AN EXPERT SYSTEM FOR THE QUANTIFICATION OF FAULT RATES IN CONSTRUCTION FALL ACCIDENTS

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Prof. Dr. Canan Özgen
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Erdal Çokça
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Asst.Prof. Dr. İrem Dikmen Toker
Co-Supervisor

Prof. Dr. Talat Birgönül
Supervisor

Examining Committee Members

Asst. Prof. Dr. Metin Arıkan	(METU,CE)	____________________
Prof. Dr. Talat Birgönül	(METU,CE)	____________________
Asst. Prof. Dr. İrem Dikmen Toker	(METU,CE)	____________________
Asst. Prof. Dr. Rıfat Sönmez	(METU,CE)	____________________
Dinçer Hacıbaloğlu	(TUBİN)	____________________

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Name, Last name : Tuncay Demirel

Signature :

ABSTRACT

AN EXPERT SYSTEM FOR THE QUANTIFICATION OF FAULT RATES IN CONSTRUCTION FALL ACCIDENTS

DEMİREL, Tuncay
M.S. Department of Civil Engineering
Supervisor: Prof. Dr. Talat BİRGÖNÜL
Co-Supervisor: Asst. Prof. Dr. İrem Dikmen TOKER

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Due to its hazardous nature, occupational injuries are unavoidable in the construction industry. Although many precautions are taken and educations are given to the laborers and employers, zero occupational injury rate could not be achieved, but a decrease in the number of injuries and fatalities could be maintained. The conventional studies conducted so far, usually focused on the prevention and causation models. The approach of the researchers was, either proactive or reactive about the accidents which offered preventive or protective precautions. However, after the occurrence of an injury, these precautions become useless and from this point on, determination of the fault rates for the parties being involved in that injury becomes the critical issue. Mostly, it is difficult to reach an objective and correct conclusion at the phase of determining fault rates and decisions achieved may display great fluctuations from one expert to another. The aim of this study is to develop an expert system that reflects the knowledge of occupational safety experts for the determination of fault rates. In order to facilitate this research, required data were collected from related organizations and experts. These data were compiled and classified, the significant factors were determined and all of these factors were evaluated within a quantitative approach. In addition to this evaluation, questionnaires were submitted to the experts; at which they were asked to rate the factors which were determined by the researcher of this study. The expert system is based on these ratings and factors obtained from questionnaires.

Key Words: Occupational Safety, Knowledge Management, Expert Systems, Construction Fall Accidents, Expert Witness

ÖZ

İNŞAATTAN DÜŞME SONUCU YAŞANAN KAZALARDA KUSUR ORANLARININ BELİRLENEBİLMESİNE YÖNELİK BİR UZMAN SİSTEM GELİŞTİRİLMESİ

DEMİREL, Tuncay
Yüksek Lisans, İnşaat Mühendisliği Bölümü
Tez Yöneticisi: Prof.Dr. Talat BİRGÖNÜL
Y. Tez Yöneticisi: Yrd. Doç. Dr. İrem Dikmen TOKER

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İnşaat sektörünün riskli doğası gereği, iş kazalarının oluşması kaçınılmazdır. Bir çok önlem alınmasına ve işçi ve işverene eğitimler verilmesine rağmen, sıfır iş kazasının olması gerçekleşmemişse de, yaralanma veya ölümle sonuçlanan kazaların sayısında azalma sağlanmıştır. Şimdiye kadar yürütülen çalışmalarda, genellikle, kaza önleme modelleri ve kazaya neden olan faktörler üzerinde yoğunlaşılmıştır. Bu kapsamda araştırmacıların kazalara yaklaşımı proaktif ya da reaktif olmuş, önleyici ya da koruyucu tedbirler öne sürmüşlerdir. Bunula birlikte, bir kazanın oluşmasından sonra bu önlemlerin bir değeri kalmamaktadır. Bu noktada, kazada yer alan tarafların kusur oranlarının tesbiti gerekmektedir. Çoğu zaman, kusur tespiti yapılırken objectif ve doğru kusur oranlarına ulaşılması zor bir işlem olup, benimsenen kusur oranları bir uzmandan diğerine göre büyük değişimler gösterebilmektedir. Bu çalışmanın amacı, inşaattan düşme sonucu yaşanan iş kazalarında kusur oranlarının tespiti için iş güvenliği uzmanlarının deneyimlerini yansıtacak bir uzman sistem geliştirilmesidir. Bu amaçla, ilgili kurumlardan ve uzmanlardan, deneyimlerini yansıtan veriler toplanmış ve bu veriler derlenerek sınıflandırılmış; önemli faktörler belirlenmiş

ve sayısal yaklaşımlar kullanılarak modellenmiştir. Bununla birlikte; uzmanlara, belirlenen senaryolar için değerlendirme yapmaları amacıyla, belirlenen faktörlerin yer aldığı bir anket sunulmuştur. Bu çalışma kapsamında önerilen uzman sistem, elde edinilen verilere ve faktörlere dayanılarak geliştirilmiştir.

Anahtar Sözcükler: İş Güvenliği, Bilgi Yönetimi, Uzman Sistemler, İnşaatlardan Düşme Türü Kazalar, Bilirkişilik

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To

My Family

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LIST OF ABBREVIATIONS

AI	Artificial intelligence
ANN	Artificial neural network
CSSR	Construction site safety regulations
ESAW	European statistics on accidents at work
EU	European Union
GDP	Gross domestic product
HHWR	Health and safety regulations for work equipments and Heavy and Hazardous Works Regulations
LIB	Labor inspection board
KM	Knowledge management
KR	Knowledge representation
KBES	Knowledge-based expert system
LIG	Labor inspection groups
MLSS	Ministry of Labor and Social Security
OHSR	Occupational health and safety regulations
OHSRC	Occupational health and safety regulations for construction
SHSR	Safety and health signs regulations
SSO	Social security organization
UPPEWR	Usage of personal protective equipment at the workplace regulations
UI	User interface
US	United States

CHAPTER I

INTRODUCTION

Safety is of great importance for all industries as well as construction. Improving construction worker safety continues to be a major goal for all parties involved in a construction facility. While significant improvements have been made in the past decades, occupational injuries and fatalities are still serious problems in the construction industry. The majority of the construction accidents have been occurring due to the lack of education and training of both employers and workers.

In Turkey, an average of 1000 occupational fatalities has been reported per year (SSO). In United States (US) (2003) the number of occupational fatalities was around 5500 whereas it is 5237 in European Union (EU) (2000). When the distributions of these fatalities are analyzed, it is observed that most of the fatalities have been occurred in construction industry. In Turkey, of the 1000 reported fatalities, about 311 of them belong to the construction industry. This figure is 1126 and 1279 fatalities in US and EU respectively. These high fatality rates are the result of high accidents rates. In US and EU, about 5 million accidents have been occurring in a year. These high incident rates not only threat the safety of human beings but also affect the economy of that country. Some cost quantification studies reveals that the cost of injuries and fatalities has been €127 billion in US, €55 billion in EU (ESAW, 2000), but there is no study for the cost of accidents to Turkey. These studies include medical and emergency costs, lost wages, administrative costs, legal costs, workplace disruption and loss of quality of life. Although the total cost of accidents appears to be lower in

Turkey, when compared with EU, 0,64 of the GDP of EU is lost every year while it is supposed to be around %4 of the GDP of Turkey. However, a similar discrepancy can be observed from the rate of fatalities per incident. Rate of fatalities per incident is 0, 00065 in EU, while it is 0,015 in Turkey which means 23 times greater than EU.

The above mentioned statistics and results display the importance of safety for human life and economical resources. To save these two important resources, many studies have been conducted for minimizing the rate of incidents. Some researchers have proposed some tools while others proposed accident causation models. Generally, these studies can be considered under three topics: Accident causation models, human error theories and synthesis of causation models and human error theories. The common subject of these theories is to prevent the accidents either by giving advice or by proposing new techniques and equipments.

When these studies are examined, it is concluded that nearly all of the studies are related with the background of the accidents which means there is a few studies concerning "after-the-fact". When excluding the statistical studies concerning the results of the accidents, the initial study about the investigation of accidents become the Fault-Tree models. The aim of these models is to identify the root causes of the accident and to determine the party who is responsible for that cause. The root causes of accidents differ from one accident to another. There is no clear-cut way of determining root causes. Usually the interpretation of inspectors identifies the root cause of accident. For example, the root cause of the accident, where a worker was falling down when climbing to a defective ladder, can be considered as the defective step of the ladder. Contrary to this opinion, another inspector may consider that the root cause of the accident is the lack of supervision for not determining the defective step of the ladder. These two opposite opinions bring people to two different conclusions. The one who considers the defective step as root cause of the accident may find employer or the material itself faulty whereas another who considers the lack of supervision as root cause may find worker or employer faulty for the occurrence of accident. As mentioned previously, there is no definite way of determining the root cause of the accident and the party responsible for the accident. To facilitate such a process a specialized expertise branch which is called as expert witness seervice is deduced to investigate the accidents and determine the responsible party for the occurrence of accident. Expert witnesses are knowledgeable in the area of construction safety. Expert witnesses should consider all information related to the accident such as the place of accident, the age and experience of victim, the prevention systems and so on. The information gathered during an investigation tends to be evidence-based and practical. Expert witnesses come to a conclusion considering these information's. However, witnesses do not always give similar decisions about accidents. Sometimes their opinions are completely different from each other. This contradiction results due to the distinct perception of expert witnesses about accidents.

In Turkey, at the government level, the investigation of occupational accidents is in the responsibility area of Ministry of Labor and Social Security (MLSS). MLSS employs inspectors for the supervision of jobsites and investigation of occupational accidents. When an accident occurs, the first investigation is undertaken by these inspectors. The inspection reports prepared by these inspectors include the type of jobsite, information about victim, the opinions about safety precautions, the assessment of the inspector which points out the fault rate of party for the occurrence of accident. In Turkey, the quantification of fault rates is being done for two different cases. This quantification should be done over 8 for criminal cases and over percentage for compensation cases. The labor courts take these reports into consideration when arriving to a conclusion. If the judge agrees, either defendant or plaintiff has a right to object these reports and request a new report from another inspector or expert witnesses. After the acceptance of these objections, the judge assigns usually three expert witnesses evaluate the accident and submit a new report. These experts can be from governmental institutions, universities or private sector. If the judge concludes that the submitted reports are sufficient to arrive into a conclusion, the court makes a decision. However, there is usually contradiction between the submitted expert witness reports. The probable causes of these contradictions are listed below:

- Insufficient professional experience of experts,
- The influence and the pressure of either defendant or plaintiff on experts to affect their decisions,
- Insufficient knowledge about laws and regulations,
- Incompatibility between real life and governmental rules and regulations,
- Insufficient inspection of case records by experts,
- Insufficiency of the governing laws and regulations,
- The inadequacy of data, clues about accident included in case records and
- The lack of objective criterions for assigning fault rates.

The contradiction between inspections reports obstruct the judge to arrive at a conclusion. Apart from this obstruction, the insufficiently prepared inspection reports lead judges into error.

The problems encountered through this process require a new system to overcome or minimize these matters. Such a novel system which is based on the knowledge of experts is proposed within the content of this study.

The proposed system is named as dsSafe which is an expert system for the determination of fault rates. The aim of this expert system is to quantify the fault rates of parties who are employers and workers. At the initial stage of the development of dsSafe, it is required to determine which type of accidents will be investigated. Though it is not possible to cover all types of accidents occurred in construction industry, the statistical studies were examined to determine the most occurring types of accidents to be considered in the expert system. In addition to statistical data, interviews were conducted with industry professionals and inspectors. These researches revealed that construction falls were the most frequently occurring type of accidents occurred in construction industry, so it was decided to investigate the construction falls within the expert system.

There are various types of construction falls in respect of location where the accidents occur. Some of types of falls are; falls from scaffolding, falls from ladders, falls from roofs, falls through floor openings, falls from the edge of floor, falls from utility poles, falls from structures, falls from vehicle, collapse of structure and others. To determine which types of falls were most occurring in the construction industry, it was required to obtain concrete data from governmental institutions. As stated previously, the initial investigation reports for accidents are being prepared by MLSS in Turkey. The MLSS is structured as 23 labor regional directorates and 10 labor inspection boards in Turkey. Although the inspection reports are prepared by inspection boards, the inspection reports are stored at regional directorates. To obtain the previously prepared reports, 23 regional directorates were contacted by letters asking the inspection reports related with construction industry. As a response to this request, 180 inspection reports were received from the offices. 117 of 180 reports were related with construction industry while 84 of 117 were about different types of falls. It was an expected result which supports the studies revealing that falls are the most occurring type of accidents. When these fall accidents were classified, it was observed that falls from scaffolding, falls from ladders, falls from roofs, falls through floor openings, falls from the edge of floor, falls from utility poles were the most occurring types of falls.

The extent of available data, determined the scope of the proposed expert system to 6 types of falls. The received reports were investigated and the governing issues were determined in assigning fault rates. It has been observed that; there exits no objective and clear-cut methods for the quantification of fault rates. The knowledge and perception of the expert is the only tool while assigning fault rates. As stated previously, this causes contradiction between experts. In order to construct a quantification system, the knowledge of experts should be transformed into tangible data. This has been realized with an evaluation form that was submitted to experts

The submitted form contained some developed scenarios related with the types of fall accidents and respondents were asked to analyze these scenarios by quantifying each of them. The respondents were selected from governmental institutions, universities and private sector. The obtained results from respondents are used in the expert system developed for the quantification of fault rates. This system prevents the possible contradictions between inspection reports and offers a common basis for an objective solution. In proposed expert system, the questions are asked to the user tracing a flowchart which is defined previously. System allows user to change the rates or use the default data. The expert system not only determines the fault rates, but also prepares a report about accidents. The report explains why these rates are assigned to each party for that accident.

The survey results, the attitude and perception of respondents, the expert system structure, the knowledge acquisition and representation stages in developing system, flowcharts of each fall type will be presented in the next chapters of the thesis, in detail.

The general topics that are examined within the context of this thesis are; safety, knowledge management, artificial intelligence and proposed expert system, the dsSafe. In addition to the main text, the original documents related with the content of this thesis are also attached at the end of thesis, as appendices.

CHAPTER II

SAFETY

2.1. Safety in Turkey

Occupational safety has a priority at jobsites as it directly affects the health and the life of workers. Therefore, provision of safety measures for the safe operation of workers is regulated and monitored by the related ministry. In Turkey, The Ministry of Labor and Social Security is in charge of occupational safety. While the safety of work place is supervised by Inspection Boards (IB), the insurance of workers is supervised by Social Security Organization (SSO).

Providing the safety of workers can not just be ensured by governmental pressure. Both the workers and employers should consider the safety manner as well. When the statistics are examined, it is observed that safety is not the priority of Turkish employers and workers. The SSO statistics reveals that, an average of 900 fatalities and 74000 injuries are recorded each year. When these fatalities and injuries are classified into sectors, the construction sector becomes the most hazardous sector in Turkey. The number of fatalities and injuries are shown in Figure 2.1 and 2.2, respectively. Other related figures are presented in the appendices of this thesis.

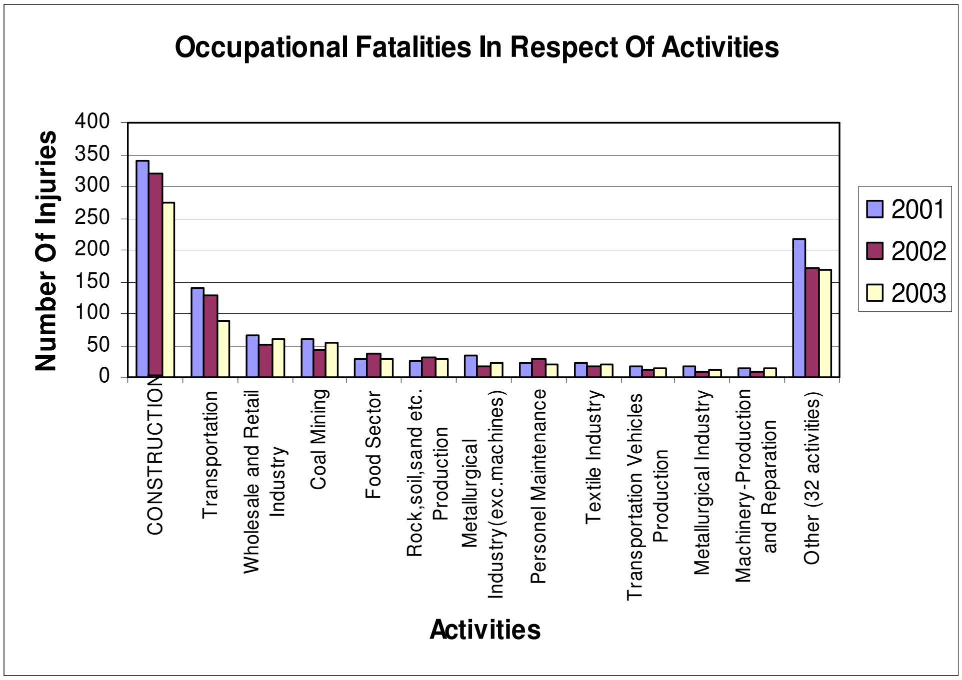

Figure 2.1 Statistics for occupational fatalities.

When these rates are compared with European Union (EU), the effect of hazards can easily be understood in Turkey as the rate of fatalities per accident in Europe is 0.00065 whereas this rate is 0.015 in Turkey. The most occurring type of accidents is the falls from different locations, that why this subject is studied in this study.

The main content of this study is about the quantification of fault rates; however the process of inspection, documentation and analysis will be discussed at the remaining parts of this section. A literature review is done and the definitions are given below. The literature review includes the process of inspection and the methodology of how to act when an investigation is undertaken.

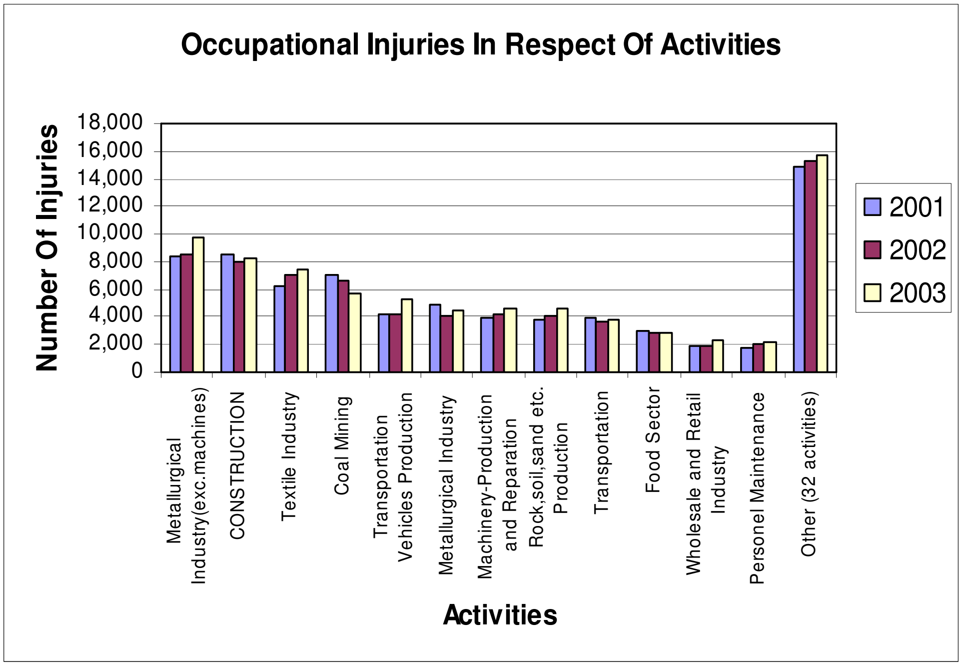

Figure 2.2 Statistics for occupational injuries.

2.2. Definitions

Failure

Dov Kaminetzky defines failure as "... a human act; omission of occurrence or performance; lack of success; nonperformance; insufficiency; loss of strength; and cessation of proper functioning or performance'' (Kaminetzky, 1991).

Structural failure

Jack Janney defines structural failure as, "The reduction of the capability of a structural system or component to such a degree that it cannot safely serve its intended purpose" (Janney, 1986).

Construction failure

‘‘A construction failure is a failure that occurs during construction and they are considered to be either a collapse, or distress, of a structural system to such a degree that it cannot safely serve its intended purpose’’ (Janney, 1986).

2.3. Accident investigations in Turkey

In Turkey, the experts of Investigation Board which are affiliated to MLSS are authorized for investigating the accidents and preparing a reports. Generally there are 4 main parts in these reports. These parts can be summarized as; identification of work place, determination of facts about the accident/site, precautions to be taken and finally the opinion of the inspector which reports the fault rates of the parties being involved in an accident. Where necessary, photos and interrogations victim(s) and eye witnesses are also attached to these reports. The courts take these reports into consideration when arriving at a conclusion and punish the responsible party. However, any of the parties have the right to object to the fault rates, declared as an opinion of the experts. In this case, if the court accepts this objection as valid then the judge assigns another experts board and asks them to prepare a new report or sends the objected points to the current team of experts and asks them to prepare an additional report whereby the objected points are critically analyzed. The Figure 2.3 illustrates this process chain in the Turkish legal system.

As seen from Figure 2.3, the process of accident investigation is finalized through the decision of three types of courts. These are criminal courts, labor courts and Supreme Court. In Turkey when an accident happens, the first trial is undertaken for the punishment of liable party for the accident. These trials are done by criminal courts. Almost in all cases, the employers are subjected to punishment. This punishment can even include imprisonment. The decision of court becomes definite after the approval of Supreme Court. After this process, another trail can be done in labor courts for the compensation. Either victims or their social security companies can open the case for compensation. In compensation cases, generally, the parties who were found as guilty in criminal case should be given a minimum default rate, although the court is free to accept or modify the previously accepted fault rates of the criminal court decision. This is the policy of the Supreme Court, for approving compensation cases.

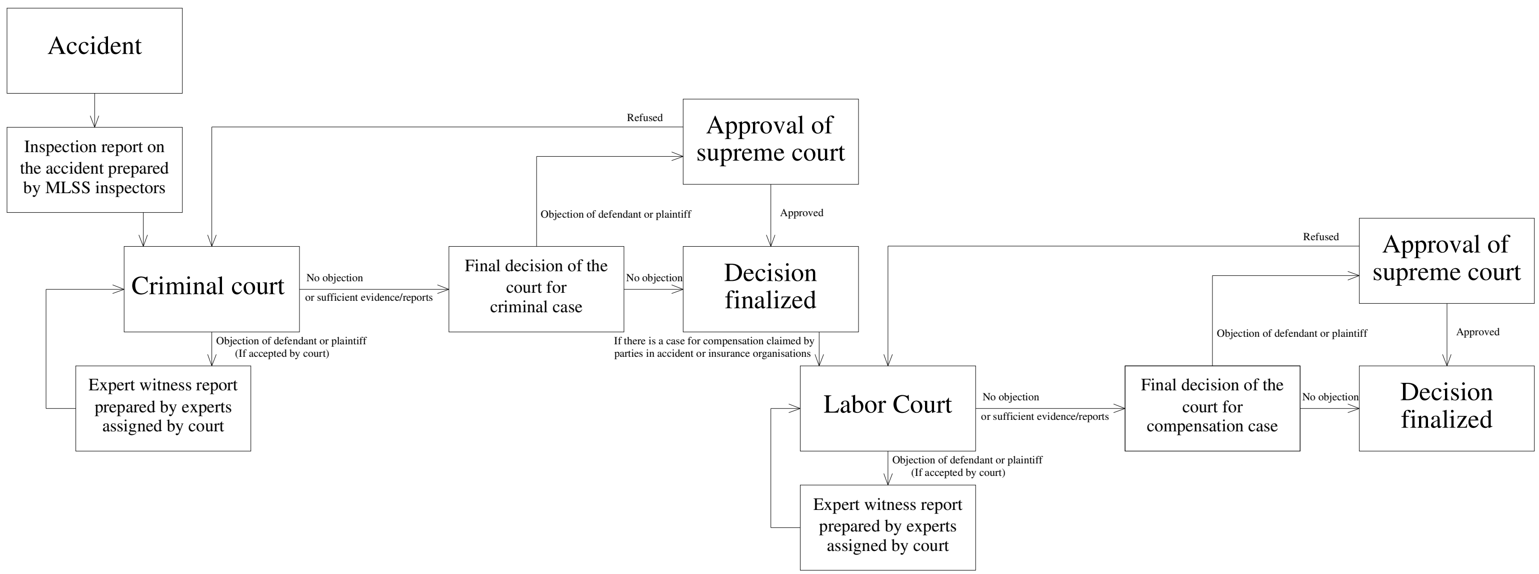

Figure 2.3 Flowchart of decision process in Turkish Legal System.

