cm at all over the building (The risk faktor = 5)

8- Is there any modification on the building

No modification (The risk faktor = 0)0
There are some inner walls that have been destroyed (The risk faktor = 1)
There are many of inner walls that have been destroyed (The risk faktor = 2)
Windows are constructed on the outer walls or existing windows are enlarged (The risk faktor = 3)
Windows are constructed on all over the building and some of the walls are destroyed (The risk faktor = 4)
İnner rooms and all of the walls are destroyed completely (even for one floor) (The risk faktor = 5)

9- Is the building utilized for what it was build for

Yes the building is utilized for what it was build for (The risk faktor = 0)
The building is constructed for residance but it is utilized for workshop (The risk faktor = 1)
The basement is construted for resisdence but it is used as shop or workshop (The risk faktor = 2)
An elevator is mounted on the building soon after the construction (The risk faktor = 3)
A water tank weighting higher than 1 tons is placed at the roof soon after the construction (The risk faktor = 4)
An elevator and a water tank is added on the building soon after the construction (The risk faktor = 5)

10- Have any repairment applied to the building

No repairment (The risk faktor = 0)
Repairment with an vibratory equipment (The risk faktor = 1)
The carriers of the framework of the building is repaired with an vibratory eqipment (The risk faktor = 2)
There are holes on the columns and rows of the building due to a repairment (The risk faktor = 3)
An extra floor is constructed afterwards (The risk faktor = 4)
Some of the parts of building are burned (The risk faktor = 5)

11- Is there any damages and/or cracks on the building

There exist no visible cracks (The risk faktor = 0)
There are tiny cracks on the balcony and/or at the corners (The risk faktor = 1)
There are tiny cracks at the intersections of columns and rows at the outer plaster of overhangings (The risk faktor = 2)
There are horizontal cracks on the walls below the Windows (The risk faktor = 3)
Threre are horizontal and vertical cracks along the whole building on the outer plaster (The risk faktor = 4)

12- outline and shape of the building

Square or polygon (The risk faktor = 0)
Rectangle (The risk faktor = 1)
Star shaped (The risk faktor = 2)
Deep holes in the building (The risk faktor = 3)
Twin blocks of building with different levels (The risk faktor = 4)
Twin blocks of building with different number of floors (The risk faktor = 5)

The total of the risc factors of the answers of every question:

0-6 There is not a severe risc of damage during an earthquake

7-12 There is little risc of damage during an earthquake

13-20 There is intermediate risc of damage during an earthquake

21-60 There is high risc of damage during an earthquake. Call the architectures and engineers of the building and desire help from an expert foundation.