A brief summary of the legal decision process is explained above. In the following section, the steps of this decision process which is illustrated in Figure 2.3 will be summarized:

1. The accident is happened.
2. The MLSS inspector comes to the accident site and prepares a report.
3. This report is submitted to criminal court.
4. If there is no objection to this report, the court gives a decision.
5. If there is an objection to this report, and this objection is accepted by the court, then the court assigns another team of experts to prepare a report. These experts can be selected either from private sector, universities or public sector. Alternatively, the judge may send the objected points to the current team of experts and asks them to prepare an additional report in which the objections raised by the parties are critically analyzed.
6. The objections of the parties, to the expert witness report is an iterative process and continues until the judge is completely satisfied. In this respect, several teams of experts could be assigned for preparing a report or additional reports might be issued from the same team of experts, until the court is completely satisfied with the fault rates being declared within the report.
7. The court gives its decision. After then, the plaintiff or the defendant has the right to object to the decision of court within the required time of 30 days. If there is no objection to the decision of court, then the decision finalized. These objections are made to the Supreme Court.
8. If there is an application of objection to the Supreme Court, the Supreme Court examines the decision of court. If the decision of the court is rejected either wholly or partially, then the criminal court should renew the trials and comply with the decision of the Supreme Court.
9. The criminal cases are finalized after the approval of Supreme Court.
10. After criminal court stage, if there exits a compensation case; this is been executed in the labor court. The process of labor court stage is similar to criminal court stage. The decision is finalized again after the approval of Supreme Court.

The expert witnesses' reports and also the inspector reports have great influence on the decision of courts. However, great fluctuations and contradictions are observed very frequently among expert witness reports, leading to serious objections raised by both parties and thus loss of time due to the iterative nature of objection process. Although same law and specification articles have been utilized by all experts, they might assign different and contradicting fault rates, for the same accident type. This situation creates confusion and great frustration among parties, which further endangers the trust felt to legal system. In the light of the above summarized current situation; the aim of this research is bring a standard for the quantification of fault rates, thus eliminating the subjective nature of expert witness perceptions.

2.4. Law and regulations related with safety in Turkey

The current Labor Law number is 4857 which was issued in 2003. This law consists of 120 items and occupational safety issues are regulates in the fifth part of this law. Regulations are prepared through this law. The regulations reviewed for this study are Occupational Health and Safety Regulations (OHSR), Occupational Health and Safety Regulations for Construction (OHSRC), Safety and Health Signs Regulations (SHSR), Use of Personal Protective Equipment at the Workplace Regulations (UPPEWR), Health and Safety Regulations for Work Equipments and Heavy and Hazardous Works Regulations (HHWR). In addition to these law and regulations, the decisions of the Supreme Court are also examined in this study.

CHAPTER III

KNOWLEDGE MANAGEMENT (KM) IN CONSTRUCTION

3.1. Definitions and stages of KM

Knowledge management (KM) has a lot of definitions; Hibbard (cited in Beckman 1999) defines it as "... the process of capturing a company's collective expertise wherever it resides-in databases, on paper, or in people's heads-and distributing it to wherever it can help produce the biggest payoff". Beckman (1999) notes that, "In order to transform knowledge into a valuable organizational asset, knowledge, experience, and expertise must be formalized, distributed, shared, and applied". For this purpose, several authors proposed models for the KM process. Beckman (1999) proposes eight stages of the KM process:

(1) Identifying, determining core competencies, sourcing strategy, and knowledge domain;

(2) Capturing, formalizing existing knowledge;

(3) Selecting, assessing knowledge relevance, value, and accuracy;

(4) Storing, representing corporate memory in knowledge repository with various knowledge schemas;

(5) Sharing, distributing knowledge automatically to users based on interest and work;

(6) Applying, retrieving and using knowledge in making decisions, solving problems, automating or supporting work, job aids, and training;

(7) Creating, discovering new knowledge through research, experimenting, and creative thinking; and

(8) Selling, developing, and marketing new knowledge-based products and services.

In order to capture knowledge, it is very important to know typologies of knowledge. Several writers, such as Nonaka and Takeuchi (cited in Beckham 1999), Von Krogh et al (2000), and Alter (2002), identify two types of knowledge typologies: explicit and tacit knowledge. Explicit knowledge is defined as knowledge which is precisely and formally articulated and is often codified in databases of corporate procedures and best practices, whereas tacit knowledge is understood and applied unconsciously (Alter, 2002). Nonaka and Takeuchi (cited in Beckman 1999) differentiate these two typologies of knowledge in terms of experience-rational and practice-theory aspects. Tacit knowledge is knowledge of experience and it is related to practical aspects, while explicit knowledge is knowledge of rationality and it is related to theoretical aspects.

3.2. Types of knowledge typologies

3.2.1. Explicit knowledge

The explicit knowledge of construction site safety exists in accident records, and safety regulations as well as safety guidelines. The accident records represent the knowledge of actual accidents reported on construction sites. This record is useful for the purpose of risk assessment for categorizing the safety hazards in terms of ''frequency-consequence'' level. By categorizing the hazards in terms of this frequency-consequence relationship, an organization can have better information regarding hazards which must be prioritized since it is not possible to allocate all of the organizational resources to respond to all the hazards which can occur.

Another type of explicit knowledge in site safety is safety regulations, such as Occupational Safety and Health Acts from the U.S. and Construction Site Safety Regulations (CSSR) Of Hong Kong. The regulations state the minimum required conditions that must be met in a construction project; however these conditions are not enough to provide a safe working condition. This is especially true for contractors working in countries encouraging self-regulation through the implementation of a safety management system. This system provides general duties for an employer, thus allowing them to determine the best way of achieving the objectives of the legislation in an approach best suited to their organizational culture (Phillips, 1998). In the self-regulatory system, tacit knowledge of construction site safety is of paramount importance for organizations since the knowledge of safety engineers and managers (i.e., experience knowledge) determines the quality of safe working conditions acceptable, and therefore their knowledge must be captured.

3.2.2. Tacit knowledge

Von Krogh et al (2000) noted that tacit knowledge is tied to the senses, skills in bodily movement, individual perception, physical experiences, rules of thumb, and intuition. In construction site safety, safety hazard recognition is an important actualization of tacit knowledge. Safety hazard recognition is considered a tacit knowledge because it relies on the safety engineer's experience. A hazard is "a condition with the 'potential' of (causing) an accident or ill health" (King and Hudson, 1985). This definition of a 'hazard' must be noted to avoid confusion with the definition of risk, which is the likelihood of an occurrence of a hazard (Phillips, 1998). Ramsey (cited in Furnham 1998) noted an important theory of hazard recognition, which in itself is an important element in the occurrence of an accident. If management does not recognize the hazards that may occur on a site, then management cannot provide relevant training or procedures to handle the uncertain conditions. The importance of this theory is shown in a study of behavior-based safety management conducted by Lingard and Rowlinson (1997). The results of their study showed that, behavior-based safety management successfully improved the safety performance with respect to personal protective equipment and housekeeping, but not bamboo scaffolding and access to heights. One reason for this was attributed to the failure of workers to recognize hazards. In knowledge management, which is usually manifested in the form of a business system that is enabled by an array of technologies (Auditore, 2002), both the explicit and tacit knowledge of construction site safety personnel must be captured to gain advantages including:

1. Establishment of an effective safety program which recognizes the actual safety hazards. Different persons might have different perceptions toward a condition; one might perceive the condition as a safety hazard, while the other might not. This ambiguity can be eliminated by capturing the knowledge and studying and discussing whether a certain construction condition and process would be considered to be an actual safety hazard. Once the knowledge is captured, an organization can ensure that the safety engineers and operational units have the same perception of the actual hazards. This can be used to develop a safety program containing a working procedure to solve the actual hazards.

2. Establishment of an effective training program which improves workers' skill related to the actual safety hazards identified. Once the knowledge is captured by the safety management team, they can provide an effective training program to improve workers' skill in coping with the actual hazard identified.

3.3. Knowledge process for dsSafe

The investigation of construction accidents requires a great deal of experience in safety. Although the government publishes laws and regulations for achieving and controlling safety, the interpretation of these regulations depends upon the perception of experts.

In this research, construction of an expert system based on the knowledge of experts is the main objective. Since there exist no clear-cut methods for quantifying the fault rates, capturing the knowledge of an expert for the determination of fault rates is essential. In the investigation of construction accidents, experts reflect their knowledge through the inspection reports they prepare, which can be named as explicit knowledge. Of course, experts do not only reflect their knowledge, but also utilize and interpret the laws and regulations published by governmental institutions. These regulations come into the evaluation medium through the perception of experts. Therefore, the opinions of different experts display fluctuations with each other.

Within the context of inspection reports, experts point out the fault rates of the parties who are considered as faulty, in the investigated accidents. The fault rates are tangible rates and there is no method of quantifying them. Each expert has its own method of quantifying fault rates. Actually it can be claimed that, no expert is aware of his/her method of quantifying fault rates. This knowledge of expert can be named as tacit knowledge. It should be kept in the mind that, although the same laws and regulations are used by all experts, their perceptions and interpretations could display great fluctuations among themselves.

When the inspection reports are considered completely, it is clear that the inspection reports include both explicit knowledge and tacit knowledge. The explicit knowledge directly affects the tacit knowledge of experts. For example, if the regulations forces employer to take a precaution and if the employer do not provide such essential equipments, then the experts find employer faulty and assign the higher fault rates to employer. In this example, all experts can have access to the same regulation, which can be called as explicit knowledge, but in general all experts do not assign the same fault rate to the employer. This can be called as decision of expert by his/her tacit knowledge.

As a conclusion, it is observed that the expert system to be constructed has to be based on two types of knowledge, explicit and tacit knowledge. The methodology followed in this study has two stages. In the initial stage, it is aimed to obtain explicit knowledge. Explicit knowledge is attained through laws, regulations and inspection reports about construction accidents.

The types of accidents investigated within the content of expert system, should be well examined for the determination of factors which are considered in assigning fault rates. In order to achieve this purpose, required data has been collected from related governmental institutions.

Before getting in contact with governmental institutions, a preliminary survey has been conducted in order to identify the most frequently occurring accident types. The statistical data related with construction accidents are published at the web pages of governmental organizations. The web page of SSO is a great source for researchers who are investigating occupational accidents. These statistics are not only providing number of fatalities or injuries, but also present the economical loss arising from occupational accidents. The figures given in statistics revealed the fact that the most occurring types of accidents in the construction industry are the falls from various locations.

After this overview, the inspection reports were requested from governmental institutions. In Turkey, this duty is assigned to the Labor Inspection Board (LIB) which is related to MLSS. There exists 10 Labor Inspection Groups (LIG) responsible for inspections in Turkey. There are different numbers of cities affiliated to each LIG. When an accident is occurred in anywhere, this accident is reported to the related LIG. After receiving this report, inspectors are sent to the jobsite to investigate the causes of accident and determine the faulty parties.

Afterwards, these reports will be used as evidence in courts when the parties are judged either for punishment or for compensation.

As mentioned above, the inspectors who are experts in investigating accidents are the members of LIGs. The database planned to be used for the proposed expert system, should be constructed on the factors considered in inspection reports prepared by these inspectors.

The knowledge management process for this study has two stages. In Fig. 3.2, these stages are shown. In initial stage, a review of construction accidents was done together with data collection and organization. The second stage was about the quantification of scenarios developed from the initial stage. The inspector reports were required in the initial stage of this study. In addition to the inspector reports, the researcher utilized expert-witness reports prepared by academicians. In the introduction part of this thesis, explained the situations when academicians or other experts should submit reports to the demanding organization such as courts has been explained. The general knowledge management process for the initial stage of knowledge acquisition is shown in Figure 3.2.

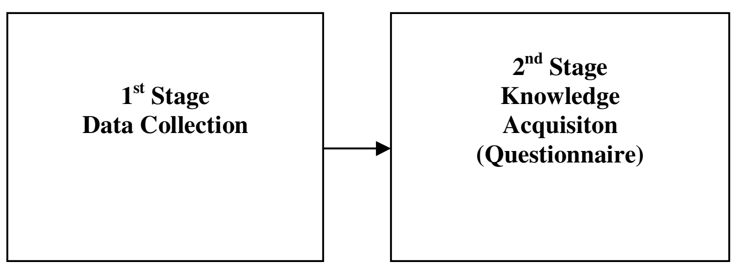

Figure 3.1 Stages of knowledge acquisition.

3.4. Knowledge acquisition

Jackson (1999) stated that knowledge acquisition is a generic term, as it is neutral with respect to how the transfer of knowledge is achieved. For example, it could be achieved by a computer program that learns to associate symptom sets with diagnostic categories by processing a large body of case data. The term *knowledge elicitation,* on the other hand, often implies that the transfer is accomplished by a series of interviews between a domain expert and a knowledge engineer who then writes a computer program representing the knowledge (or gets someone else to write it).

However, the term could also be applied to the interaction between an expert and a program whose purpose is (Jackson 1999);

- to elicit knowledge from experts in some systematic way, for example, by presenting them with sample problems and eliciting solutions;
- to store the knowledge so obtained in some intermediate representation;
- to compile the knowledge from the intermediate representation into a runnable form, such as production rules.

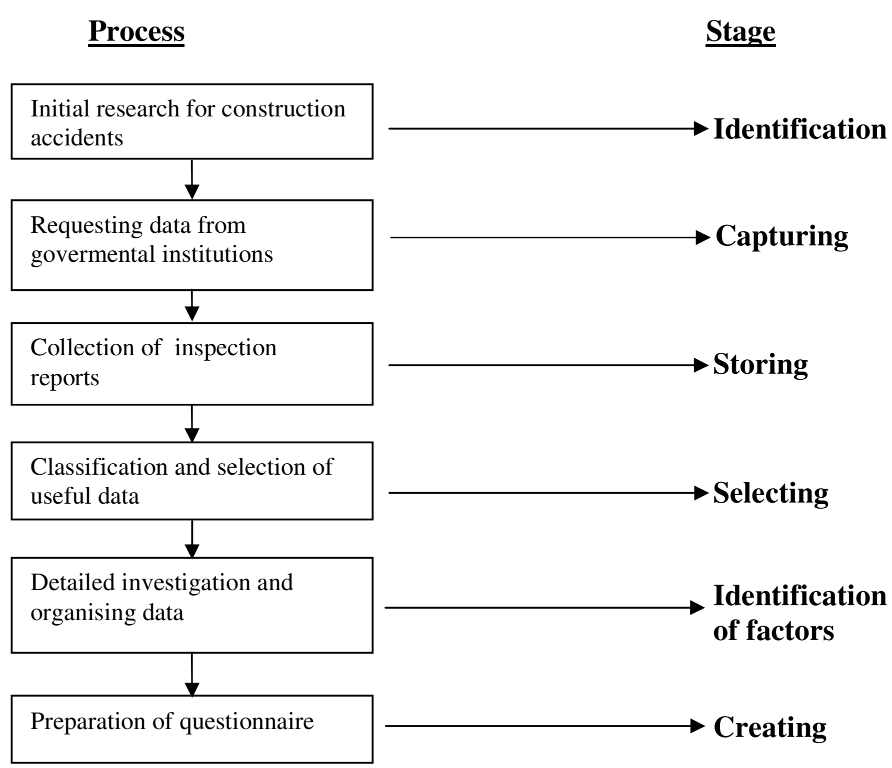

Figure 3.2 The framework for data collection.

The use of such programs is advantageous because it is less labor intensive, and because it accomplishes the transfer of knowledge from the expert to a prototype in a single step.

In next sections, both theoretical analysis and practical approaches will be examined. Section 3.4.1.1. suggests ways in which knowledge acquisition can be broken down into different stages of activity or levels of analysis.

3.4.1. Theoretical analyses of knowledge acquisition

Knowledge elicitation interviews generate between two and five 'production rule equivalents' per day. The reasons why productivity is so poor include (Jackson, 1999):

- the technical nature of specialist fields requires the non-specialist knowledge engineer to learn something about the domain before communication can be productive;
- the fact that experts tend to think less in terms of general principles and more in terms of typical objects and commonly occurring events; and
- the search for a good notation for expressing domain knowledge, and a good framework for fitting it all together, is itself a hard problem, even before one gets down to the business of representing the knowledge in a computer.

As with any difficult task, it is beneficial to try to break the process of knowledge acquisition down into subtasks that are easier to understand and simpler to carry out.

3.4.2. Implementation of knowledge acquisition process for the first stage of study

The general steps were explained in Section 3.4. The acquisition of knowledge expected to be captured from the inspection reports depends on the cooperation between the researcher and governmental institutions. However this cooperation was maintained with the interviews conducted with authorities. The authorities guided the researcher where to apply in order to obtain reports and the way of requesting such inspections reports. At the beginning the authorities were concerned whether to share the inspection reports or not, but after giving guarantee for the confidentiality of these reports, this suspicion disappeared. After this overview, the supervisor of this thesis decided to send letters to regional directorates where inspection reports were stored. A sample of this letter is attached to the appendices as Appendix B. In this letter, briefly, the aim of this study was explained and their support was requested by forwarding inspection reports. At Table 3.1; date of sending the letter, response date of regional directorates and number of received inspection reports are listed.

As it can be understood from the above given table, some regional directorates did not forward any inspection reports. Some of which declared that, it was not allowed to share inspection reports with the unrelated bodies due to confidentiality reasons whereas others declared that, they did not have any inspection reports at which construction accidents were investigated.

The reports which were received till to the end of October are considered within this thesis. After this date, the inspection reports were classified according to the types of accidents. During classification process, it was observed that received inspection reports were not related to construction accidents completely while some of which were related to some rare and extreme cases.

Table 3.1 Response dates

Regional directorates	Date of sending letter	Date of response	N'of inspection reports received
Directorate 1	14 July 2004	12 July 2004	10
Directorate 2	14 July 2004	27 July 2004	1
Directorate 3	14 July 2004	27 July 2004	13
Directorate 4	14 July 2004	27 July 2004	12
Directorate 5	14 July 2004	27 July 2004	6
Directorate 6	14 July 2004	28 July 2004	20
Directorate 7	14 July 2004	28 July 2004	20
Directorate 8	14 July 2004	28 July 2004	10
Directorate 9	14 July 2004	29 July 2004	8
Directorate 10	14 July 2004	29 July 2004	10
Directorate 11	14 July 2004	02 August 2004	15
Directorate 12	14 July 2004	02 August 2004	2
Directorate 13	14 July 2004	05 August 2004	8
Directorate 14	14 July 2004	12 August 2004	20
Directorate 15	14 July 2004	12 August 2004	8
Directorate 16	14 July 2004	27 August 2004	8
Office 17	14 July 2004	28 Sept. 2004	0
Office 18	14 July 2004	12 Oct. 2004	9
Office 19	14 July 2004	20 Oct. 2004	0
Office 20	14 July 2004	20 Oct. 2004	0
Office 21	14 July 2004	25 Oct. 2004	0
Office 22	14 July 2004	25 Oct. 2004	0
Office 23	14 July 2004	08 Febr. 2005	0
		Total	180

At the end of the classification, 117 inspection reports were found to be related with the construction industry. The majority of the remaining reports were related with machinery accidents, while a few of other remaining cases were related to very specific cases encountered in the construction industry.

The most occurring type of accidents in construction industry was expected to be fall accidents. The received inspection reports supported this opinion of the researcher. Out of the 117 inspection reports, 84 reports were related to construction fall accidents. The received reports are classified in Table 3.2.

Table 3.2 Percentage distribution of reports concerning fall accidents.

Location of Fall	Percentage
Falls from the edge of floors	45%
Falls from scaffoldings	25%
Falls from roofs	8,3%
Falls through floor openings	7,1%
Falls from ladders	7,1%
Falls from utility poles	5,9%

3.4.2.1. Structure of inspection reports

The inspections reports prepared by MLSS inspectors have a fix format. Excluding first cover page, the following pages contain 6 parts. The first page gives information about inspector, jobsite, dates, subject, parties involved in accidents. In the first part of report, the general information is given about employer and its representatives together with the statistical data about jobsite. In second part, the current situation of investigation is presented whether any inspections were carried out recently or not. Third part of the investigation reports includes information about how the accident has occurred and identification of victim or victims. In the fourth part of the report, the determined issues about accident as perceived by the inspector are presented. These issues are usually about the prevention systems or protective equipment and their availability in the construction site. The causes of accidents together with the attributes of parties triggering the accident are also examined within this part. The fifth part of the report discusses the precautions to be taken in jobsite. Particularly, the inspectors reflect their knowledge in fifth part. Together with their knowledge, their perception of assessing accidents can easily be found out in this part. The opinions of inspector are also supported by related the items of governing laws and regulations. This part is the most important part of the reports which effects the decision of inspector. The final part which is the sixth part of report is the decision part. In this part of the report, inspector assigns fault rates to parties involved in related accident by considering the previous parts of the report. In criminal cases, these rates are over a full scale of 8 whereas in compensation cases it is over percentage. In some inspection reports, interrogations of parties are also attached within this report. These interrogations include the interviews with eyewitnesses, injured victims, employer and other people related with the accident.

3.4.2.2. Analysis of inspection reports

The scope of this research is limited with the investigation of construction falls from different locations. The classification of construction falls revealed that, the most frequently occurring types of fall accidents are; falls from the edge of floors, falls from scaffoldings, falls from roofs, falls through floor openings, falls from ladders and falls from utility poles. Reports investigating these types of construction falls were examined in detail to understand the causes of such accidents and to determine the factors considered in assigning fault rates.

Generally, the causes of accidents can be examined under two topics. First topic can be considered as root causes of accidents and the second topic is the enabling causes of accidents. Root causes are visible causes of accidents which trigger the accident to occur. The enabling causes are the secondary causes which lead to accidents to occur. For example, the root cause of falling from a ladder can be the defective step of ladder, whereas the enabling cause for this accident can be considered as the lack of supervision in determining the defective step or unavailability of a site engineer responsible for the safety of workers.

The inspectors consider both root causes and enabling causes when assigning fault rates. In this study, inspection reports were examined through these perspectives. However, it is usually conflicting to distinguish root causes from enabling causes. For example, if an accident occurs by falling through floor opening at a poorly illuminated jobsite, the determination of root cause becomes conflicting. Some experts may assume that, the root cause of accident is poor illumination whereas others may assume that the unguarded floor opening caused the accident. Therefore, the perceptions of experts in principle determine the root cause of accidents.

When these inspection reports were analyzed, it was observed that some issues were commonly asked for all accident types. These issues were usually the enabling causes of accidents. The types of accidents and the factors affecting the assignment of fault rates are summarized in Section 3.4.2.3.

3.4.2.3. Factors considered through the investigation of accidents

3.4.2.3.1. General issues

Some issues are considered to be important for all accident types. When the received reports were examined, it was concluded that these issues can be summarized under seven headings. These factors are listed in Table 3.3.

Table 3.3 General factors for all types of fall accidents.

1	Whether the worker has medical report or not
2	Whether the construction works were carried out under the supervision of an engineer or not
3	Whether the worker was experienced or not
4	Whether the accident happened through carelessness, in a moment of abstraction or as a result of vertigo or not
5	Whether there was safety belt or not
6	Whether there was hard hat or not
7	Availability of warning signs and training of workers

The importance of above mentioned factors changes with respect to the type of accidents. At identification stage, it is unable to assign the importance level of factors. Assigning importance levels will be conducted after identification stage, when the questionnaire is prepared using these findings.

These general issues which the inspectors investigate are generally the enabling causes in the occurrence of accidents. However these issues are not the only factors considered by inspectors, since items stated in the safety laws and regulations are also considered.

3.4.2.3.2. Specific issues for falls from the edge of floors

In addition to the general issues, the following two factors listed in Table 3.4 were determined as the critical factors when assigning fault rates, in falls from the edge of floors.

Table 3.4 Specific factors to be considered while evaluating accidents under the falls from the edge of floors category

1	Whether any fall protection systems such as work planks, safety nets, guardrails were provided or not
2	Whether the accident happened due to the carelessness of crane operator or an mechanical failure or not

Other significant factor encountered when the inspection reports were examined, was the effect of mechanical lifting machines in the occurrence of accidents. The mechanical lifting machines are being widely used in constructions for lifting equipments. These equipments are usually located at the edge of floor openings. While an operator operates the machine on the ground, others lift the equipments from conveyor bucket. There were two causes determined in which the mechanical lifting machines contributed to accidents. One of these causes is the mechanical failure arising from the brakes of lifters. In inspections reports, there were such cases which were happened through the brakes. For example, when the operator lifted the materials to the upper floors, the worker wanted to capture the bucket to transfer materials. While capturing these materials, there happened a failure in the brakes and the worker fall from the edge of floor together with bucket. Another case leading to accidents through mechanical lifter is the falling of materials on to the workers who lift equipments to the buckets on ground level. The secondary cause leading to an accident arising from mechanical lifting machines is the fault of operators operating the lifting machine. In inspection reports, it was observed that some accidents were happened through the fault of operators. The most occurring type of fault of operators encountered through the research of reports, was the timing of lifting or braking. While the worker is transferring the materials, the operator runs the lifter. This action of operators is a fault and may lead to an accident. The inspectors assign fault rates to operators for their such faults. However, if the accident was happened through a mechanical failure, then the employer was assumed to be faulty party. The general opinion of both inspectors and experts is that, the employers has to provide the well working equipments and they were in charge of the supplying the maintenance of equipments periodically.

3.4.2.3.3. Specific issues for falls from scaffoldings

The additional factors are listed in Table 3.5. Scaffoldings are used either indoor or outdoor jobs. The accidents happened at indoors usually do not have serious results whereas the scaffolding accidents at outdoors have serious results as the outdoor scaffoldings are usually constructed to higher levels. The illumination, availability of protection equipments were explained in previous sections. The distinct perception of some subjects come into account when the scaffolding accidents are investigated. These are the availability of safe access gates, the failure of the scaffolding and the working planks.

The bad planking on scaffoldings causes accidents. The gaps, cracks or splits on planks create a hazardous situation for workers, who work on scaffoldings. These types of accidents were reported by inspectors. These reports reveal that bad planking is a cause of accident. Therefore, inspectors assign fault rates to associated parties, if they observe this kind of deficiency.

Table 3.5 Specific factors to be considered while evaluating accidents under the falls from scaffoldings category.

1	Whether the jobsite was illuminated or not
2	Whether the scaffolding was failed or not
3	Whether there were any safe access gates to the scaffolding or not
4	Whether the planks used on scaffolding were safe enough or not
5	Whether any fall protection equipments such as guardrails, lifelines were provided or not

The inspectors as well as experts propose to provide safe gates for accession to scaffoldings. These safe gates are required in two places; accession from floor to scaffolding and climbing from ground to scaffolding. The unavailability of safe accession gates causes accidents. However these issues were also emphasized in inspection reports.

The most hazardous factor causing accidents is the failure of scaffoldings. The inspection reports revealed that, there were two causes leading to the failure of scaffoldings. These are the overloading of scaffolding and improper construction of scaffolding.

3.4.2.3.4. Specific issues for falls from roofs

Roofs are among the most hazardous jobsites where accidents might happen. Generally roofs are not flat jobsites and might cause accidents due slipping of workers. Probability of the occurrence of accidents increases with respect to the slope of roofs which implies that, the higher the slope of roof, the more probable is the occurrence of accidents. In order to prevent accidents at roofs, the jobsite should be protected with safety equipments. Some of these equipments are scaffoldings, guardrails or safety nets. Upon examination of inspection reports, it has been observed that employers are usually very reluctant in providing such preventative measures which in return compels to assign higher fault rates due to their great negligence. This factor is the most dominant one affecting primarily the opinion of inspectors, as well as the experts.

Another factor that appears specific to falls from roofs is the weather conditions. In some cases as observed from inspection reports, weather conditions cause to accidents. As the roofs are sloping structures, especially in rainy or snowy days, the surface of the roof becomes slippery. In such days, employers should not allow workers to work on roofs as well as the workers should not accept to work on the roof by considering their own safety.

The third factor determined as a cause for the roof accidents is the determination of safe access paths on roofs. The roof structure is supported by some frames which are under the roof surface and these frames can not be seen when the workers are on the roof. Thus the whole roof surface is not safe for workers to walk. However, the roof material may be safe enough to bear the load of workers. To prevent such accidents, the safe access paths should be determined for workers, while moving at any place where they want to reach on roofs. The three additional factors that are specific to roof accidents as determined from the inspection reports are listed in Table 3.6.

Table 3.6 Specific factors to be considered while evaluating accidents under the falls from roofs category.

1	Whether the weather conditions were convenient for working or not
2	Whether any fall protection equipments such as scaffolding, guardrails or safety nets were provided or not
3	Whether any safe access paths were identified on the roof or not

3.4.2.3.5. Specific issues for falls through floor openings

The most specific factors causing to falls through floor openings are presented in Table 3.7.

Table 3.7 Specific factors to be considered while evaluating accidents under the falls through floor openings category.

1	Whether the workers uncovered the protective floor covering without informing the employer or not
2	Whether the surrounding of floor opening was illuminated or not
3	Whether any fall protection systems such as work planks, safety nets, guardrails were provided or not

When the inspection reports investigating falls through floor openings were examined, the above mentioned issues were found to be most specific factors that play role in the occurrence of this type of accidents. There exist such cases in which the employers claimed that, they were unaware of hazardous circumstances. In some cases they were right in their claim, since the worker removed the floor covering without informing the employer. Sometimes workers do this action in order to facilitate the lifting of heavy materials to upstairs or to shorten their ways. Although the employers could be found right in their claim to certain extent, still the inspectors assign fault rates to employers considering the lack of supervision at jobsite.

Another factor leading to an accident is the insufficient illumination provided at jobsite. These types of accidents are usually occurring at nights. Of course the insufficient illumination itself is not a root cause of an accident, but it is an enabling factor. If the floor opening is covered well, then the worker may not fall due the insufficient illumination. It was understood from inspection reports that, provision of sufficient illumination is under the responsibility of employer. On the other hand, if the employer provides illumination equipments, then the workers should use them.

Fall protection systems are the essential equipments to prevent accidents. These types of protection systems are not only essential for the prevention of falls through floor openings, but also required to prevent almost all types of accidents. In order to prevent falls through the floor openings, safety nets, guardrails or working platforms are the essential equipments that can be remembered in the first instance. In inspection reports, the unavailability of such equipments was considered as the one of the major factors leading to an accident. In case that the employer did not provide these equipments, they were assigned the major fault rates by inspectors as well as experts.

3.4.2.3.6. Specific issues for falls from ladders

Ladders that are used in construction jobsites can be classified into two groups. These ladder groups are built-in ladders and temporary ladders. Built-in ladders are the main parts of the structure, whereas temporary ladders are being used to enable workers to do their job. Temporary ladders are usually made of metal or timber, thus these types of ladders are weaker than built-in ladders. The weakness of these ladders causes accidents due to the breakage of the ladder itself or one step of the ladder. The majority of the inspection reports were about the temporary ladders. As stated in laws and regulations, and also it was the opinion of experts and inspectors, the surrounding of the ladders should be protected by guardrails or handrails. In addition to these precautions, the temporary ladder should be well fixed to prevent slipping. The precautions against slipping have more importance in mobile ladders. The upper and the lower parts of the mobile ladders should be fixed to prevent slipping. In cases reported by inspectors, the above mentioned issues were clearly implied. Another factor concerning about ladder accidents was the illumination of jobsite. Inspectors consider that the insufficient illumination of jobsite may cause accidents, particularly for the ladder accidents.

The availability of alternative safe gates is considered as an important factor to prevent accidents. Upon examination of received inspection reports, it was observed that the employers claimed that they were not faulty as they warned the workers to use the safe gates. In such events, the inspectors considered that the employers had supervised the workers, so employers should not be blamed. The specific issues for ladder accidents are presented in Table 3.8.

Table 3.8 Specific factors to be considered while evaluating accidents under the falls from ladders category.

1	Whether the jobsite was illuminated or not
2	Whether the ladder itself or its step was broken or not
3	Whether any precaution was taken to prevent the slipping of ladder or not
4	Whether any guardrails or handrails were constructed around the ladder or not
5	Whether there were any alternative safe gates apart from ladders or not

3.4.2.3.7. Specific issues for falls from utility poles

Falls from utility poles is another subject covered within this thesis. These utility poles can be either phone poles or electrical poles. Particularly at electrical poles, the electrical current is the most hazardous event to be avoided. Since there exits long distances between electrical poles, the workers should communicate with each other before supplying electricity to the system. In inspection reports, it was reported that poor communication among workers is one of the potential factors that might cause to accidents, especially in case of utility poles.

The most frequently occurring type of accident arising in utility poles is the failure of the utility pole. The inspectors observed that defective material from which the utility poles made of and the insufficient base for utility poles lead to failure of utility poles. Thus, inspectors have to determine the robustness of poles and the cause for the failure of utility pole. The fall protection systems should be constructed to protect workers when the utility poles fail. The unavailability of protection systems is an enabling cause for the injury of workers. The issues to be consider while assigning fault rates are listed in Table 3.9.

Table 3.9 Specific factors to be considered while evaluating accidents under the falls from utility poles category.

1	Whether the weather conditions were convenient for working or not
2	Whether the organization and communication among workers were sustained or not
3	Whether the material of utility poles was defective or the base of utility pole was insufficient or not
4	Whether any temporary fall prevention systems were provided or not
5	Whether electrical insulated equipments were provided or not

3.4.3. Implementation of knowledge acquisition process for the second stage of study

In previous sections, it has been stated that the knowledge acquisition process will be conducted in two stages. The first stage is presented in Section 3.4.2. and in this section, the second stage will be presented. In the second stage of knowledge acquisition process, the questionnaire methodology was used as a tool for collecting data. The contents of the prepared questionnaire depend on the findings compiled from the first stage including data collection and organization. The questionnaire form is attached in the appendices part of this study, namely in Appendix C.

3.4.4. Structure of questionnaire

The questionnaire consists of 26 pages. The first 8 pages are related to the introduction part of the questionnaire, which includes information about respondents, a survey about the opinions of respondents and the explanations about how the questionnaire will be answered. The information about respondents includes their names, their organizations, phone numbers, e-mail and their experience. After receiving information about respondents, a survey is submitted to respondents in order to gather their opinion about safety in Turkey. This survey consists of 3 questions. In the first question, whether in Turkey safety is considered as an important concept or not has been asked. If the respondent answers as “Yes”, then respondent can continue answering the following questions, otherwise the respondent is requested to skip to the third question.

In the second question, there exits 6 items to be rated by the respondents. These items are about the reasons why either employers or workers give less importance to safety.

In the third question, respondents are requested to rate the listed 8 items which are found among the probable causes of contradicting fault rates, appearing in different expert witness reports. In this question, it is again requested to determine any additional factors which the respondents consider to be important for the reasons of contradiction among fault rates assigned by inspectors or experts.

The main part of the questionnaire comes after these parts. As stated previously, six types of construction falls were investigated within this thesis. When the factors causing the accidents were investigated, it was observed that some factors are common almost in all types of construction falls, so these factors were collected together and submitted as the general issues. The main part of the thesis consists of 8 parts. These are;

1. General issues,
2. Falls through floor openings,
3. Falls from roofs,
4. Falls from ladders,
5. Falls from scaffoldings,
6. Falls from utility poles,
7. Falls from the edge of floors,
8. Distribution of fault rates.

Except for the last part, respondents are requested to answer 60 scenarios. Each scenario has two blanks to be filled out. These scenarios were developed by considering the factors as determined from inspection reports. In addition to these scenarios, respondents are requested to fill out the importance of these factors. These sections are at the 2, 3, 4, 5, 6 and 7 parts of the questionnaire. There are 65 factors to be rated for their importance. Thus, each part namely part 2, 3, 4, 5, 6 and 7, has two sub topics; one is about the determination of importance of factors whereas the other is the scenarios to be filled out. The number of factors whose importance are to be determined and the number of scenarios to be considered and answered are summarized in Table 3.10. At the last part, the respondents are asked to distribute the total fault rates within the groups involved in accident. There are 4 scenarios proposed for this part.

Table 3.10 Comparison of factors and scenarios for fall accidents.

Part	N'of factors	N'of scenarios
General issues	-	14
Falls through floor openings	10	6
Falls from roofs	10	5
Falls from ladders	12	7
Falls from scaffoldings	12	16
Falls from utility poles	12	7
Falls from the edge of floors	9	6

3.4.5. Assumptions made in the questionnaire

Upon examining inspection reports, as stated previously, two causes of accidents have been observed such as root causes and enabling causes. Although the root causes change with respect to each type of accident, the enabling causes remain similar. Due to this enabling causes are collected under the topic of general issues. Under the general issues part, respondents were requested to assign the fault rates to parties involved in that accident. It has been assumed that, the fault rates will be same in all types of constructions falls, but their importance might change with respect to the type of accident. Thus, in general issues part, only the fault rates were expected to be filled out. The importance of these factors was asked in the forthcoming parts, which were specific to that type of accident. For example, the unavailability of medical report is a general factor considered by inspectors or experts when assigning fault rates. In this study, it was assumed that the degree of fault rate would not change, however the importance weight of this factor would change with respect to that specific type of accident. Thus, the factor of medical report was asked in general issues part and respondents assigned fault rates for the unavailability of medical report. However, the importance of this factor was asked within each type of accident.

The second assumption was the ignorance of force majeures. In some accidents, it was observed that neither employer nor the worker had any fault for the occurrence of accident. For example when the worker was working on scaffolding, the lightning flash injured the worker. Together with other factors, these force majeures should be considered as a reason when assigning fault rates, however in this study, all types of such force majeures were ignored. Some respondents were assigned fault rates to developed scenarios considering these force majeures. In this study, the rates assigned to force majeures were distributed to parties according to their rate of fault.

The third assumption is related to the determination of responsible parties. It has been assumed that, there exist two parties who would be assigned fault rates. These parties are employer and the worker. The parties who were considered as employer or worker are summarized below. The employers include the representatives of employers as well.

<u>Employer:</u>

Contractor firm, sub contractor firm, project manager, owner of contractor firm, owner of sub contractor firm, safety engineers

<u>Workers:</u>

Victim, other worker, foreman, operator

In the questionnaire, each factor and each scenario is not relevant to remaining factors or scenarios. For example the unavailability of medical report is not dependent to the availability of site engineers. However, some scenarios were developed considering these dependences. For example, the usage of safety belt by worker is dependent to the availability of safety belt. If the worker did not use the provided belt, he/she becomes faulty, on the contrary if safety belt was not provided, thus he/she could not use the safety belt, so he/she would not be blamed. These above mentioned situations were considered when constructing the questionnaire and the scenarios were developed reflecting these facts.

The last assumption is the validity of importance factors for the same group of scenarios. For example, in the former parts, the respondents are requested to determine the importance of whether there was a safety belt or not. The rating assigned by the respondent for this factor is assumed to be valid both for the case which the employer did not provide safety belt and the case which the worker did not use the provided safety belt. The importance weight of these two cases is assumed to be equal.

3.4.6. General profile of respondents

In this study, 20 of the answered questionnaires were used to acquire knowledge. All of the respondents are known as knowledgeable in the field of safety. 7 of the respondents were from public sector, 8 of the respondents were from private sector and 5 of the respondents were academicians. At Table 3.11, the professional experience and the profile of the respondents are shown.

Table 3.11 Experiences of respondents.

	Number of Respondents		
Experience	Public Sector	Private Sector	Academicians
More than 16 years	5	6	5
13-16 years	1	2	
4-7 years	1		

2 of the questionnaires were received via internet. A copy of questionnaire was sent to a mail group of engineers and 2 of the engineers answered the questionnaire completely. These respondents were from private sector. Other

questionnaires were sent as hard copies to companies, and pre-interviews were conducted with 2 of the private sector respondents. The similar interviews were conducted with 4 of the academicians and 1 of respondent that belong to public sector.

3.4.7. The methodology for the evaluation of questionnaire results

There were three kinds of ranking. Two of the ranking types are about the determination of importance weights. At the initial part of the questionnaire where the respondents are requested to imply their opinions about safety and expertise for safety, the scale of importance weight is 5, as shown at Table 3.12. At the main part of the questionnaire, the importance of factors is rated over 10 where the description of 10 is most important and 0 is "not important". The third and the last type of ranking is over 100. The respondents were asked to distribute this 100 percentage of fault between employer and worker. These three types of ranking are illustrated below.

Table 3.12 Scale for rating over 5.

Rating	1	2	3	4	5
Importance	Very low	Low	Medium	High	Very high

Example:
The probable causes of deficiency about occupational safety are listed below. Please, evaluate the importance of these factors within the (1-5) importance scale.

No	***Factor***	***Importance***
1.	The insufficient knowledge of workers about occupational safety	**4**

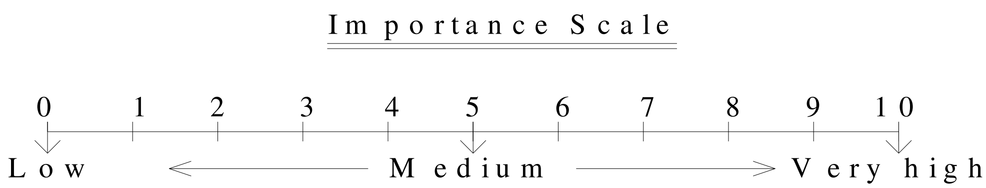

Figure 3.3 Scale for rating over 10.

Example:

Please determine the importance weight of factors identified from the investigation of falls thorough floor openings considering [0-10] scale for the assignment of fault rates to involved parties.

No	***Factors***	***Importance weight***
1.	Whether the worker has medical report or not	**8**

Example: Type of ranking which is over 100.

Determine the fault rates of parties considering developed scenarios for the falls through floor openings.

		Scenario 1
1	**Was there adequate illumination** around the floor opening?	**No**
	Fault rate of employer :	90
	Fault rate of worker :	10

Scenario

Response sections

As stated previously, the questionnaire was answered by 20 respondents. The experience of these respondents differs from each other. At the personal information part of the questionnaire, the respondents were asked to write the years of their experience. The experience interval was structured to be 5 categories and each category was assigned with a level, which increases according to the experience years. At Table 3.13, these periods and levels are shown.

Table 3.13 Conversion of experience years to experience levels.

Experience Interval (Years)	Level
0-3	1
4-7	2
8-12	3
13-16	4
More than 16	5

The aim of this classification is to reflect the knowledge of respondents according to their experience. In this study, this methodology was required to determine the weighted average of results which were assigned by respondents. The numerical data assigned by respondents were multiplied by their experience level, and then the total of these data was divided by total of experience level. In this study, the average of experience level is 4.7 which mean the respondents are very experienced.

$$a \cong \frac{\sum_{i=1}^{20} bi \times c}{\sum_{i=1}^{20} bi}$$

Description of variables:

a: The weighted average of numerical data assigned by respondents. These data can be either importance of factors or fault rates.

b_i: The experience level of each respondent

c: The numerical data assigned by each respondent. These data can be either importance of factors or fault rates.

3.4.8. Survey results for the initial part of questionnaire

The respondents were requested to share their opinion about safety practice in Turkey. Six items, as shown in Table 3.15, were identified to reveal why employers or worker do not give importance to safety. The respondents rated the importance of these factors considering the scale shown in Table 3.14.

Table 3.14 Scale for rating.

Rating	1	2	3	4	5
Importance	Very low	Low	Medium	High	Very high

The probable causes of deficiency about occupational safety are listed below. Please, evaluate the importance of these factors within the (1-5) importance scale.

Table 3.15 Questionnaire results for ignorance of safety.

#	**Factor**	**Imp.**
1	The insufficient knowledge of employers about occupational safety	**4.8**
2	The insufficient knowledge of workers about occupational safety	**4.4**
3	The insufficient supervision of government about occupational safety	**4.1**
4	The additional cost to employers for ensuring occupational safety	**3.9**
5	Inadequate punishment/compensation assigned to employers when avoiding to implement safety issues	**3.8**
6	The inconvenience caused by the usage of protective equipments to workers	**3.1**

These results show that, the most important cause of deficiency about safety is the lack of knowledge. The dramatic result is the insufficient knowledge of employers about safety. It shows that the training and education about safety is poor in Turkey. Other causes are lack of supervision, cost of safety, inadequate penalties and inconvenience of protective equipments respectively. Other factors declared by respondents for this subject are listed below.

- The lack of reconciliation within individuals,
- The worthless of human beings,
- Outperforming laws and regulations by governmental organizations (Giving license to illegal constructions),
- Working without required business permissions,
- The lack of sensitivity to safety (Employer or workers are aware of hazards, but they do nothing for prevention.).

As a conclusion, it has been proposed that a strategic planning should be implemented for safety education. Both employers and workers should be trained for safety manner. This can be performed by governmental organizations or professional associations.

In the questionnaire, another question was related with the experts. At the identification stage of this study, it was observed that the experts could propose conflicting opinions even for the similar cases. The probable causes of the conflicting opinions were listed and the respondents were requested to rate these factors over 5 importance levels. The factors and achieved result are shown at Table 3.16.

The probable causes of conflicting opinions about fault rates assigned by different experts in same event are listed below. Please, evaluate the importance of these factors within the (1-5) importance scale.

Table 3.16 Results of the experts' opinions for the contradictional decisions.

#	**Factor**	**Imp.**
1	Insufficient professional experience	**4.5**
2	The inadequacy of data, clues about accident included in case records	**4.4**
3	The lack of objective criterions for assigning fault rates	**4.1**
4	Insufficient knowledge about laws and regulations	**4.0**
5	Insufficient inspection of case records by experts	**3.7**
6	Incompatibility between real life and governmental rules and regulations	**3.0**
7	The influence of defendant or plaintiff party to the experts for their decisions	**2.8**
8	Insufficiency of the governing laws and regulations	**1.9**

When the factors listed at Table 3.16 are considered, it can be concluded that the laws and regulations are sufficient, but knowledge and expertise are insufficient. Other factors stated by respondents are listed below.

- The experts are prejudged,
- The unethical attitudes and corruption among experts,
- The selection of unqualified experts(!) by courts,
- Insufficient inspection of jobsite,
- Selection of experts who are not qualified for the type of investigating accident (for example, the investigation of electrical accidents may be done by chemical engineers).

3.4.9. Survey results for the main part of questionnaire

The questionnaire was constructed for knowledge acquisition from experts. The achieved data was used for developing a database for the quantification of fault rates. As stated previously, there exists no method for the quantification of fault rates. The assigned fault rates could show great fluctuations depending on perception and knowledge of experts. In this respect, the aim of this study is to bring a standard for the quantification of fault rates in construction accidents. The results reveal that there are significant variances among the respondents. The general results are given in respect of accident type. At the conclusion column, the results were the weighted averages. At the appendices, the responses to questionnaires were presented through the group of respondents who are from public sector, universities and private sector. The values shown under the conclusion column are the weighted average of data. In conclusion column, “importance” refers to the importance weight of this factor and the other two values are the fault rates assigned to parties by experts, expressed in percentage. In the next section, the results of the questionnaire concerning falls from roofs will be presented.

3.4.9.1. Falls from roofs

19 scenarios were developed for investigating accidents under the category of falls from roofs. Each of these scenarios has an effect while assigning fault rates. There were some obvious scenarios at which there were no need to ask any fault rates, thus these scenarios were excluded from the survey form. The examined scenarios, statistical results and the conclusion for each scenario are presented below.

		St.Dev.	Conclusion	
		3.3	**5.8**	Importance
Did the worker have medical report?	No	24.8	**88**	Employer
		15.2	**12**	Worker
		2.1	**7.0**	Importance
Was there an engineer responsible for construction site?	Yes	29.4	**32**	Employer
		40.3	**68**	Worker
		2.1	**7.0**	Importance
Was there an engineer responsible for construction site?	No	15.6	**87**	Employer
		15.6	**13**	Worker
		2.3	**6.9**	Importance
Was the worker an experienced person?	Yes	30.7	**39**	Employer
		34.1	**61**	Worker
		2.3	**6.9**	Importance
Was the worker an experienced person?	No	28.4	**70**	Employer
		24.8	**30**	Worker
		2.0	**6.8**	Importance
Did the worker fall due to his/her personal carelessness, in a moment of abstraction or while feeling dizzy?	Yes	15.3	**20**	Employer
		15.3	**80**	Worker
		1.3	**8.8**	Importance
Considering the type of work, was it required to provide safety belt?	Yes	11.5	**88**	Employer
		11.5	**12**	Worker
Did the employer provide safety belt?	No			
Did the worker use the safety belt?	--			

		1.3	**8.8**	Importance
Considering the type of work, was it required to provide safety belt?	Yes	22.5	**31**	Employer
		22.5	**69**	Worker
Did the employer provide safety belt?	Yes			
Did the worker use the safety belt?	No			

		3.6	**4.3**	Importance
Did the employer provide hard hat at the construction?	Yes	23.1	**29**	Employer
		23.1	**71**	Worker
Did the worker use the hard hat?	No			

		3.6	**4.3**	Importance
Did the employer provide hard hat at the construction?	No	11.2	**89**	Employer
		11.2	**11**	Worker
Did the worker use the hard hat?	--			

		2.3	**6.8**	Importance
Was there a warning sign informing about hazard?	Yes	22.0	**65**	Employer
		22.0	**35**	Worker
Were the workers informed about the hazards of works?	No			

		2.3	**6.8**	Importance
Was there a warning sign informing about hazard?	Yes	18.5	**19**	Employer
		25.9	**81**	Worker
Were the workers informed about the hazards of works?	Yes			

		2.3	**6.8**	Importance
Was there a warning sign informing about hazard?	No	22.7	**49**	Employer
		22.7	**51**	Worker
Were the workers informed about the hazards of works?	Yes			

		2.3	**6.8**	Importance
Was there a warning sign informing about hazard?	No	8.5	**94**	Employer
		8.5	**6**	Worker
Were the workers informed about the hazards of works?	No			

		2.3	**7.3**	Importance
Were the weather conditions convenient for working?	No	12.8	**80**	Employer
		12.8	**20**	Worker

		2.4	**7.6**	Importance
Was safe path identified or was roof ladder provided?	Yes	26.1	**33**	Employer
		26.1	**67**	Worker

		2.4	**7.6**	Importance
Was safe path identified or was roof ladder provided?	No	10.2	**91**	Employer
		10.2	**9**	Worker

		1.1	**9.4**	Importance
Were safety equipments such as scaffolding, guardrails or safety nets provided for preventing roof falls?	Yes	18.4	**82**	Employer
		18.4	**18**	Worker
Were the equipments safe enough to prevent falls?	No			

		1.1	**9.4**	Importance
Were safety equipments such as scaffolding, guardrails or safety nets provided for preventing roof falls?	No	7.0	**96**	Employer
		7.0	**4**	Worker
Were the equipments safe enough to prevent falls?	--			

3.5. Knowledge representation

In this section of the thesis, a literature review is done about the knowledge representation process. After the literature review, the application of knowledge representation will be presented. The final outcome of this study is an expert system which quantifies fault rates, so the knowledge representation process is undertaken by considering this aim.

Knowledge Representation (KR) refers to the method which is used to represent knowledge in a way recognizable to the computer in a knowledge-based expert system (KBES) or expert system. Choice of the appropriate KR method is often critical to the development, functionality and extension of an expert system. A number of different KR methods and formalisms exist.

Much progress has been made in the last decade in knowledge-based expert system applications to civil engineering; yet, there remain innumerable opportunities for expert system technology to improve the way of engineering. These opportunities will become more available in the years ahead as expert systems are known in general; specifically, more about how to develop, teach and use expert systems, how to represent knowledge in expert systems, and how to integrate expert systems with conventional software.

3.5.1. Knowledge-based expert systems

Expert systems originate from the branch of computer science called artificial intelligence (AI). The utility of this computer science technology to engineers is similar to algorithms (having been derived from numerical analysis) and software engineering (having been derived from computer languages, operating systems and database management systems) (Fenves, 1982).

One brief definition of an expert system is as follows: a knowledge-based expert system is a computer program that contains heuristic knowledge and performs a task (such as design or interpretation) normally done by an expert (Robert 1992). All computer programs contain knowledge about the problem they solve. Finite element programs, for example, contain knowledge about finite elements;

however, the knowledge is in the form of particular algorithms and the procedures determining which algorithms to use under certain circumstances. However, knowledge in procedural programs, such as finite elements codes, is not represented explicitly and cannot be readily expanded or manipulated. Given a conventional finite elements program, it would be virtually impossible to make deductions about assumptions used in element formulations, yet this is part of the knowledge on which the program is based and which is used in the development of the code.

Having established that the separation of knowledge from the way the knowledge is used within a program is a critical difference between expert system software and conventional code, there are other distinguishing characteristics between the two types of programming. These distinctions are summarized in Table 3.17. The focus on knowledge, rather than data, in expert systems is an important change from algorithmic programming, as is inferential processing. This type of processing is the most difficult to grasp, especially for programmers experienced in procedural code development, because it is counterintuitive to the way we program in conventional code. Rather than specifying when something will occur, this restriction will be removed and the associated algorithm because the control mechanism, or inference engine, automatically determines the order in which the knowledge base is traversed. The reason for separating knowledge from control is that it is hypothesized that the reasoning process within an expert (and hence within a KBES) is basically the same - only knowledge and experience increase.

3.5.2. Rule-based representation

Specifically, the basic components of a rule-based system will be described and traced; these components to their cognitive analogues will be described. Figure 3.4 shows the structure of a rule-based expert system.

Table 3.17 Comparison of characteristics of conventional programs and expert systems (after (Maher, 1987)).

Conventional Programs	Expert Systems
Representation and use of data	Representation and use of knowledge
Knowledge and control integrated	Knowledge and control separated
Algorithmic process	Inferential process
Effective manipulation of large data bases	Effective manipulation of large knowledge bases
Programmer ensures uniqueness and completeness	Developer relaxes uniqueness and restraint
Midrun explanation impossible	Midrun explanation desirable and achievable
Oriented toward numerical processing	Oriented toward symbolic processing

3.5.2.1. Typical architecture of rule-based systems

The use of rules to represent knowledge has its basis in human problem-solving where it has been shown (Simon, 1965), (Newel, 1972) that an excellent psychological model for symbolic human knowledge is production systems, or sets of rules or productions.

In this model, short term memory is represented by one class of rules (working memory) and long term memory is represented by another class of rules (rule or production memory). As a result of these landmark studies in human cognition, the fundamental components of production systems are as depicted in Figure 3.4. In this architecture, working memory is a dynamic list that stores facts entered by the user (given), by the right hand sides of executed rules (observed) or by the right hand sides of “likely” rules to be executed (hypothesized). This list changes as subsequent information is discovered or entered. The rule memory, or knowledge base, is the component of the production system that represents the knowledge. These rules are cast in clauses:

IF condition(s) THEN action(s)

that represent causal relationships, heuristics, and a priori knowledge. The IF part of a rule is also referred to as the Left Hand Side (LHS) or antecedent of a rule. The THEN part is often called the Right Hand Side (RHS) or the consequent of a rule. The rules are the core part of the expertise associated with any expert system. They represent situation-action pairs, as knowledge is so often expressed (Brownston, 1985), (Buchanan, 1984). When they are executed, the rules alter working memory by asserting new facts or deleting or modifying existing facts.

The rule interpreter, often called the inference engine, is the component of the system that selects the appropriate rule from rule memory and performs the associated actions. This is termed rule execution or rule firing. The interpreter then is the basic distinguishing factor separating expert system rules from conventional conditional statements. The flow of control does not pass from one rule to the next in lexical sequence but is determined by the interpreter, an entirely separate component. Knowledge bases of rules can be expressed independently of the control structure; the causal relationship associated with each rule must be "true" independently of when the rule is applied. The fundamental decision of which rule to fire at a particular point in program execution is determined by the inference mechanism.

The user interface is the set of screens with the help of which the user communicates with the system. It is the "feel" and "look" part of the system.

Some additional characteristics that a rule-based system may possess include an explanation facility (Buchanan, 1984), (Williams, 1988) and a knowledge-acquisition facility (Kidd, 1987), (Marcus, 1990). An explanation facility provides information on the chain of reasoning the system used to reach a conclusion. This helps the user to judge the plausibility of the answers provided by the system. The knowledge-acquisition facility enables the enhancement of the knowledge-base by experts. This characteristic allows the expert to alter or add to the knowledge base directly without having to learn the programming language or having to deal with programming issues.

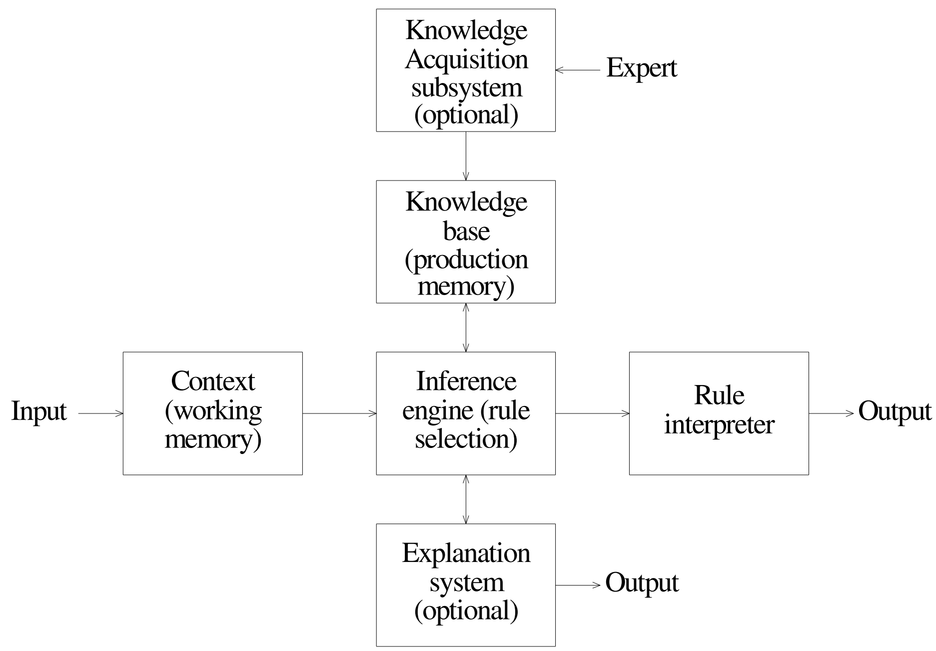

Figure 3.4 Basic components of a rule-based system.

In this study, the expert system which quantifies the fault rates can be named as rule-based expert system. The knowledge representation is conducted by the help of rule-based expert system. In next section of the this study, the expert system constructed for the purpose of quantifying fault rates will be explained in detail.

3.6. The methodology for the quantification of fault rates in dsSafe

The questionnaire results reflect the knowledge of experts when they assign fault rates. Each scenario consists of fault rates which belong to both employer and worker. The answers to the questions determine the fault rates of employer and worker. The fault rates of both employer and worker are accumulated separately according to the answers given to the questions. Finally the fault value of each party is determined. As the fault rates of parties are dependant to each other, the percentages of fault rates are quantified considering this dependency. The fault value of each party is divided by the total fault value and the percentage of fault rates is obtained. The formula for this quantification is given below. For example, in the case of the unavailability of medical report, the employer is % 90 and the worker is % 10 faulty. In addition to this case, there is a site engineer at construction and it is assumed that worker ignored the warnings of engineer. In this case, consider that the employer is % 30 and worker is % 70 faulty. Each of these factors has an importance weight. Consider that the importance factor of medical report and availability of engineer is 5 and 8 respectively. The fault rate of each party is quantified as shown in Table 3.18.

Table 3.18 Quantification of fault rates.

	Importance	Fault rates		Weighted fault values	
		Employer	Worker	Employer	Worker
Unavailability of medical report	5	90	10	450	50
Availability of site engineer	8	30	70	240	560
			Total	**690**	**610**

The fault rates are quantified as below.

$$FaultRateofEmployer = \frac{CummulativeFaultValueofEmployer}{TotalFault}$$

$$FaultRateofWorker = 1 - FaultRateofEmployer$$

For this example:

Fault rate of employer = 690 / 1300 = 53 %

Fault rate of worker = 1 - 53 % = 47 %

The fault rates of parties are dependent to the questions and their values. These questions are submitted through a sequence. In next part of the thesis, these flow charts will be presented.

Table 3.19 Summary of the methodology for the quantification of fault rates.

1. Each factor has an importance weight and each scenario related with that factor contains the fault rate of both employer and worker
2. The final fault value of employer and the worker is calculated by multiplying the importance weight of factor and the fault rate of parties determined at scenarios.
3. The final fault values of parties are accumulated separately and the total fault value of each party is calculated.
4. The comparison of fault rates is determined by relativity to total fault rates. For this, the fault rate of each party is divided by total of whole fault rates which are assigned to both employer and worker.

CHAPTER IV

ARTIFICIAL INTELLIGENCE

4.1. Definitions

1- Artificial Intelligence is a branch of science which deals with helping machines find solutions to complex problems in a more human-like fashion. (Alex J. Champandard)

2- The branch of computer science concerned with making computers behave like humans. The term was coined in 1956 by John McCarthy at the Massachusetts Institute of Technology. Artificial intelligence includes

- games playing: programming computers to play games such as chess and checkers,
- expert systems : programming computers to make decisions in real-life situations (for example, some expert systems help doctors diagnose diseases based on symptoms),
- natural language : programming computers to understand natural human languages,
- neural networks : Systems that simulate intelligence by attempting to reproduce the types of physical connections that occur in animal brains,
- robotics : programming computers to see and hear and react to other sensory stimuli.

3- The capability of a device to perform functions that is normally associated with human intelligence, such as reasoning and optimization through experience.

4- The part of computer science concerned with designing intelligent computer systems, that is, systems that exhibit the characteristics we associate with intelligence in human behavior-understanding language, learning, reasoning, solving problems, and so on. (Barr and Feigenbaum, 1981)

Expert system

1- A computer application that performs a task that would otherwise be performed by a human expert. To design an expert system, one needs a knowledge engineer, an individual who studies how human experts make decisions and translates the rules into terms that a computer can understand.

2- An expert system is a computer program that represents and reasons with knowledge of some specialists subject with a view to solving problems or giving advice (Jackson, 1999).

4.2. What is an expert system?

Expert systems, or knowledge-based expert systems, have received considerable attention among professional and academic groups. The attention is due to the advertisement of a few relatively successful expert systems and the potential for the development of more successful applications. With all this advertisement and attention, little space and time is generally devoted to defining the term "expert system." More significantly, definitions often do not delineate how expert systems are different from conventional software. For example, one popular definition is:

Expert systems are interactive computer programs incorporating judgment, experience, rules of thumb, intuition, and other expertise to provide knowledgeable advice about a variety of tasks. (Gaschnig, 1981)

The definition given above does not necessarily distinguish expert systems from many conventional computer programs. Conventional programs can be interactive, and contain judgment and rules of thumb, yet they are not expert systems. Table 3.17 lists some of the distinguishing characteristics of conventional programs and expert systems.

4.2.1. Origins

Expert systems technology comes from a branch of computer science that is referred to as Artificial Intelligence (AI). AI is concerned with a broad range of topics that are related to simulating human intelligence in a computing machine. Some of the better known areas of AI are natural language understanding, machine vision, robotics, and expert systems.

Expert systems are a result of many years of attempting to simulate or reproduce intelligent problem-solving behavior in a computer program. The early attempts were directed toward the development of general problem solvers, such as GPS (Newel, 1963). After years of research, it was determined that general problem solvers are weak, at best, unless specific knowledge about the problem being solved is added to guide the search for a solution. This determination led to what is now referred to as expert systems. Expert systems include some general strategy for solving problems, but specific knowledge about the class of problems the expert system solves is used to reproduce intelligent problem-solving behavior.

Expert systems created before 1981 include MYCIN (Buchanan et al, 1983), for diagnosing infectious diseases, PROSPECTOR (Duda and Reboh, 1984), for interpreting geological information, and MOLGEN (Stefik, 1981), for planning molecular genetics experiments. These expert systems receive much attention and are considered successful. Their success is based on their ability to solve problems at the level of an expert in their respective fields and the ability for the expert systems to communicate easily with novice users. Differing from earlier attempts at automated intelligent problem solving, these systems are capable of solving problems in specific and highly specialized fields.

The early expert systems were developed using conventional programming techniques, such as sequential execution of program statements, because those techniques were available at the time. Other programming techniques have since been developed, largely due to the experience gained in developing MYCIN and similar expert systems. These other programming techniques, usually referred to as expert system techniques; include relaxing the sequential nature of the computer program, and providing facilities for separating the problem solving strategy from the knowledge about the problem itself.

4.2.2. Expectations

Expectations of expert system technology exceed reality in many situations. Some of these expectations include the following:

- Expert systems can be developed to solve any problem currently solved by experts.
- Expert systems are developed by knowledge engineers with occasional interaction with experts.
- Expert systems can be quickly prototyped and expanded.
- Expert systems may be the answer to all our software problems.

These expectations have arisen from descriptions of expert systems indicating that the techniques available provide higher level programming environments in which knowledge can be easily represented and modified, and that this knowledge need not be numerical. Although the techniques currently available for designing and implementing expert systems do have these characteristics, there are many limitations that are not as well advertised.

Expert systems can be developed to solve any problem currently solved by experts. The appropriate problems for using expert system techniques are those that require expertise for the solution; the reverse is not true. Many problems solved by human experts are not easily solved using current expert system techniques. Some criteria for selecting an appropriate problem for an expert system application are given in (Hayes and Roth, 1983), and they include: (1) The problem should focus on a narrow specialty area and should not involve a lot of common-sense knowledge; (2) the problem should not be too easy or too difficult for human experts; (3) the problem should be clearly defined; and (4) commitment from an articulate expert or group of experts is necessary.

Expert systems are developed by knowledge engineers with occasional interaction with experts. Many expert systems are currently developed by a team of dedicated professionals. Part of this team includes knowledge engineers who are familiar with knowledge representation techniques and tools for implementing such representations. The other part of this team is the experts and their resources. Successful development requires a commitment from both parts of the team. A knowledge engineer must interact with an expert on a regular and as-needed basis. The knowledge engineer cannot be expected, in general, to correctly extract the knowledge needed from publications or textbooks. In some situations, management decides that an expert should be developed but does not commit the resources-such as time from experts, and experienced knowledge engineers-to make the effort successful.

Expert systems can *be quickly prototyped and expanded.* This statement is true in limited situations, but certainly not in all situations. Expert systems can be quickly prototyped if the problem the system is to solve is clearly identified, and if the environment chosen for the prototype is suitable for the type of problem solving behavior expected. The more common situation is that the problem to be solved is only vaguely specified, and the environment chosen for the prototype is one that is inexpensive and runs on house hardware. An expert system should be easily expanded; however, current technology in knowledge representation still requires that someone experienced in the language or tool used to develop the expert system be available for expansion and maintenance.

Expert systems may be the answer to all our software problems. This is an expectation that is reflected in the number of proposals made and contracts offered for developing expert systems in many different domains, with little consideration given to the type of problem to be solved. In many cases, software problems are identified, with the expectation that expert systems are going to solve these problems. Expert systems are appropriate for limited situations, and careful consideration should be given to the nature of the software problem and the current state of software technology.

4.2.3. Characteristics

The fundamental characteristics of an expert system are identified in many articles, for example (Fenves, 1986), (Stefik, 1986). This section presents some of these characteristics which are compiled from the books such as (Harmon 1985, Waterman, Hayes and Roth 1983) for a more extensive account.

An expert system exhibits the following characteristics:

1. The domain knowledge and the control knowledge are implemented separately, i.e., there is a distinction made in the implementation of the expert system between what knowledge is used to solve the problem and *how* that knowledge is applied to a specific problem.
2. The knowledge used to solve the problem can be expressed in primarily symbolic terms rather than primarily numerical terms.

3. The implementation of the expert system results in a transparent representation of the knowledge and the process that uses the knowledge. Transparency implies that the implementation language does not obscure the knowledge it represents.
4. An expert system contains human expertise and judgment through the use of heuristics and “compiled” knowledge. A heuristic is the study or practice of procedures that are valuable but are incapable of proof. Compiled knowledge implies information that, although it may have its origins in basic principles, is closer to experiential knowledge. For example, a relationship is used because it works rather than because it can be proved that it will work.

Many programs developed are called expert systems because they exhibit some or all of the characteristics described above; however, the term “expert system” is often misunderstood, owing to the similarity between conventional software characteristics and the characteristics of an expert system. A brief look at architecture should make the distinction clearer.

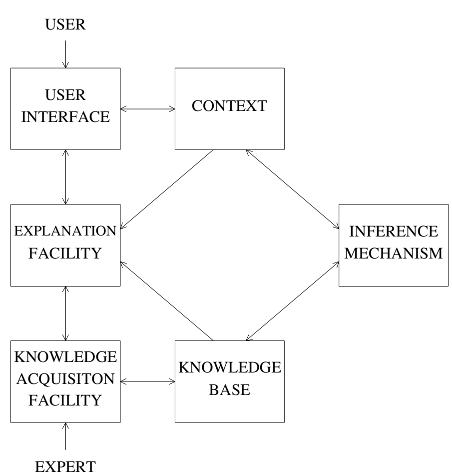

Figure 4.1 Expert system architecture.

4.2.4. Expert system architecture

The architecture of an expert system is difficult to define because of the variation in the tools and languages in which expert systems are developed. This section provides a generalization of an expert system architecture of which each expert system application may be a variation.

4.2.4.1. Basic architecture

The basic architecture of an expert system exhibits a separation of domain knowledge, control knowledge, and knowledge about the specific problem currently being solved. This leads to the identification of three basic components of an expert system: the knowledge base, the context, and the inference mechanism. Additional components needed to make the expert system more usable are a user interface and an explanation facility. To enhance extensibility, a knowledge acquisition facility is desirable. The relationship between the components is illustrated in Figure 4.2; the components are further described in the following subsections.

4.2.4.2 Knowledge base

The knowledge base is the component of an expert system that contains the facts and heuristics associated with the domain in which the expert system is applied. The facts are typically represented as declarative knowledge, and heuristics take the form of rules.

For example, the potential contents of a knowledge base for structural design would include related facts that can be grouped according to the physical objects used to describe a design. One example of a fact, or object, is a beam. A beam could be represented in the knowledge base as a structural component with attributes including width, span, cross section, location, and loads. The rules related to structural design could be based on heuristics, experience, or functional relationships. An example of a heuristic is: If beam span < 40 feet and preferred material is steel, then use a wide flange section. An important note to make here is that the preceding heuristic contains information about structural design with no explicit reference as to how or when the knowledge is used.

The knowledge base should be transparent enough so that it can be easily modified. Modification is important in most engineering domains since knowledge is continually changing and expanding. Many expert system environments provide higher level representation schemes than procedural code, such as rules or frames, in order to make this knowledge as transparent as possible.

4.2.4.3. Context

The context is the component of the expert system that contains the information about the problem currently being solved. The context initially contains the information that defines the parameters of the problem and, as the expert system reasons about the given problem; the context expands and contains the information generated by the expert system to solve it. Upon completion of the problem solving process of the expert system, the context contains all the intermediate results of the problem solving process as well as the solution. For example, a context in an expert system to select the appropriate liner for a hazardous waste site initially contains information about the site and the nature of the waste to be stored. The context would expand as the problem solving process progresses to include information about potential liners for the given site and a certainty factor associated with each liner reflecting relative appropriateness.

4.2.4.4. Inference mechanism

The inference mechanism is the part of the expert system that contains the control information. The inference mechanism uses the knowledge base to modify and expand the context. There are many different levels at which the inference mechanism controls the reasoning process. If the inference mechanism operates at a very low level (providing flexibility in solution strategy), the knowledge base must contain additional control information specific to the application domain. The more specific the inference mechanism, the less control information there is in the knowledge base.

An example of the inference mechanism for determining the best welding materials to use is one in which the potential weld technologies are checked individually, using the input data to verify the validity of the technology being considered. This approach is referred to as backward chaining; the possible solutions are tried using the given data to determine which solution is the best. This inference mechanism can be applied to a knowledge base containing a set of rules that define the relationships between the possible solutions and intermediate or input data.

4.2.4.5. Explanation facility

The explanation facility in an expert system varies from a trace of execution to the ability to respond to questions about the reasoning process used to develop a solution. Any well-written interactive computer program contains a trace of its execution; this is not a concept unique to expert systems. An expert system can provide more than a passive trace of execution by responding to questions about specific aspects of the problem solution.

4.2.4.6. Knowledge acquisition

The knowledge acquisition facility in an expert system is the component that facilitates entering knowledge into the knowledge base. In the simplest case, this facility acts as an editor, and knowledge is entered directly in a form acceptable by the software in which the expert system is implemented. On a more sophisticated level, the knowledge acquisition facility understands the inference mechanism being used and can actively aid the expert in defining the knowledge base.

The extreme possibilities for a knowledge acquisition facility are currently reflected by the type of editor provided for creating and modifying the knowledge base. At one extreme, the knowledge engineer uses a screen editor to create or modify a file of rules. At the other extreme, the editor is itself an expert system, knowledgeable about problem solving using the inference mechanism or mechanisms provided, that aids the expert in defining a knowledge base. More commonly, the expert system tool provides a graphical editor through which the system developer can modify the relationships between nodes in a decision network.

4.2.4.7. User interface

The expert system user interface extends the traditional capabilities of conventional user interfaces. In addition to being highly interactive, an expert system user interface needs a transparency of dialogue, whereby some form of an explanation facility indicates the inference, or reasoning, process used.

4.3. Rules and expert systems

Maher (1987), in his book, stated that rule-based systems can be either *goal driven* using *backward chaining* to test whether some hypothesis is true, or *data* *driven*, using *forward chaining* to draw new conclusions from existing data. Expert systems may use either or both strategies, but the most common is probably the goal driven/backward chaining strategy. One reason for this is that normally an expert system will have to collect information about the problem from the user by asking them questions - by using a goal driven strategy we can just ask questions that are relevant to a hypothesized solution.

Anyway, in a simple goal-driven rule-based expert system there are often a set of possible solutions to the problem - maybe these are a set of illnesses that the patient might have. The expert system will consider each hypothesized solution (e.g., has cold (fred)) and try to prove whether or not it might be the case. Sometimes it will not be able to prove or disprove something from the data initially supplied by the user, so it will ask the user some questions (e.g., “have you got a headache?”). Using any initial data plus answers to these questions it should be able to conclude which of the possible solutions to the problem is the right one.

CHAPTER V

THE dsSafe EXPERT SYSTEM

In this study, the methodology of representing knowledge is undertaken by an expert system. The expert system is a knowledge-based expert system. The knowledge acquisition process was explained in previous chapters. In addition to its feature for being a knowledge-based expert system, the expert system which is named as dsSafe is a ruled based-system. The relations between activities are maintained by IF-THEN rules, but the decisions are not taken through these rules. Each answer to the questions has a value of fault. These values of faults are accumulated in the memory of the program and a conclusion is arrived through the total of these values. The methodology of quantification was explained in knowledge representation section. An example of rule is given below.

Question:
Did the worker have medical report?
Rule 1:
If the answer is "Yes", then the fault rate of both employer and worker is "0"
Rule 2:
If the answer is "No", then the fault rate of employer is "100" and fault rate of worker is "0".

The dsSafe expert system is a data-driven expert system which means there is no goal to be reached for a conclusion. The answers to the questions determine the conclusion which identifies the fault rate of party. The questions are submitted to the user in a sequence. Some of the questions are conditional questions, so the dsSafe recognizes these questions and follows the flowchart through the answers of users. For example, the dsSafe asks whether the safety belt is required or not. If the user answers as “No”, the system does not ask whether the employer provided safety belt or not. On the contrary, if the user answered as “Yes”, the system asks whether the employer provided safety belt or not. According to the answer of user, the system asks other conditional questions.

The flowchart of each type of fall accidents is presented in the following sections. A numerical notation is used to represent questions in the flowcharts. The numbers in the flowcharts refer to the number of questions which are presented in the inspection checklists. In flowcharts, “Y” refers to “Yes”, “N” refers to “No” and “U” refers to the “Unknown”. At the end of the flowcharts, there are the graphics which shows the features of expert system. These features will be explained broadly at the next sections of the thesis.

An example for the structure of experts system which investigated the falls from roofs is explained in the next section. The inspection checklists and the flowcharts of the remaining construction falls investigated through this study are presented in the appendix.

5.1. The flowchart of expert system for falls from roofs

The inspection checklist should be well understood for the evaluation of flowchart as the flowchart consists of numbers. As explained previously each number refers to a question. The inspection checklist and flowchart of roof falls are given Table 5.1 and Figure 5.1 respectively.

Table 5.1 Inspection checklist for the falls from roofs.

No	Questions	Response (Y/N)
1	Did the worker have medical report?	
2	Was there an engineer responsible for construction site?	
3	Was the worker an experienced person?	
4	Did the worker fall due to his/her personal carelessness, in a moment of abstraction or while feeling dizzy?	
5	Considering the type of work, was it required to provide safety belt?	
6	Did the employer provide safety belt?	
7	Did the worker use the safety belt?	
8	Did the employer provide hard hat at the construction?	
9	Did the worker use the hard hat?	
10	Were the weather conditions convenient for working?	
11	Was there a warning sign informing about hazard?	
12	Were the workers informed about the hazards of works?	
13	Were safety equipments such as scaffolding, guardrails or safety nets provided for preventing roof falls?	
14	Were the equipments safe enough to prevent falls?	
15	Was safe path identified or was roof ladder provided?	
-?-	Note any additional information if available.	

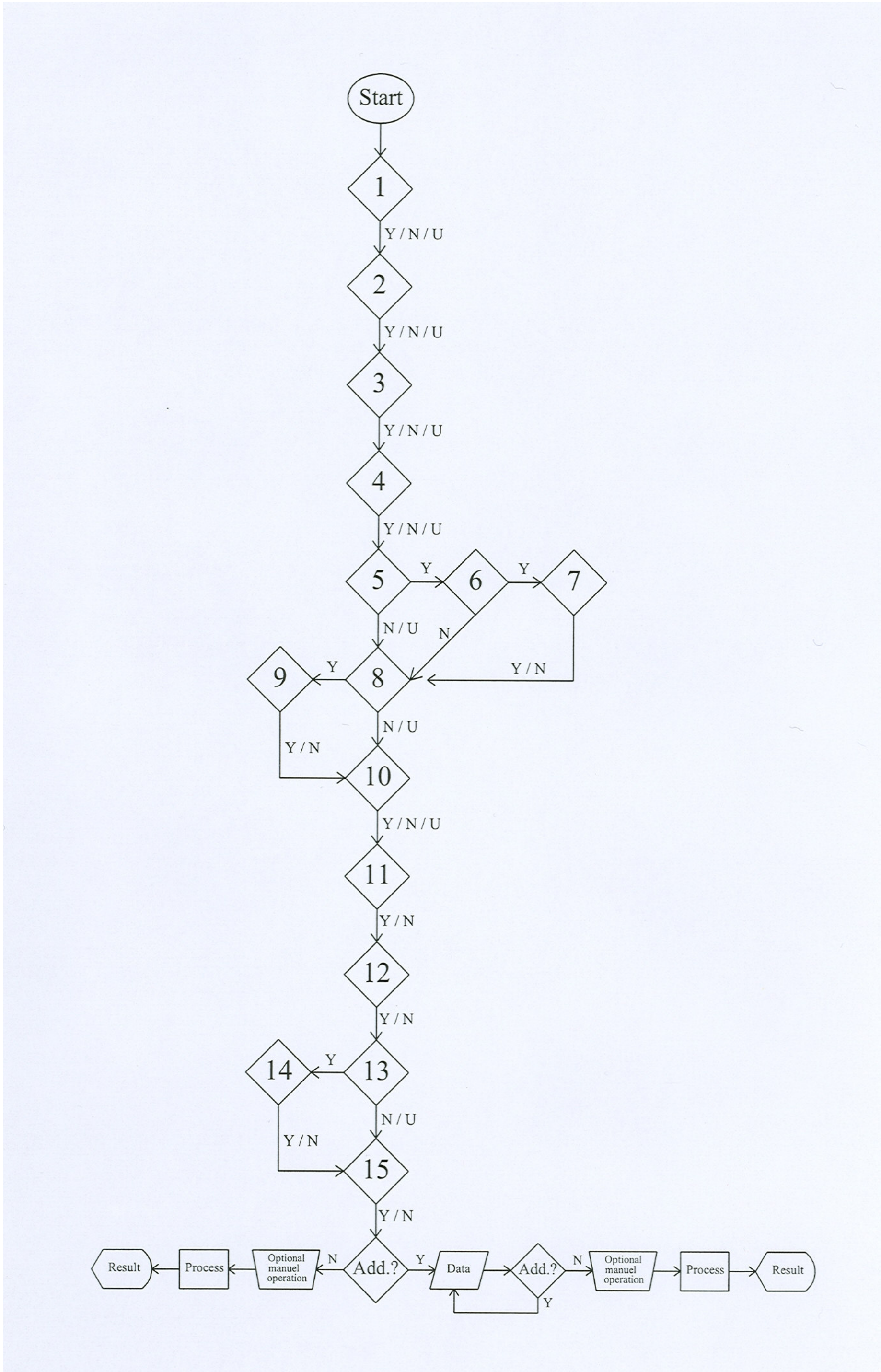

Figure 5.1 Flowchart for the falls from roofs.

The idea behind the system is simple. The pre-determined questions are asked in a sequence. After the last question, the system asks the user whether there is additional factor to be considered. If the user answers that there is no additional factor, then the system displays the factors which are considered within the investigation. The user has an opportunity to change the importance weights of factors. After this process, the system quantifies the fault rate of each party and displays the results.

If the user considers that there are additional factors to be considered, the system has a feature to maintain this requirement. A data acquisition screen appears to user and it is expected from user to enter the factor or factors and the numerical data for the quantification of that/those factors. After this process, the system provides opportunity to add, delete or edit any factor. If there is no other additional data, then the system displays the factors which the user can change the importance weights. Finally, the system displays the results.

5.2. A manual application for the quantification of fault rates

As stated previously, the numerical data for all scenarios were gathered through questionnaire. The responses of the user to the questions determine the fault rates of parties. An example is made for the quantification of fault rates in roof falls. The sequence determined in flowchart is followed. The responses and their values are given as well. The values are obtained from the results of questionnaire.

			Employer	Worker
1	Did the worker have medical report?	No	509.8	68.9
2	Was there an engineer responsible for construction site?	Yes	221.7	478.3

3	Was the worker an experienced person?	Yes	267.4	418.8
4	Did the worker fall due to his/her personal carelessness, in a moment of abstraction or while feeling dizzy?	No	0.0	0.0
5	Considering the type of work, was it required to provide safety belt?	Yes	775.4	102.2
6	Did the employer provide safety belt?	No		
7	Did the worker use the safety belt?	--		
8	Did the employer provide hard hat at the construction?	Yes	125.5	301.1
9	Did the worker use the hard hat?	No		
10	Were the weather conditions convenient for working?	Yes	0.0	0.0
11	Was there a warning sign informing about hazard?	No	337.3	346.8
12	Were the workers informed about the hazards of works?	Yes		
13	Were safety equipments such as scaffolding, guardrails or safety nets provided for preventing roof falls?	Yes	0.0	0.0
14	Were the equipments safe enough to prevent falls?	Yes		
15	Was safe path identified or was roof ladder provided?	No	692.3	68.4
		Total	2929.3	1784.5

The total of the fault values is 4713, 8. The relative fault rates, as explained previously, can be calculated as below.

$$FaultRateofEmployer = \frac{2929{,}3}{4713{,}8} \cong 62\%$$

$$FaultRateofWorker = 1 - 62\ \% = 38\ \%$$

5.3. The reporting system in dsSafe

The dsSafe expert system not only quantifies the fault rates, but also prepares a report which explains why these rates are assigned to employer or worker. The reporting clauses are pre-prepared for each scenario. The valid laws and regulation are reviewed and the recommendations are made through this laws and regulations. For example, if the user reports that the worker has no medical report, then the system adds a clause to the investigation report which is shown below:

"The employer can not employ any worker without a medical report determining his/her health conditions. The employer should consider if workers are convenient for that work or not. Otherwise, the employer will be in faulty situation in respect of Labor Law (4857) item 86, OHSR item 14 and 6.c/2 and HHWR item 5.

If workers are aware of any diseases regarding their health, they should work in kind of works which do not threat their health and safety."

Some of the evaluations are gathered from the inspection reports, but the majority of the report is based on legal laws and regulations. In this study, there exist 60 scenarios. Each of these scenarios is investigated through the valid laws and regulations and each scenario is assigned a report.

5.4. Developing dsSafe with Delphi

The above mentioned flowchart is applied to a computer program using Delphi. This application is called as dsSafe through the thesis. Delphi is a powerful tool for developing such applications. Borland Delphi is an object-oriented, visual programming environment to develop 32-bit applications for deployment on Windows and Linux. Using Delphi, highly efficient applications with a minimum of manual coding can be created. Delphi provides a suite of Rapid Application Development (RAD) design tools, including programming wizards and application and form templates, and supports object-oriented programming with a comprehensive class library that includes:

The Visual Component Library (VCL), which includes objects that encapsulate the Windows API as well as other useful programming techniques (Windows). The Borland Component Library for Cross-Platform (CLX), which includes objects that encapsulate the Qt library (Windows or Linux).

5.5. Visualization of dsSafe

The software consists of 6 modules:

1st module : Determination of parties involved in that occupational accident,

2nd module : Selection of the construction fall accident type to be investigated,

3rd module : Furnishing the system with certain information considering pre- determined questions,

4th module : Entering and defining additional information considered by user,

5th module : Determination/modification of importance level of factors and

6th module : Quantification of fault rates and preparation of investigation report.

1. module : Determination of parties involved in that occupational accident

The expert system consists of two parties for the assignment of fault rates. These parties are employer and worker. In the first module of the program, the user should enter the name and qualification of the party who will be assigned fault rates. There are three blanks in a row. The user should enter the name to the first blank and the qualification to the second blank. The third blank automatically recognizes the group of party whether it should be defined as employer or worker. In this module of the program, the user has to define the contractor and the victim or victims; else the program warns the user to define these qualifications. Figure 5.2 visualizes the first module of the program.

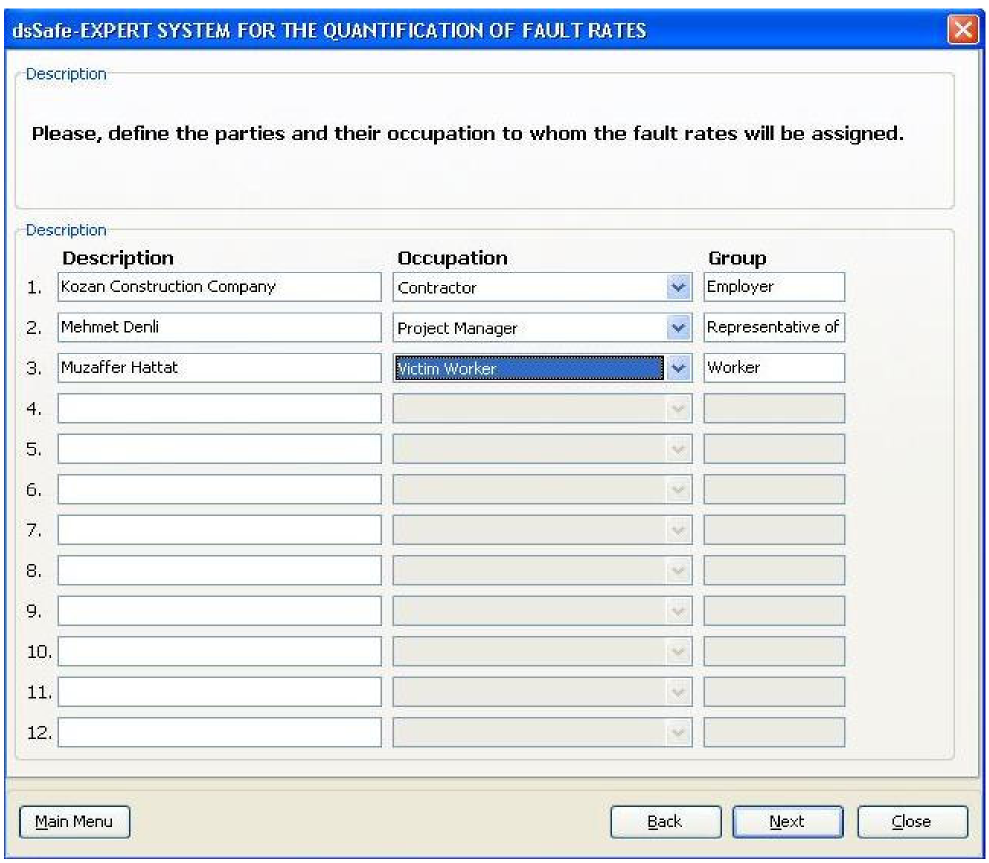

Figure 5.2 Determination of parties.

2. module : Selection of the construction fall accident type to be investigated

As explained previously, the expert system dsSafe investigates six types of construction fall accidents. After defining the parties in accident, the system asks the user to select the type of construction fall to be investigated. Figure 5.3 visualizes the second module of the program.

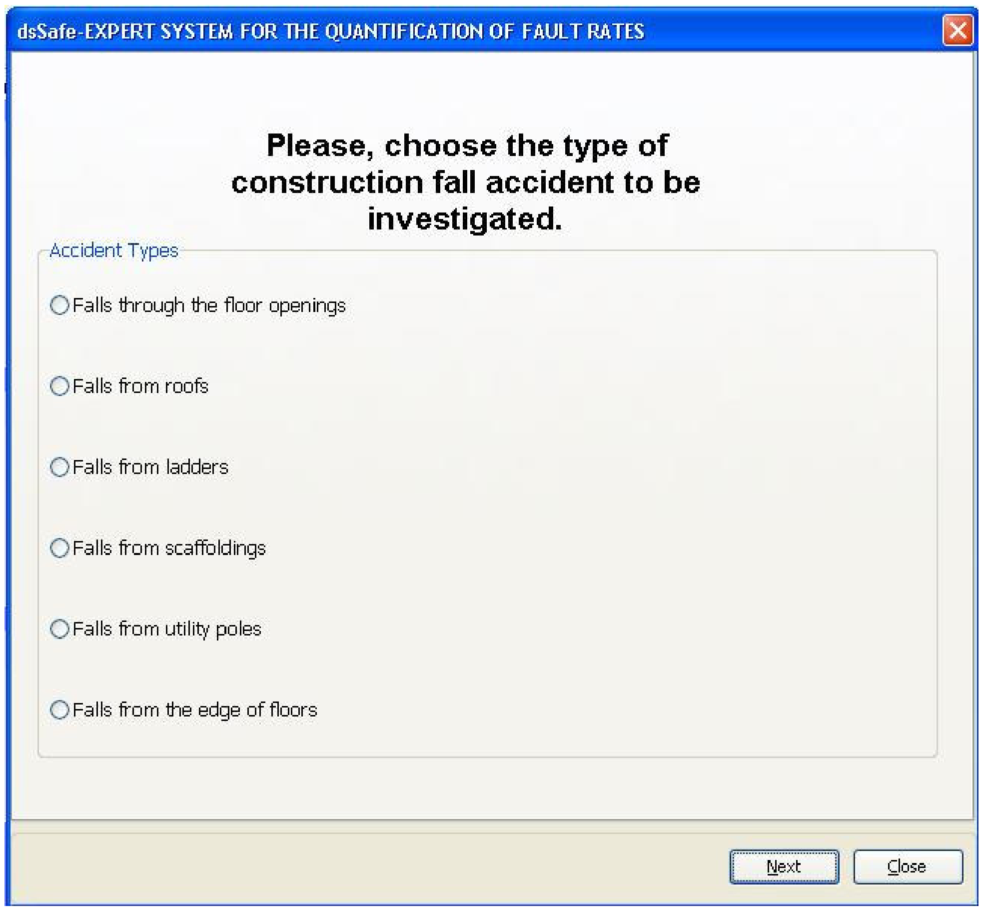

Figure 5.3 Selecting accident type.

3. module : Furnishing the system with certain information considering pre-determined questions

In this module of the expert system, the program asks the questions through a sequence which is defined in flowcharts. According to the answer of user, the program asks the next question. User has three options to define. These are “Yes”, “No” and “Unknown”, but all of the questions has not an option of “Unknown” as these cases are not considered when developing the system. The master questions have this option while others do not have. The user can define his/her confidence levels for the answers they are entering to system. Figure 5.4 visualizes a screen of the third module of the program.

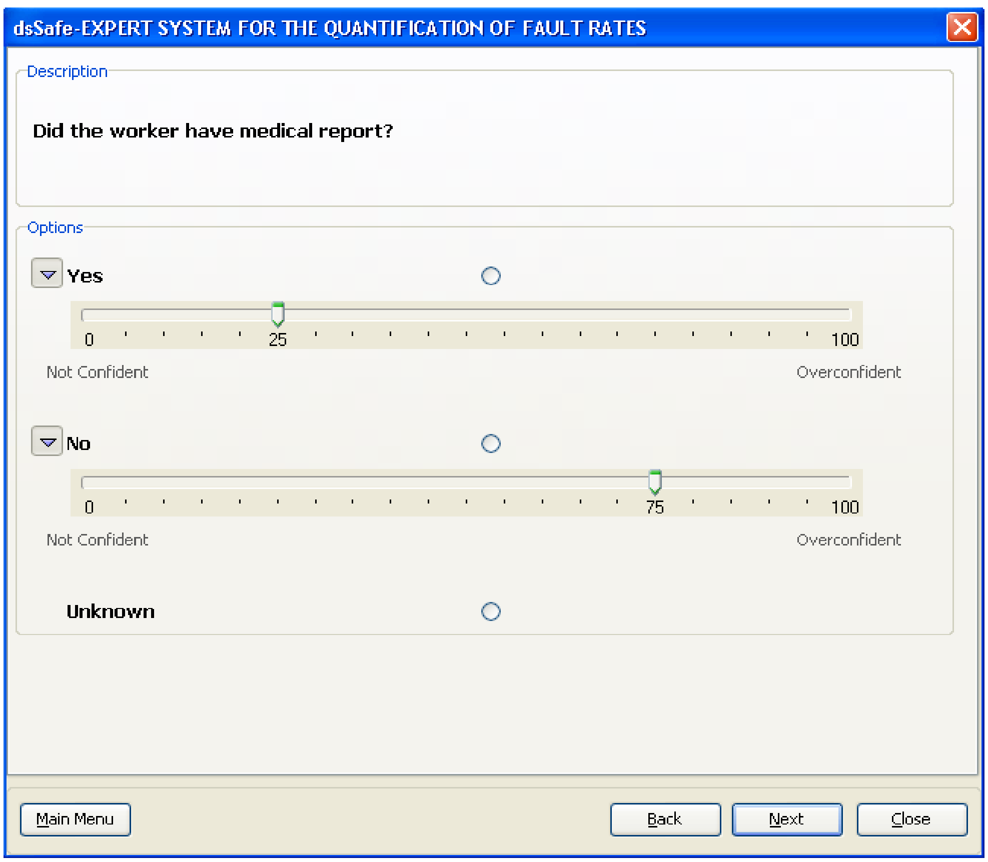

Figure 5.4 Answering section.

4. module : Entering and defining additional information considered by user

All types of the construction fall accidents have limited questions and also scenarios defined within the expert system. The system can not cover all of these factors. As the construction fall accidents depend on a large number of factors, it is considered to construct an option which the user has an opportunity to enter the factor he/she considers to be important when assigning fault rates. In this module, the user can add, delete or edit any factor which is important or essential for the investigation of accident. In this module, the user should define the factor, its importance weight and finally the fault rate of employer and worker. The special and main sections of this module are visualized in Figure 5.5 and Figure 5.6 respectively.

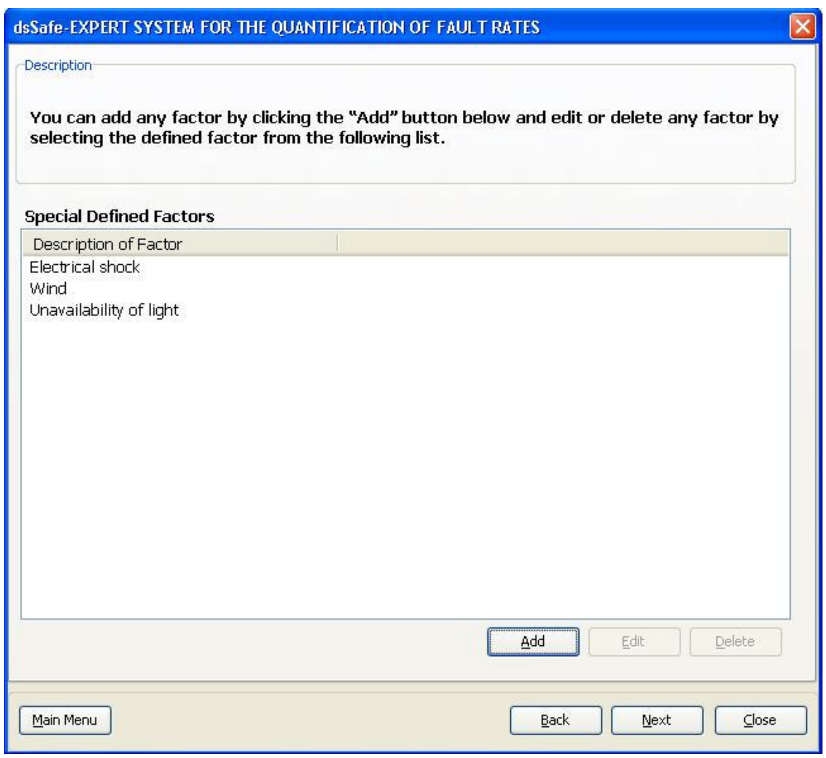

Figure 5.5 Screen of special defined factors.

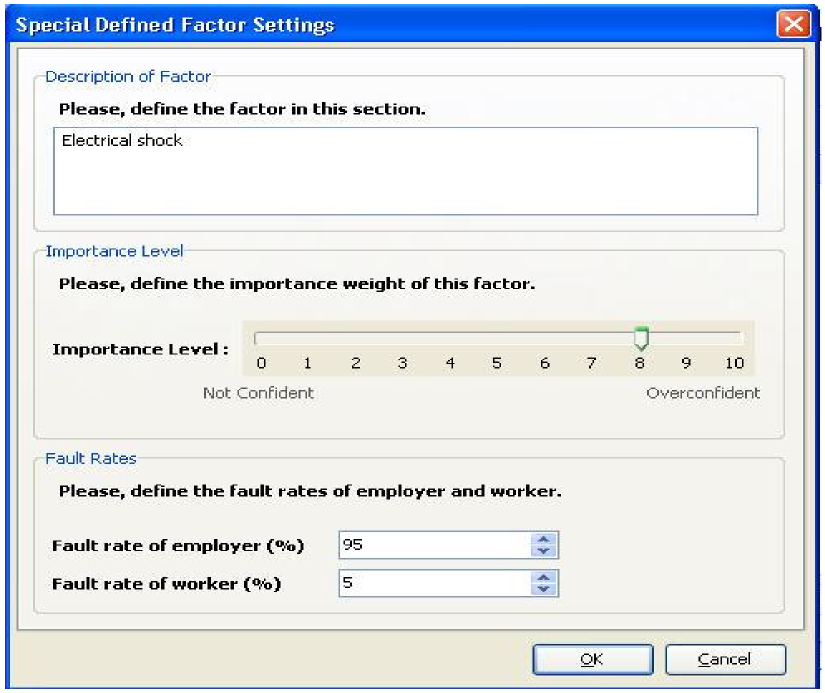

Figure 5.6 Database screen.

5. module : Determination/modification of importance level of factors

After furnishing the system with certain information, the system creates an option to user for modifying the importance weights of the factors. There are the pre-determined importance weights as default importance weights. By clicking on the weight section, the user can modify these values. If the user changes these values, the system uses the user-defined values for the quantification of fault rates. Figure 5.7 visualizes a screen of the fifth module of the program.

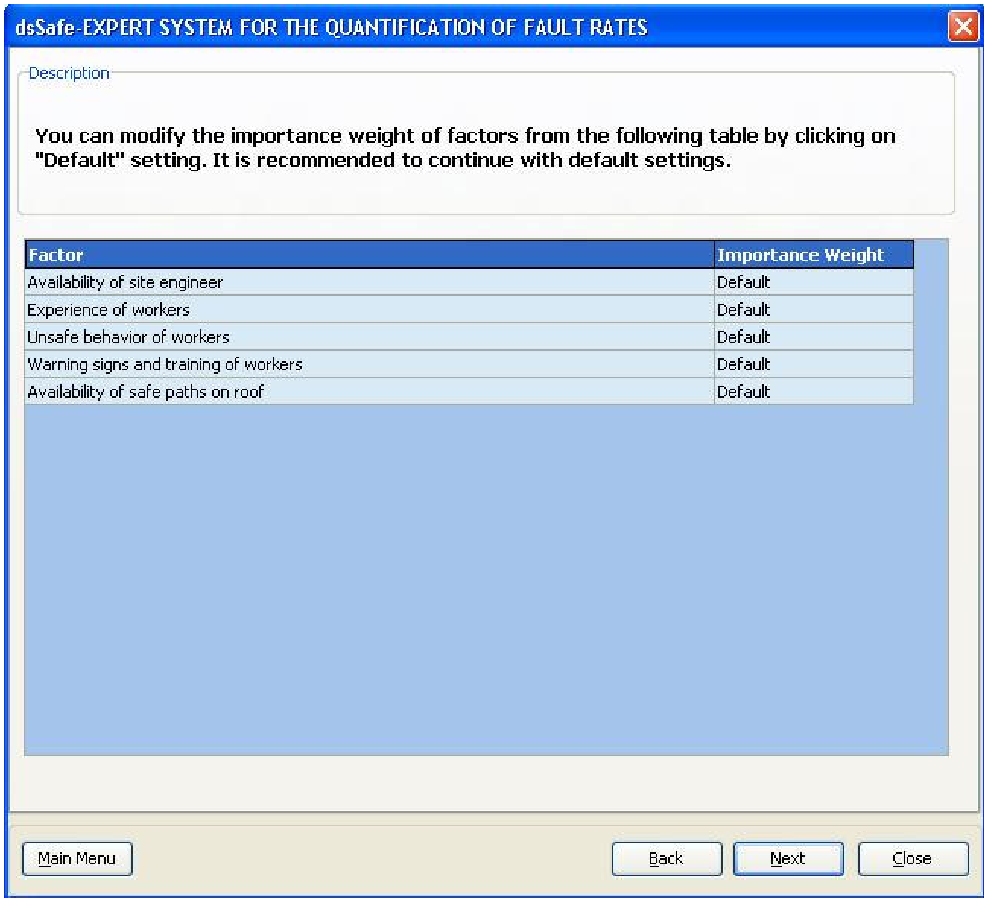

Figure 5.7 Modification screen.

6. module : Quantification of fault rates and preparation of investigation report.

This module is the last module for finalizing the process. The program displays a checklist, Figure 5.8, which shows the answers of user to questions, and if there is no modification, the system quantifies the fault rate of both employer and worker. The last screen only displays the values of fault rates. Under this display, there is a button for creating the report. The report is designed through the answers to the questions. The user can press this button to see the report. The report is displayed on another window. The user has an option to save this report as an Ms-Office document or in html format. Figure 5.9 visualizes a screen of the sixth module of the program.

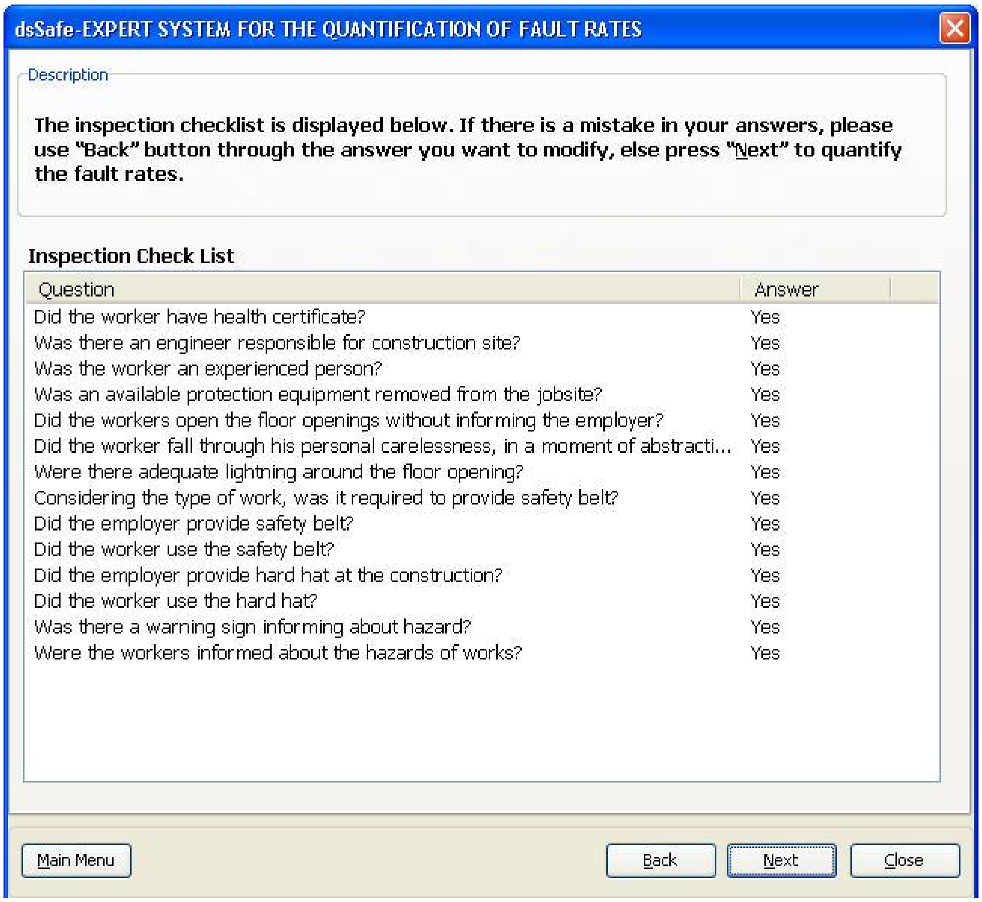

Figure 5.8 Checklist screen.

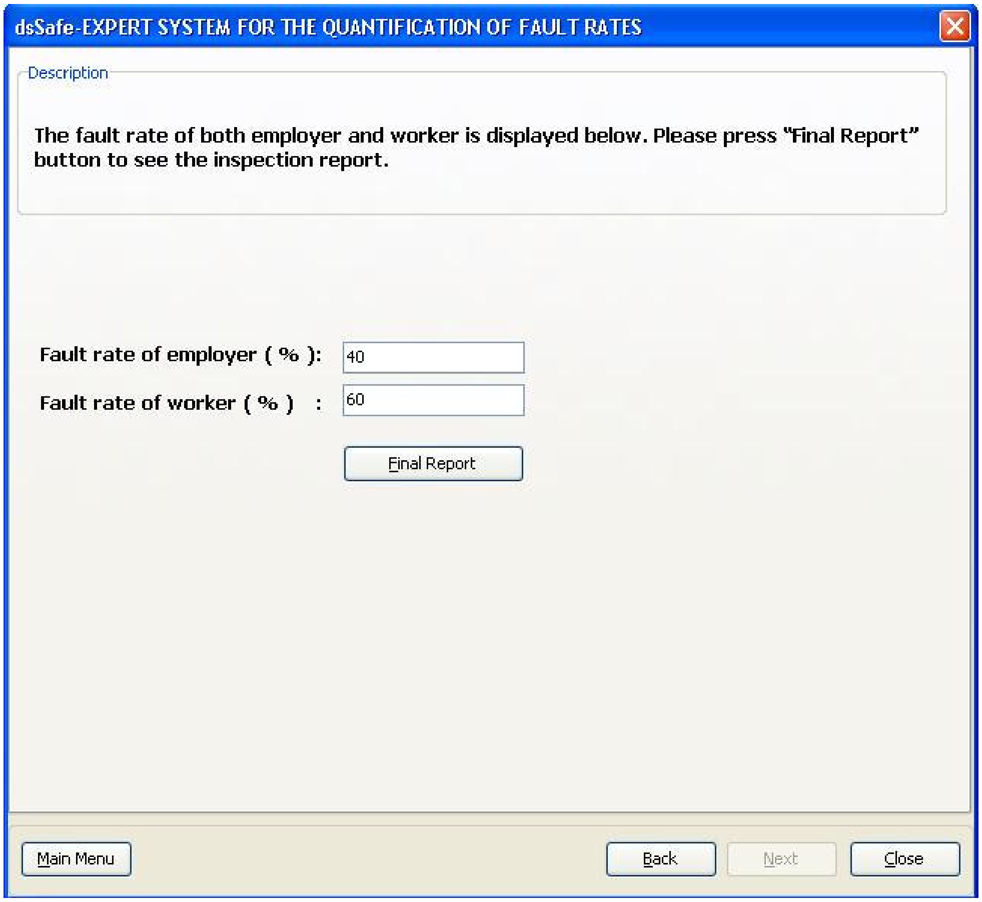

Figure 5.9 Result screen.

5.6. A case study – Fall from roof

Consider that the above mentioned case is applied to the dsSafe. Assume that Ferit Akar and Mevlüt Doğan are defined as contractor and victim respectively. The result does not change, but due to the pre-defined property, the system displays these fault rates with 5 intervals, so the fault rate of employer will be displayed as 65 % while the fault rate of worker will be displayed as 35 %. The investigation report for this case will be displayed as below.

“ ***Inspection Report***

A. Determination of Parties

Ferit Akar defined as employer will be named as employer while Mevlüt Doğan will be named as worker at the remaining parts of the report.

B. Determined Issues and Assessment

1. Unavailability of medical report

The employer can not employ any worker without a medical report determining his/her health conditions. The employer should consider if workers are convenient for that work or not. Otherwise, the employer will be in faulty situation in respect of Labor Law (4857) item 86, OHSR item 14 and 6.c/2 and HHWR item 5.

If workers are aware of any diseases regarding their health, they should work in kind of works which do not threat their health and safety.

2. Availability of site engineer

The employers are responsible for supervising the workers if they comply with the rules; take the precautions to avoid accidents. On the contrary, employer should warn the worker and enforce them to do the requirements to ensure safety. In this investigation, because the accident happened, it is determined that the employer did not supervise the workers properly. This behavior of employer or representative is contrary to the Labor Law (4857) item77.

The workers have to work in compliance with the directives of employers or representatives. As far as the employer should ensure the safety of workers, the workers should pay attention to their safety by themselves. This attention should not be in high or low level, whether there is a safety engineer on site or not. OHSR item 13/a defines the responsibility of workers.

3. Experience of workers

The employer should not avoid taking precautions considering that the workers are experienced. Employer should supervise workers and ensure their safety.

This duty is defined as the employers' responsibility in Labor Law (4857) item 77.

Because the worker was experienced, he/she should be aware of the hazardous situation and he/she should work carefully. If the workers identify any hazardous situation, they have to ask for precautions to be taken for their safety and they can avoid working as far as the safe work conditions are provided. Labor Law (4857) item 83 defines these rights of workers.

4. Unavailability of safety belt

The employer must ensure the safety of workers by providing all precautions and required equipments. Labor Law (4857) item 77, OHSR item 5/a and 6/a and UPPEWR item 8 enforce employers to ensure the safety and health of workers by supervising and enforcing them to comply with rules. Employer is faulty considering these law and regulations.

If the workers identify any hazardous situation, they have to ask for precautions to be taken for their safety and they can avoid working as far as the safe work conditions are provided. Despite these hazards, if the workers decide to work, they should be careful for their health and safety. Otherwise the workers will be moderately faulty according to Labor Law (4857) item 83 and OHSR item 13.

5. Lack of using hard hat by workers

The employer must supervise the workers whether they used the hard hat or not. This is the responsibility of employers according to Labor Law (4857) item 77 and UPPEWR item 8. The employer is faulty for the lack of supervision.

The worker behaved unguarded by avoiding using the provided hard hat. Workers must comply with the rules, regulations and directives of the employers. Also, workers, for their safety, must use the provided safety equipments without the warning of employer. The worker is faulty according to Labor Law (4857) item 77, OHSR item 13/b and UPPEWR item 8.

6. Warning signs and training

Although the employer trained the workers, it is in lack of supervision and provision of warning signs. This becomes employer faulty according to the Labor Law (4857) item 77, SHSR item 5 and OHSR item 6.

The worker was trained by employer, but this training could not prevent the accident. This can mean that the worker ignored the training and did not work carefully. Besides workers have to pay attention when they are working, they should comply with the directives and training provided by employers. The workers become faulty by acting carelessly according the Labor Law (4857) item 77, OHSR item 13/a and OHSRC item 12.

7. Unsafe protection equipments

The accident happened though the unsafe equipment. Employers are in charge of; taking all precautions for safety, training the worker for the hazards of works and enforce them to comply with rules. Any hazardous situation regarding safety equipments should be prevented by employers' actions even that can happen from the behaviors of workers. The provided equipments should be safe enough to prevent accidents. Considering these requirements, it is clear that employer is faulty according to Labor Law (4857) item 77, OHSRC appendix IV, minimum standards 1, minimum special clauses 1 and 5.

Worker should use the provided equipments properly, and avoid causing an accident. If the worker was working carefully, he/she can mitigate the risk of accident due to slipping. Worker can be found faulty considering the OHSR item 13/a and 13.b/3.

C. Decision

Considering the above mentioned issues;

Ferit Akar defined as employer are/is found to be % 65 (sixty five percent) faulty while Mevlüt Doğan defined as worker are/is found to be % 35 (thirty five percent) faulty. 30.03.2005"

CHAPTER VI

CONCLUSIONS

The system is tested with several real cases and it has been observed that, dsSafe provides satisfactory results. The comparison of fault rates assigned by dsSafe and experts are presented in Table 6.1. In addition to the utilization of experts' knowledge, the system also allows the user to create his/her database. Although the system does not cover all of the factors that need to be considered for all types of fall accidents, the system has an option to enter these factors to the system. This flexibility of program makes this system useful for all cases of accidents which are investigated in it. In addition to this flexibility, the user can modify the pre-determined information. Despite these features, it is strongly recommended to run the system, with default data as the system provides satisfactory and reasonable results. The most impressive feature of dsSafe is the preparation of investigation reports. The investigation reports are prepared after a long research of the laws and regulations, so the opinions in the investigation report are based on legal issues. Therefore, the user does not have to review the all governing laws and regulations. The system provides all required information. It can be concluded that, this study is a conceptual and preliminary study for the standardization of fault rates which will prevent the contradictional decisions.

In addition to its impressive features, dsSafe has several shortcomings. One of the shortcomings of dsSafe is that, dsSafe could not assign fault rates to the sub parties, appearing under the general group of employer and worker. For example; contractor, safety engineer are named as employer within the system and dsSafe assigns fault rates to employer group, not specifically to contractor and safety engineer. The final distribution of fault rates within the associated groups should be done by the expert. The other shortcoming of dsSafe is the requirement of knowledge about safety as some additional factors, which are not included in dsSafe, should be defined by user. The user should be familiar with the assignment of fault rates; otherwise the system could not propose the accurate fault rates.

Table 6.1 Comparison of fault rates assigned by dsSafe and experts.

<table>
<tr><th rowspan="3">Case</th><th rowspan="3">Factors</th><th colspan="4">Fault rates assigned by</th></tr>
<tr><th colspan="2">Experts</th><th colspan="2">dsSafe</th></tr>
<tr><th>Employer</th><th>Worker</th><th>Employer</th><th>Worker</th></tr>
<tr><td>Fall from scaffolding</td><td>- The scaffolding was failed.
- The scaffolding was improperly constructed.
- There is no expert report for the scaffolding.
- The worker did not use the safety belt.
- There is not any hard hat.
- There is no engineer at jobsite.
- The worker did not have medical report.</td><td>60</td><td>40</td><td>70</td><td>30</td></tr>
</table>

Table 6.1 Comparison of fault rates assigned by dsSafe and experts. (cont'd)

Case	Factors	Fault rates assigned by			
		Experts		dsSafe	
		Employer	Worker	Employer	Worker
Fall from the edge of floor	- The worker failed while feeling dizzy. - There are no guardrails. - The plank had broken. - There is no engineer at jobsite.	80	20	80	20
Fall from ladder	- Despite safe alternative gates, the worker used the ladder where the accident happened. - The worker was careless. - The step of ladder was broken. - No guardrails at the surrounding of the ladder.	60	40	70	30
Fall from the utility pole	- The worker was experienced. - The pole was failed due to insufficient base. - The worker was careless. - No engineer at jobsite. - The workers were not informed about the hazards of work. - No protection systems were provided. - The utility pole was failed due to the work done by worker.	60	40	65	35

The above given examples reveal that dsSafe proposes similar fault rates with experts. As discussed through the thesis, the perception of experts differs from each other, so the assigned fault rates can display variations. When the assigned fault rates proposed by dsSafe and experts are compared, it is observed that there is not a big variation between these rates. These results raise the plausibility of dsSafe. Finally it can be concluded that, dsSafe is a successful tool for the quantification of fault rates.

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APPENDIX A

STATISTICS FOR SAFETY IN TURKEY

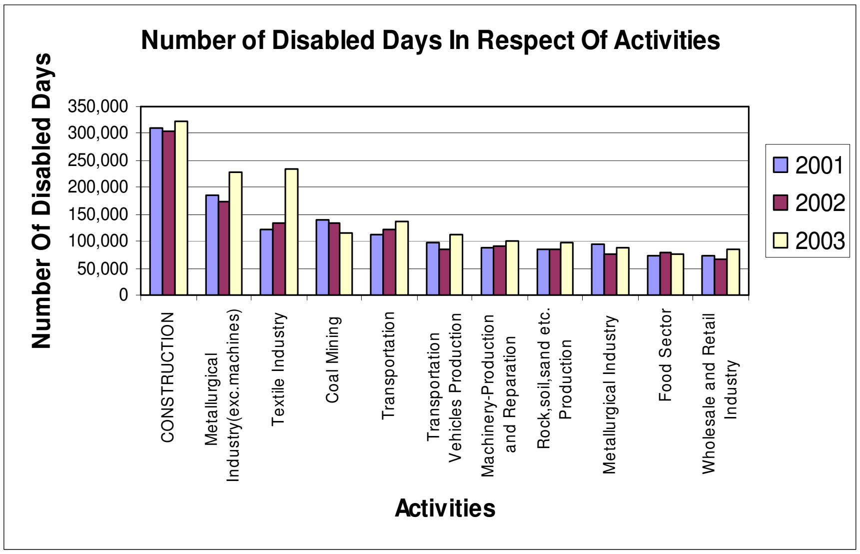


Figure A.1 Statistics of disabled days.

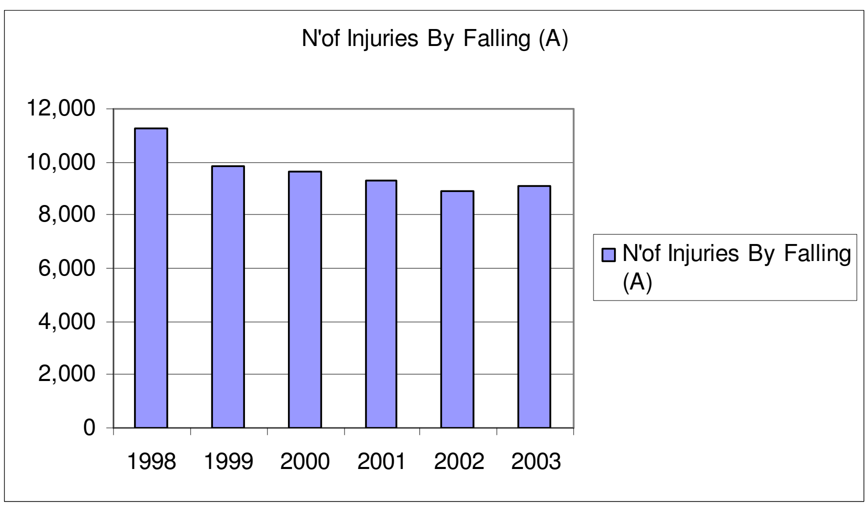


Figure A.2 Statistics of injuries

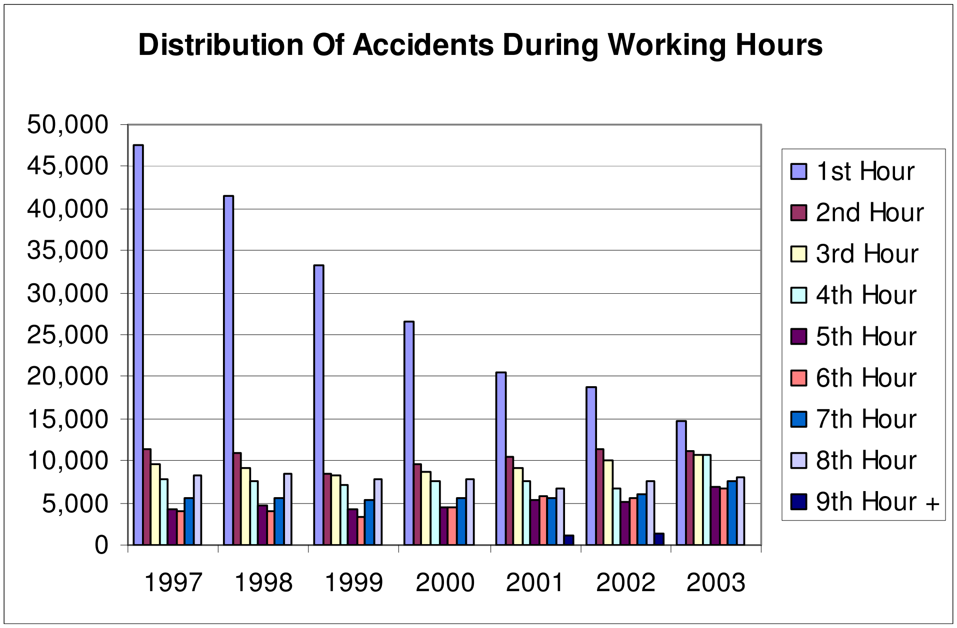


Figure A.3 Statistics of accidents during work hours.

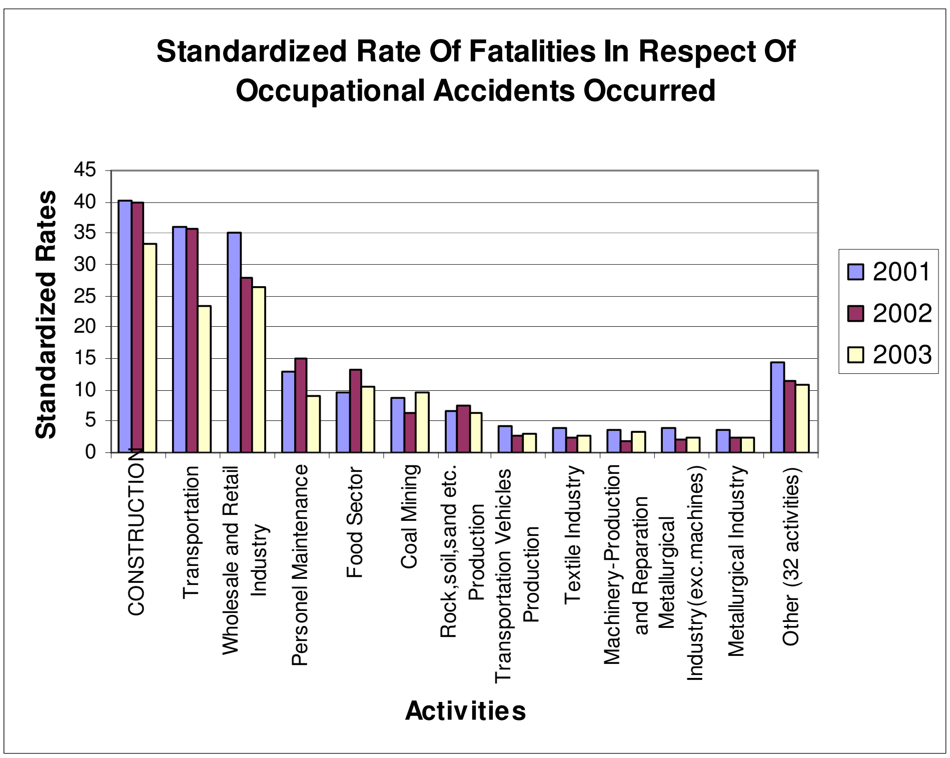


Figure A.4 Statistics of fatalities.

APPENDIX B

SAMPLES OF LETTERS

Sample 1: Requesting Inspection Reports

Turkish Republic
Ministry of Labor and Social Security
Directory of Labor Inspection Board
Ankara

Dear Sir/Madam,

A research is being conducted by METU Construction Management Division to construct an expert system for the quantification of fault rates in construction accidents.

We hope that, you as an expert board having data of construction accidents, could help us by sending any available information for construction accidents. We would be grateful, if you could forward the requested data to the assistant mentioned below.

Thank you in advance for your participation in this survey. Best regards.

Contact Address:

Middle East Technical University
Civil Engineering Department
Ankara

Prof.Dr. Talat Birgönül

Director of Construction
Management Division

Assistant in charge of the project:

Tuncay Demirel
METU Civil Eng. Department
Building: K-1 No: 412 Ankara

Sample 2: Requesting Inspection Reports

Turkish Republic

Ministry of Labor and Social Security

.... Labor Regional Directorate

....

Dear Sir/Madam,

A research is being conducted by METU Construction Management Division to construct an expert system for the quantification of fault rates in construction accidents.

The database of the expert system should be constructed onto the basis of experts' knowledge. Initially the support of Labor Inspection Board was demanded, but the Board informed us that the inspection reports were being kept at the regional directorates, so we should contact with regional directorates.

As mentioned previously, the inspection reports are required to construct the expert system. We hope that you could help us by sending any available inspection report investigating construction accidents. We would be grateful to you, for forwarding your data to the assistant mentioned below.

Thank you in advance for your participation in this survey. Best regards.

Prof.Dr. Talat Birgönül

Director of Construction
Management Division

Contact:

Middle East Technical University
Civil Engineering Department
Ankara

Assistant in charge of the project:

Tuncay Demirel
METU Civil Eng. Department
Building: K-1 No: 412 Ankara

Sample 3: Requesting to Answer Questionnaires

Turkish Republic
Ministry of Labor and Social Security
.... Labor Regional Directorate

Dear Sir/Madam,

The research which you were participated by forwarding accident inspection reports is supposed to be based on expert's knowledge which is tangible. To provide this requirement for database, the inspection reports were analyzed, evaluated and a questionnaire is prepared.

The attached questionnaire aims to increase our knowledge concerning the quantification of fault rates. The analysis of the answers to this questionnaire forms one of the first essential phases of the study. We hope that you as an expert office having knowledge of quantifying fault rates could help us by answering the questionnaires. We will take into account the confidential nature of your information.

We would be grateful to you, if you could forward your answers of February to the assitant mentioned below before the 25^{th}.

Thank you in advance for your participation in this survey. Best regards.

Prof.Dr. Talat Birgönül

Director of Construction
Management Division

Contact:

Middle East Technical University
Civil Engineering Department
Ankara

Assistant in charge of the project:

Tuncay Demirel
METU Civil Eng. Department
Building: K-1 No: 412 Ankara

APPENDIX C

A SAMPLE OF THE QUESTIONNAIRE

Personal Information For Respondents

Name-Surname: ....

Organization: ....

Phone: ....

e-mail : ....

A- Professional Experience

0-3 Years □ 4-7 Years □ 8-12 Years □ 13-16 Years □ More than 16 years □

B- Opinions

1. **Do you think that in Turkey, people give sufficient importance to occupational safety?** *(If "Yes" skip 2nd question and continue from 3rd question.)*

Yes ( ) **No ( )**

Please evaluate 2nd and 3rd questions considering *(1-5) importance scale* and give ratings between 1 and 5.

Rating	1	2	3	4	5
Importance	Very low	Low	Medium	High	Very high

2. **<u>The probable causes of deficiency about occupational safety</u> are listed below. Please, evaluate the importance of these factors within the (1-5) importance scale.**

No	***Factor***	***Importance***
1.	The insufficient knowledge of workers about occupational safety	
2.	The insufficient knowledge of employers about occupational safety	
3.	The insufficient supervision of government about occupational safety	
4.	The additional cost to employers for ensuring occupational safety	
5.	The inconvenience caused by the usage of protective equipments to workers	
6.	Inadequate punishment/compensation assigned to employers when avoiding to implement safety issues	

Other *(Please add any factor(s) that you are consider important).*

....

3. **<u>The probable causes of conflicting opinions about fault rates</u> assigned by different experts in same event are listed below. Please, evaluate the importance of these factors within the (1-5) importance scale.**

No	***Factor***	***Importance***
1.	Insufficient professional experience	
2.	The influence of defendant or plaintiff party to the experts for their decisions	
3.	Insufficient knowledge about laws and regulations	
4.	Incompatibility between real life and governmental rules and regulations	
5.	Insufficient inspection of case records by experts	
6.	Insufficiency of the governing laws and regulations	

7.	The inadequacy of data, clues about accident included in case records	
8.	The lack of objective criterions for assigning fault rates	

Other *(Please add any factor(s) that you are consider important).*

....

1. EXPLANATIONS FOR THE RESPONDENTS

- Questionnaire contains 8 parts and all parts are studied under two subjects except 1^{st} part.
- In 1^{st} part, it is expected to quantify the fault rates of parties considering the general issues regarding an investigation of an occupational accident
- In 8^{th} part, it is expected to assign the fault rates within groups of workers and employers separately.

For other parts;

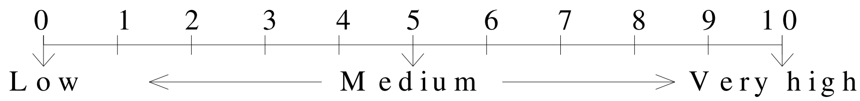
- Primary subject is about the determination of importance weights of factors in assigning fault rates.
- Secondary subject is about the quantification of fault rates between worker and employer under different scenarios.

2. DETERMINATION OF IMPORTANCE WEIGHTS

In 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, 6^{th} and 7^{th} parts, the importance weights should be determined in <u>(0–10) scale.</u>

Expression of importance scale:

Importance Scale



Example 1:

	Factor	Importance Weight
1	Whether the worker has medical report or not	**2**

This means that when an accident investigation is being done, the expert considers that this factor has a low importance in assigning fault rates and assigns the importance level of 2 over 10.

Example 2:

	Factor	Importance Weight
1	Whether the worker was experienced or not	**8**

This means that when an accident investigation is being done, the expert considers that this factor has a moderately high importance in assigning fault rates and assigns the importance level of 8 over 10.

3. ASSIGNING FAULT RATES UNDER DIFFERENT SCENARIOS

In 1st, 2nd, 3rd, 4th, 5th, 6th and 7th part of questionnaire, there are questions and scenarios considering these questions. All scenarios are determined by different numbers and they are shaded to be differentiated from each other. The fault rates should be assigned considering these scenarios.

Fault rates should be assigned over 100; but in some scenarios, both worker and employer may not have any fault, so fault rate can be assigned as (0). Hence, the total of fault rates should be 0 or 100.

Example 1:

		Scenario1
1	Did the worker have medical report?	**No**
	Fault rate of employer :	**80**
	Fault rate of worker :	**20**
	Total :	**0 / 100**

Scenario

Response Section

Total should be 0 or 100.

In this example, the expert assigned %80 fault to employer and % 20 faults to worker because of the absence of medical report of worker. As seen, the total of fault rates is 100.

Example 2:

		Scenario1	Scenario2
1	Considering the type of work, was it required to provide safety belt?	Yes	Yes
	Did the employer provide safety belt?	Yes	Yes
	Did the worker use the safety belt?	Yes	No
	Fault rate of employer :	**0**	**20**
	Fault rate of worker :	**0**	**80**
	Total :	**0 / 100**	**0 / 100**

In scenario 1, the type of the work required to provide safety belt, employer provided this equipment and worker used it. Hence, no party has any fault, so that both employer and worker were given 0 fault rate. In this scenario, the total of fault rates is 0.

In scenario 2, although the employer provided safety belt because of the type of work, the worker did not use it. Hence, the expert concluded that the employer was %20 and the worker was %80 faulty. In this scenario, the total of fault rates is 100.

4. DISTRIBUTION OF FAULT RATES WITHIN THE GROUP

In 1st, 2nd, 3rd, 4th, 5th, 6th and 7th part of questionnaire, the fault rates are assigned to worker and employer. Actually, worker and employer concepts include sub-parties under their definitions. In 8th part of the questionnaire, the cumulative total of fault rates obtained from previous parts will be distributed within the group members.

<u>Parties involved in employer group:</u>

Contractor, project manager, sub-contractor

<u>Parties involved in worker group:</u>

Foreman, worker

<u>Section 1 : General Issues</u>

The aim of this part is to evaluate the general issues considered when an accident investigation is undertaken.

1.1. Determine the fault rate of parties considering developed scenarios.

		Scenario1
1	Did the worker have medical report?	No
	Fault rate of employer :	
	Fault rate of worker :	
	Total :	**0 / 100**

		Scenario1	Scenario2
2	Was there an engineer responsible for construction site?	Yes	No
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1	Scenario2
3	Was the worker an experienced person?	Yes	No
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1
4	Did the worker fall due to his/her personal carelessness, in a moment of abstraction or while feeling dizzy?	Yes
	Fault rate of employer :	
	Fault rate of worker :	
	Total :	**0 / 100**

		Scenario1	Scenario2
5	Considering the type of work, was it required to provide safety belt?	Yes	Yes
	Did the employer provide safety belt?	No	Yes
	Did the worker use the safety belt?	--	No
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

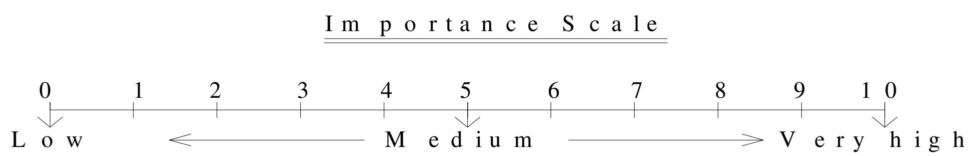
		Scenario1	Scenario2
6	Did the employer provide hard hat at the construction?	Yes	No
	Did the worker use the hard hat?	No	--
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scen.1	Scen.2	Scen.3	Scen.4
7	Was there a warning sign informing about hazard?	Yes	Yes	No	No
	Were the workers informed about the hazards of works?	No	Yes	Yes	No
	Fault rate of employer :				
	Fault rate of worker :				
	Total :	**0 / 100**	**0 / 100**	**0 / 100**	**0 / 100**

Section 2 : Fall through floor openings

The aim of this part is to evaluate the fault rate of parties considering the issues determined from investigations of falls through floor openings.

2.1.) Please determine the importance weight of factors identified from the investigation of falls thorough floor openings considering [0-10] scale for the assignment of fault rates to involved parties.



	Factors	Importance weight
1	Whether the worker has medical report or not	
2	Whether the construction works were carried out under the supervision of an engineer or not	
3	Whether the worker was experienced or not	
4	Whether the workers uncovered the protective floor covering without informing the employer or not	
5	Whether the accident happened through carelessness, in a moment of abstraction or as a result of vertigo or not	
6	Whether the surrounding of floor opening was illuminated or not	
7	Whether there was safety belt or not	
8	Whether there was hard hat or not	
9	Whether any fall protection systems such as work planks, safety nets, guardrails were provided or not	
10	Availability of warning signs and training of workers	

2.2.) <u>Determine the fault rates of parties considering developed scenarios for the falls through floor openings.</u>

		Scenario1	Scenario2
1	Did the workers open the protected floor openings without informing the employer?	Yes	No
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1
2	**Was there adequate illumination** around the floor opening?	No
	Fault rate of employer :	
	Fault rate of worker :	
	Total :	**0 / 100**

		Scenario1	Scenario2	Scenario3
3	Were there any fall protection equipments such as guardrails, work planks or safety nets for preventing accident?	Yes	Yes	No
	Did the accident happen through the break down of these equipments?	Yes	No	--
	Did the accident happen through the slipping of these equipments?	--	Yes	--
	Fault rate of employer :			
	Fault rate of worker :			
	Total :	**0 / 100**	**0 / 100**	**0 / 100**

Section 3 : Falls from roofs

The aim of this part is to evaluate the fault rate of parties considering the issues determined from investigations of falls from roofs.

3.1.) Please determine the importance weight of factors identified from the investigation of falls from roofs considering [0-10] scale for the assignment of fault rates to involved parties.

Importance Scale

0 1 2 3 4 5 6 7 8 9 10

Low ← Medium → Very high

	Factors	**Importance weight**
1	Whether the worker has medical report or not	
2	Whether the construction works were carried out under the supervision of an engineer or not	
3	Whether the worker was experienced or not	
4	Whether the accident happened through carelessness, in a moment of abstraction or as a result of vertigo or not	
5	Whether there was safety belt or not	
6	Whether there was hard hat or not	
7	Whether the weather conditions were convenient for working or not	
8	Availability of warning signs and training of workers	
9	Whether any fall protection equipments such as scaffolding, guardrails or safety nets were provided or not	
10	Whether any safe access paths were identified on the roof or not	

3.2.) <u>Determine the fault rates of parties considering developed scenarios for the falls from roofs.</u>

		Scenario1	Scenario2
1	Were safety equipments such as scaffolding, guardrails or safety nets provided for preventing roof falls?	Yes	No
	Were the equipments safe enough to prevent falls?	No	**--**
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1	Scenario2
2	Was safe path identified or was roof ladder provided?	**Yes**	No
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

Section 4 : Falls from ladders

The aim of this part is to evaluate the fault rate of parties considering the issues determined from investigations of falls from ladders.

4.1.) Please determine the importance weight of factors identified from the investigation of falls from ladders considering [0-10] scale for the assignment of fault rates to involved parties.

	Factors	**Importance weight**
1	Whether the worker has medical report or not	
2	Whether the construction works were carried out under the supervision of an engineer or not	
3	Whether the worker was experienced or not	
4	Whether the jobsite was illuminated or not	
5	Whether the accident happened through carelessness, in a moment of abstraction or as a result of vertigo or not	
6	Availability of warning signs and training of workers	
7	Whether there was safety belt or not	
8	Whether there was hard hat or not	
9	Whether the ladder itself or its step was broken or not	
10	Whether any precaution was taken to prevent the slipping of ladder or not	
11	Whether any guardrails or handrails were constructed around the ladder or not	
12	Whether there were any alternative safe gates apart from ladders or not	

4.2.) <u>Determine the fault rates of parties considering developed scenarios for the falls from ladders.</u>

		Scenario1	Scenario2
1	Was the ladder itself (metal or wooden) or its step broken down or not?	Yes	Yes
	Was the safety of ladder controlled?	Yes	No
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1	Scenario2
2	Was ladder a mobile ladder?	Yes	Yes
	Was the accident happened through the slipping of ladder?	Yes	Yes
	Were there any precautions taken at the top and bottom edge of the ladder to prevent slipping?	Yes	No
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1	Scenario2
3	Were there any safety equipments such as guardrails, handrails or safety lines around the ladder to prevent accidents?	Yes	No
	Were the provided equipments safe enough to prevent accidents?	No	--
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1
4	Apart from ladder, were there any other safe gates for the utilization of workers?	Yes
	Despite these ways, did the worker use the ladder where the accident happened?	Yes
	Fault rate of employer :	
	Fault rate of worker :	
	Total :	**0 / 100**

<u>Section 5 : Falls from scaffoldings</u>

The aim of this part is to evaluate the fault rate of parties considering the issues determined from investigations of falls from scaffoldings.

5.1.) Please determine the importance weight of factors identified from the investigation of falls from scaffoldings considering [0-10] scale for the assignment of fault rates to involved parties.

	Factors	**Importance weight**
1	Whether the worker has medical report or not	
2	Whether the construction works were carried out under the supervision of an engineer or not	
3	Whether the worker was experienced or not	
4	Whether the jobsite was illuminated or not	
5	Whether the accident happened through carelessness, in a moment of abstraction or as a result of vertigo or not	
6	Availability of warning signs and training of workers	
7	Whether there was safety belt or not	
8	Whether there was hard hat or not	
9	Whether the scaffolding was failed or not	
10	Whether there were any safe access gates to the scaffolding or not	
11	Whether the planks used on scaffolding were safe enough or not	
12	Whether any fall protection equipments such as guardrails, lifelines were provided or not	

5.2.) **Determine the fault rates of parties considering developed scenarios for the falls from scaffoldings.**

		Scen.1	Scen.2	Scen.3	Scen.4	Scen.5	Scen.6	Scen.7	Scen.8
1	Was the scaffolding falling?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Were there any expert report determining the adequacy of scaffolding for its use?	Yes	Yes	Yes	Yes	No	No	No	No
	Was the scaffolding overloaded?	Yes	No	Yes	No	No	Yes	No	Yes
	Was the scaffolding improperly constructed?	Yes	Yes	No	No	No	Yes	Yes	No
	Fault rate of employer :								
	Fault rate of worker :								
	Total :	**0 / 100**	**0 / 100**	**0 / 100**	**0 / 100**	**0 / 100**	**0 / 100**	**0 / 100**	**0 / 100**

		Scenario1	Scenario2
2	Was the accident happened when accessing to scaffolding?	Yes	Yes
	Were there safe gates required for accessing to scaffolding?	Yes	No
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1	Scenario2	Scenario3
3	Was the accident happened through the working plank?	Yes	Yes	Yes
	Was the working plank broken down or slipped?	Yes	No	No
	Was the accident happened through the bad planking? (Gaps, cracks, splits)	--	Yes	No
	Fault rate of employer :			
	Fault rate of worker :			
	Total :	**0 / 100**	**0 / 100**	**0 / 100**

		Scen.1	Scen.2	Scen.3
4	Did the worker fall from scaffolding?	Yes	Yes	Yes
	Were the fall protection equipments such as guardrails, lifelines provided to prevent accidents?	Yes	Yes	No
	Were the equipments safe enough to prevent falls?	Yes	No	--
	Fault rate of employer :			
	Fault rate of worker :			
	Total :	**0 / 100**	**0 / 100**	**0 / 100**

Section 6 : Falls from utility poles such as phone, electrical

The aim of this part is to evaluate the fault rate of parties considering the issues determined from investigations of falls from utility poles.

6.1.) Please determine the importance weight of factors identified from the investigation of falls from utility poles considering [0-10] scale for the assignment of fault rates to involved parties.

	Factors	**Importance weight**
1	Whether the worker has medical report or not	
2	Whether the construction works were carried out under the supervision of an engineer or not	
3	Whether the worker was experienced or not	
4	Whether the accident happened through carelessness, in a moment of abstraction or as a result of vertigo or not	
5	Whether the weather conditions were convenient for working or not	
6	Whether the workers were informed or trained for the jobsite	
7	Whether the organization and communication among workers were sustained or not	
8	Whether there was safety belt or not	
9	Whether there was hard hat or not	
10	Whether the material of utility poles was defective or the base of utility pole was insufficient or not	
11	Whether any temporary fall prevention systems were provided or not	
12	Whether electrical insulated equipments were provided or not	

6.2.) <u>Determine the fault rates of parties considering developed scenarios for the falls from utility poles.</u>

		Scen.1	Scen.2	Scen.3
2	Was the utility pole falling?	Yes	Yes	Yes
	Was the utility pole (made of metal or wood) fall over though the defective material?	Yes	No	No
	Was the utility pole fall over though the insufficient base?	--	Yes	No
	Fault rate of employer :			
	Fault rate of worker :			
	Total :	**0 / 100**	**0 / 100**	**0 / 100**

		Scenario1	Scenario2
3	Was the utility pole fall over due to the work being done by worker? (cable lying etc.)	Yes	Yes
	Was any temporary fall prevention system constructed to provide safety?	Yes	No
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1	Scenario2
4	Was the accident happened due to an electrical shock?	Yes	Yes
	Was the employer provided electrical insulated equipments to be used?	Yes	No
	Did the worker use these electrical insulated equipments?	No	--
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

Section 7 : Falls from the edge of floors

The aim of this part is to evaluate the fault rate of parties considering the issues determined from investigations of falls from the edge of floors.

7.1.) Please determine the importance weight of factors identified from the investigation of falls from the edge of floors considering [0-10] scale for the assignment of fault rates to involved parties.

Importance Scale

0 1 2 3 4 5 6 7 8 9 10

Low ← Medium → Very high

	Factors	Importance weight
1	Whether the worker has medical report or not	
2	Whether the construction works were carried out under the supervision of an engineer or not	
3	Whether the worker was experienced or not	
4	Whether the accident happened through carelessness, in a moment of abstraction or as a result of vertigo or not	
5	Whether there was safety belt or not	
6	Whether there was hard hat or not	
7	Whether any fall protection systems such as work planks, safety nets, guardrails were provided or not	
8	Whether the accident happened though the carelessness of crane operator or though an mechanical failure or not	
9	Availability of warning signs and training of workers	

7.2.) <u>Determine the fault rates of parties considering developed scenarios for the falls from the edge of floors.</u>

		Scenario1	Scenario2
1	Was the accident happened when the job of loading or unloading were being done?	Yes	Yes
	Was the employer constructed any scaffolding or any plank surrounded by guardrails at the loading/unloading place to prevent accidents?	Yes	No
	Were the equipments safe enough to prevent falls?	Yes	--
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1	Scenario2
2	Was the accident happened when using a mechanical lifting machine?	Yes	Yes
	Was the accident happened through the fault of operator using the lifting machine?	Yes	No
	Was the accident happened though a mechanical failure?	--	Yes
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

		Scenario1	Scenario2
3	Were there any fall prevention equipments such as guardrails, lifelines, safety nets at the edge of floor to prevent accidents?	Yes	No
	Were the equipments safe enough to prevent falls?	No	**--**
	Fault rate of employer :		
	Fault rate of worker :		
	Total :	**0 / 100**	**0 / 100**

Section 8 : Distribution of fault rates within the group

In previous parts, the assignment of fault rates was done among the worker and employer. Actually, these two groups involve sub-parties or personalities under their definitions. In this part of the survey; the general parties involved in a construction accident investigation are identified, and respondents are asked to assign fault rates within each group.

Parties involved in employer group:

Contractor, project manager, sub-contractor

Parties involved in worker group:

Foreman, worker

8.1.) Divide the fault rate of employer within the group defined as employer.

1. Scenario

	Fault rate (%)
Contractor	
Project manager	
Sub-contractor	
Total	**100**

2. Scenario

	Fault rate (%)
Contractor	
Project manager	
Total	**100**

3. Scenario

	Fault rate (%)
Contractor	
Sub-contractor	
Total	**100**

8.2.) Divide the fault rate of <u>worker</u> within the group defined as <u>worker</u>.

	Fault rate (%)
Worker	
Foreman	
Total	**100**

<u>END OF SURVEY</u>

Thanks for answering the questionnaire.

APPENDIX D

QUESTION LISTS AND FLOWCHARTS

1- Questions list for the falls from the edge of floors

No	Questions
1	Did the worker have medical report?
2	Was there any engineer responsible for construction site?
3	Was the worker an experienced person?
4	Did the worker fall due to his/her personal carelessness, in a moment of abstraction or while feeling dizzy?
5	Considering the type of work, was it required to provide safety belt?
6	Did the employer provide safety belt?
7	Did the worker use the safety belt?
8	Did the employer provide hard hat at the construction?
9	Did the worker use the hard hat?
10	Did the accident happen when the job of loading or unloading was being done?
11	Did the employer construct any scaffolding or any platform surrounded by guardrails at the loading/unloading place to prevent accidents?
12	Were the provided equipments safe enough to prevent falls?
13	Did the accident happen when using a mechanical lifting machine?
14	Did the accident happen due to the fault of operator using the lifting machine?
15	Did the accident happen due to a mechanical failure?
16	Were there any fall prevention equipments such as guardrails, lifelines, safety nets at the edge of floor to prevent accidents?
17	Were the provided equipments safe enough to prevent falls?
18	Were there any warning signs informing about hazard?
19	Were the workers informed by employer about the hazards of works?
-?-	Note any additional information if available.

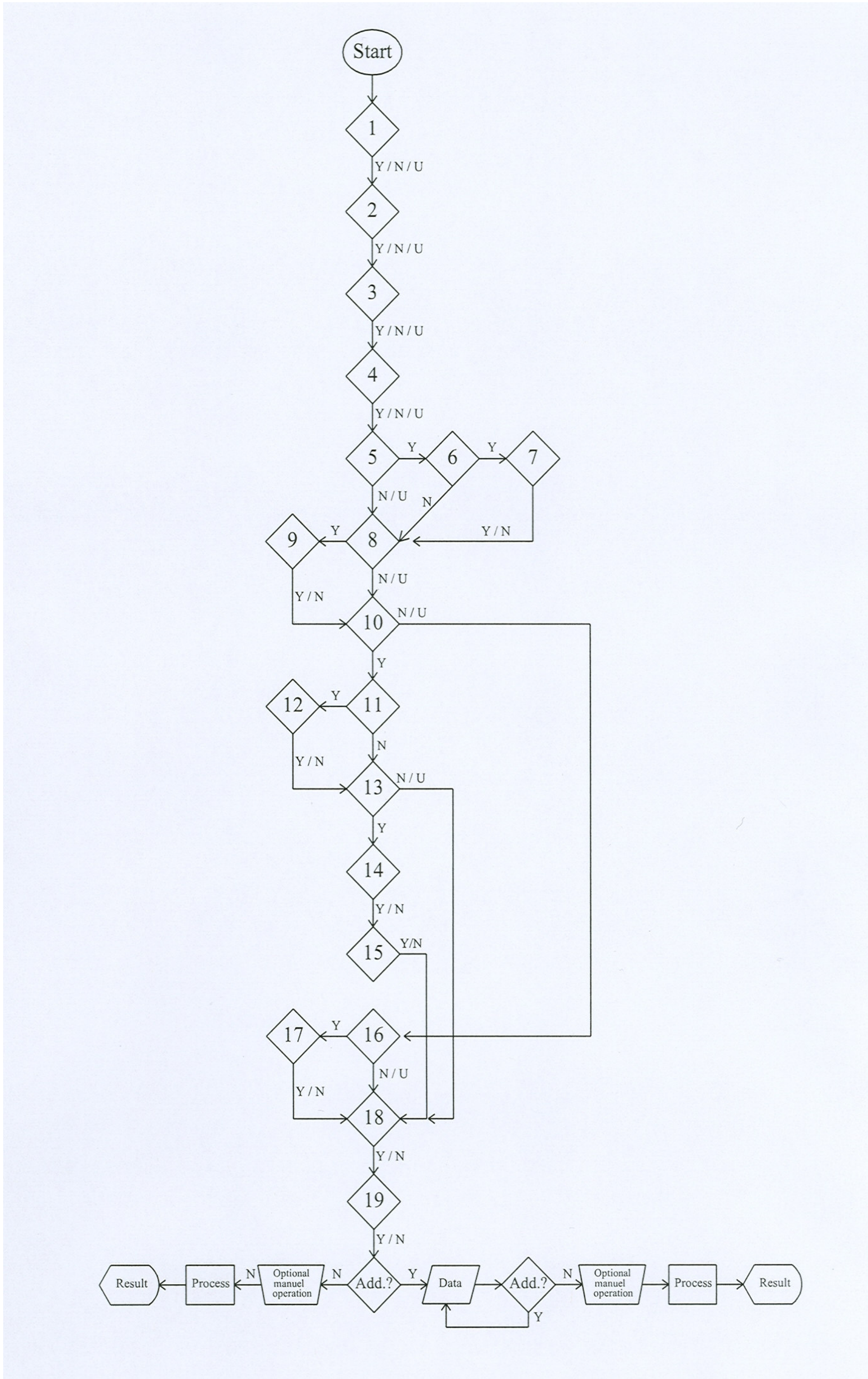


Figure D.1.1 Flowchart of the falls from the edge of floor.

2- Questions list for the falls from ladders

No	Questions
1	Did the worker have medical report?
2	Was there any engineer responsible for construction site?
3	Was the worker an experienced person?
4	Was surrounding of the ladder sufficiently illuminated?
5	Did the worker fall due to his/her personal carelessness, in a moment of abstraction or while feeling dizzy?
6	Were there any warning signs informing about hazard?
7	Were the workers informed by employer about the hazards of works?
8	Considering the type of work, was it required to provide safety belt?
9	Did the employer provide safety belt?
10	Did the worker use the safety belt?
11	Did the employer provide hard hat at the construction?
12	Did the worker use the hard hat?
13	Did the ladder itself (metal or wooden) or its step break down?
14	Was the safety of ladder controlled?
15	Was the used ladder a mobile ladder?
16	Did the accident happen due to the slipping of ladder?
17	Were there any precautions taken at the top and bottom edge of the ladder to prevent slipping?
18	Were there any safety equipments such as guardrails, handrails or safety lines at the surrounding of the ladder to prevent accidents?
19	Were the provided equipments safe enough to prevent accidents?
20	Apart from ladder, were there any other safe access gates for the utilization of workers?
21	Despite these ways, did the worker use the ladder where the accident happened?
-?-	Note any additional information if available.

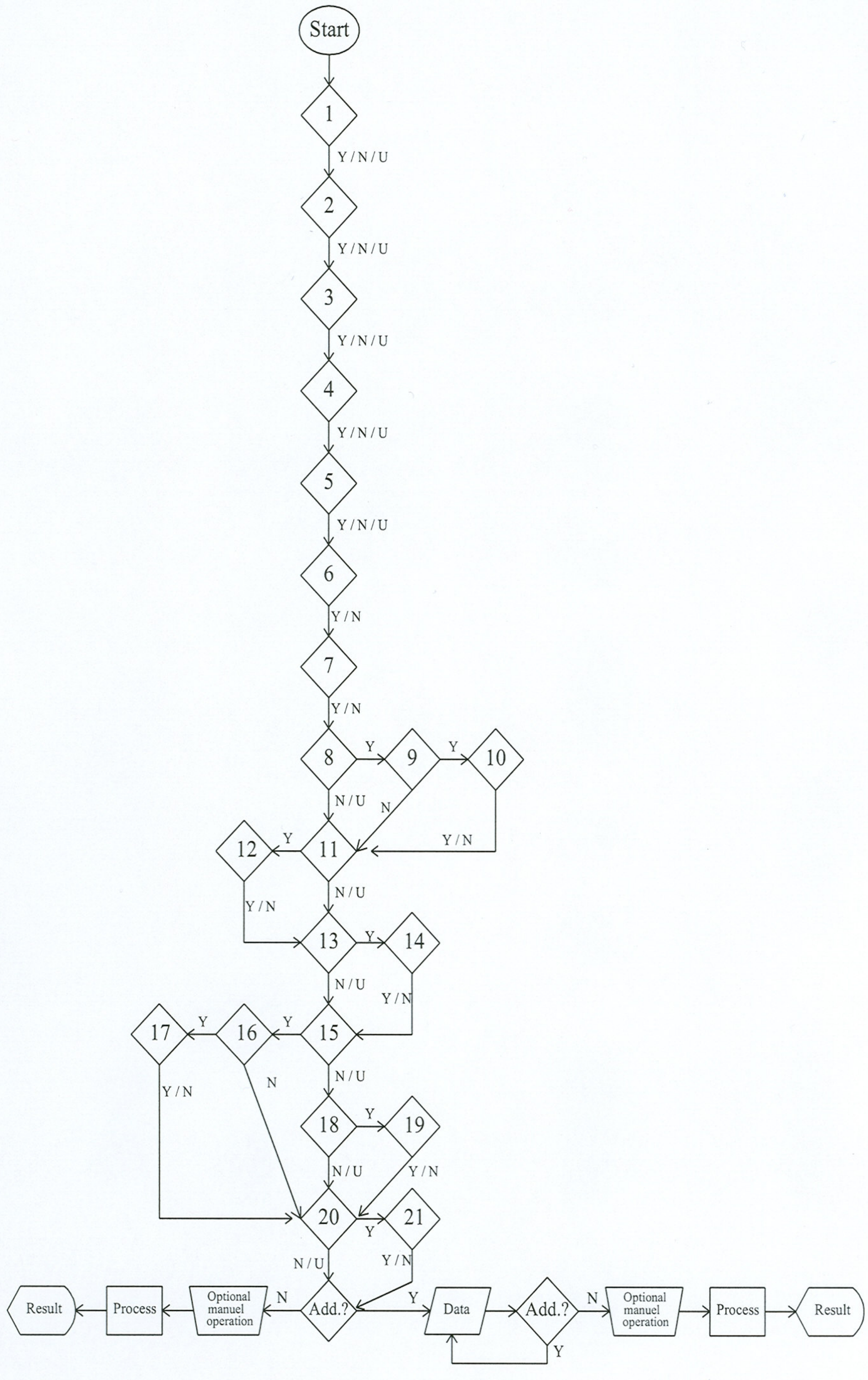


Figure D.2.1 Flowchart of the falls from ladders.

3- Questions list for the falls from utility poles

No	Questions
1	Did the worker have medical report?
2	Was there any engineer responsible for construction site?
3	Was the worker an experienced person?
4	Did the worker fall due to his/her personal carelessness, in a moment of abstraction or while feeling dizzy?
5	Were the weather conditions convenient for working?
6	Were the workers informed by employer about the hazards of works?
7	Were there any warning signs informing about hazard?
8	Considering the type of work, was it required to provide safety belt?
9	Did the employer provide safety belt?
10	Did the worker use the safety belt?
11	Did the employer provide hard hat at the construction?
12	Did the worker use the hard hat?
13	Did the utility pole fail?
14	Did the utility pole (made of metal or wood) fail due to the defective material?
15	Did the utility pole fail due to the insufficient base?
16	Did the utility pole fail due to the work being done by worker? (cable lying etc.)
17	Were any temporary fall preventions system constructed to provide safety?
18	Did the accident happen due to an electrical shock?
19	Did the employer provide any electrical insulated equipment to be used?
20	Did the worker use these electrical insulated equipments?
-?-	Note any additional information if available.

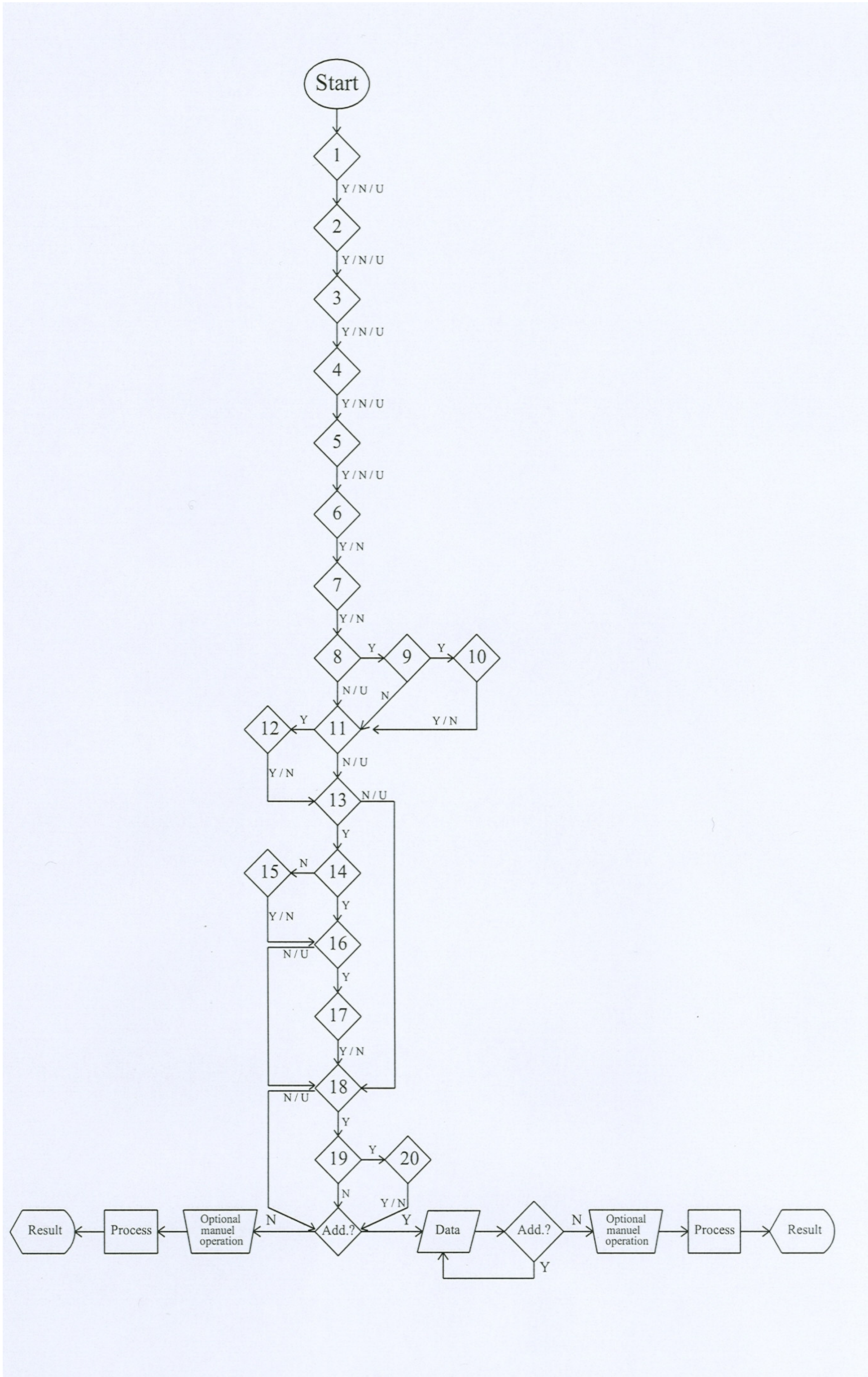


Figure D.3.1 Flowchart of the falls from utility poles.

4- Questions list for the falls through the floor openings

No	Questions
1	Did the worker have medical report?
2	Was there any engineer responsible for construction site?
3	Was the worker an experienced person?
4*	Was any available protection equipment removed from the jobsite?
4	Did the workers open the floor openings without informing the employer?
5	Did the worker fall due to his/her personal carelessness, in a moment of abstraction or while feeling dizzy?
6	Was the surrounding of the floor opening sufficiently illuminated?
7	Considering the type of work, was it required to provide safety belt?
8	Did the employer provide safety belt?
9	Did the worker use the safety belt?
10	Did the employer provide hard hat at the construction?
11	Did the worker use the hard hat?
12	Were there any fall protection equipments at jobsite such as guardrails, work platforms or safety nets for preventing accident?
13	Did the accident happen through the break down of these equipments?
14	Did the accident happen through the slipping of these equipments?
15	Were there any warning signs informing about hazard?
16	Were the workers informed by employer about the hazards of works?
-?-	Note any additional information if available.

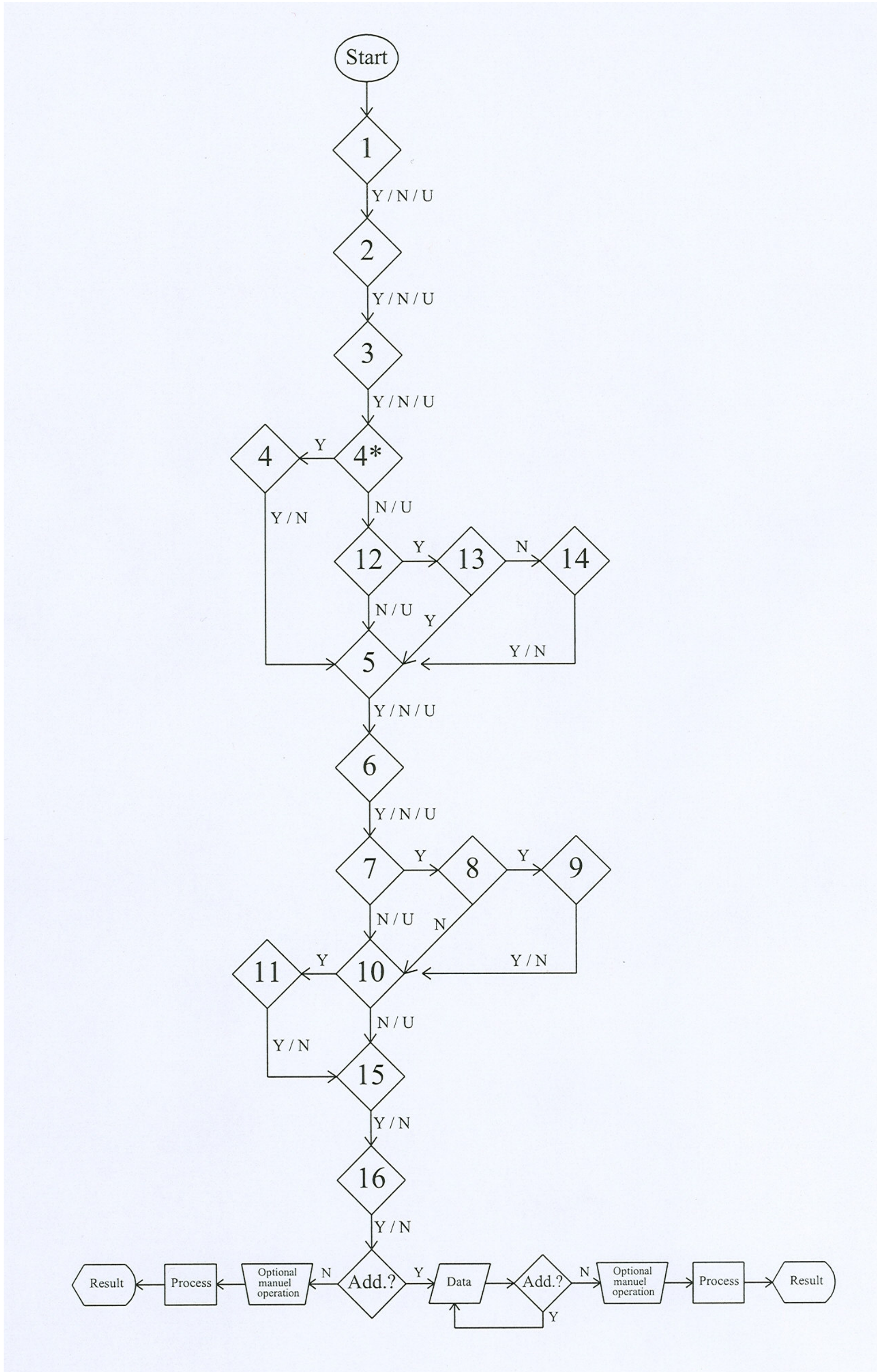


Figure D.4.1 Flowchart of the falls through the floor openings.

5- Questions list for the falls from scafflodings

No	Questions
1	Did the worker have medical report?
2	Was there any engineer responsible for construction site?
3	Was the worker an experienced person?
4	Was the surrounding of the scaffolding sufficiently illuminated?
5	Did the worker fall due to his/her personal carelessness, in a moment of abstraction or while feeling dizzy?
6	Were there any warning signs informing about hazard?
7	Were the workers informed by employer about the hazards of works?
8	Considering the type of work, was it required to provide safety belt?
9	Did the employer provide safety belt?
10	Did the worker use the safety belt?
11	Did the employer provide hard hat at the construction?
12	Did the worker use the hard hat?
13	Did the scaffolding fail?
14	Were there any expert reports determining the adequacy of scaffolding for its use?
15	Was the scaffolding overloaded?
16	Was the scaffolding improperly constructed?
17	Did the accident happen when accessing to scaffolding?
18	Were there any safe access gates to scaffolding?
19	Did the accident happen due to the working platform?
20	Did the working platform break down or slip?
21	Did the accident happen due to the bad planking? (Gaps, cracks, splits)
22	Did the worker fall from scaffolding?
23	Were any fall protection equipments such as guardrails, lifelines provided to prevent accidents?
24	Were the equipments safe enough to prevent falls?
-?-	Note any additional information if available.

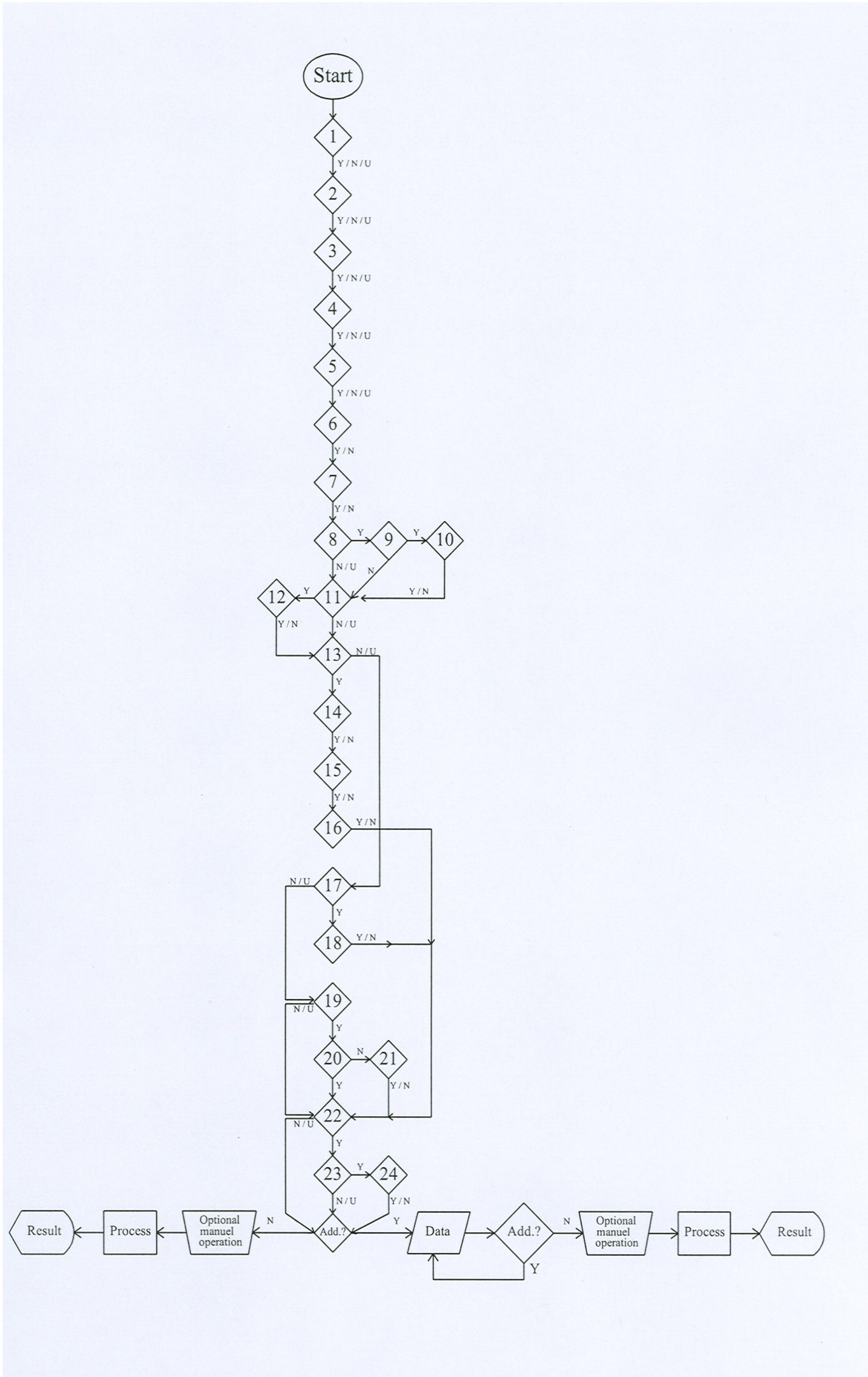


Figure D.5.1 Flowchart of the falls from scaffoldings.

6- Questions list for the falls from roofs

No	Questions
1	Did the worker have medical report?
2	Was there any engineer responsible for construction site?
3	Was the worker an experienced person?
4	Did the worker fall due to his/her personal carelessness, in a moment of abstraction or while feeling dizzy?
5	Considering the type of work, was it required to provide safety belt?
6	Did the employer provide safety belt?
7	Did the worker use the safety belt?
8	Did the employer provide hard hat at the construction?
9	Did the worker use the hard hat?
10	Were the weather conditions convenient for working?
11	Were there any warning signs informing about hazard?
12	Were the workers informed by employer about the hazards of works?
13	Were any safety equipments such as scaffolding, guardrails or safety nets provided for preventing roof falls?
14	Were the provided equipments safe enough to prevent falls?
15	Were any safe paths identified or roof ladder provided?
-?-	Note any additional information if available.

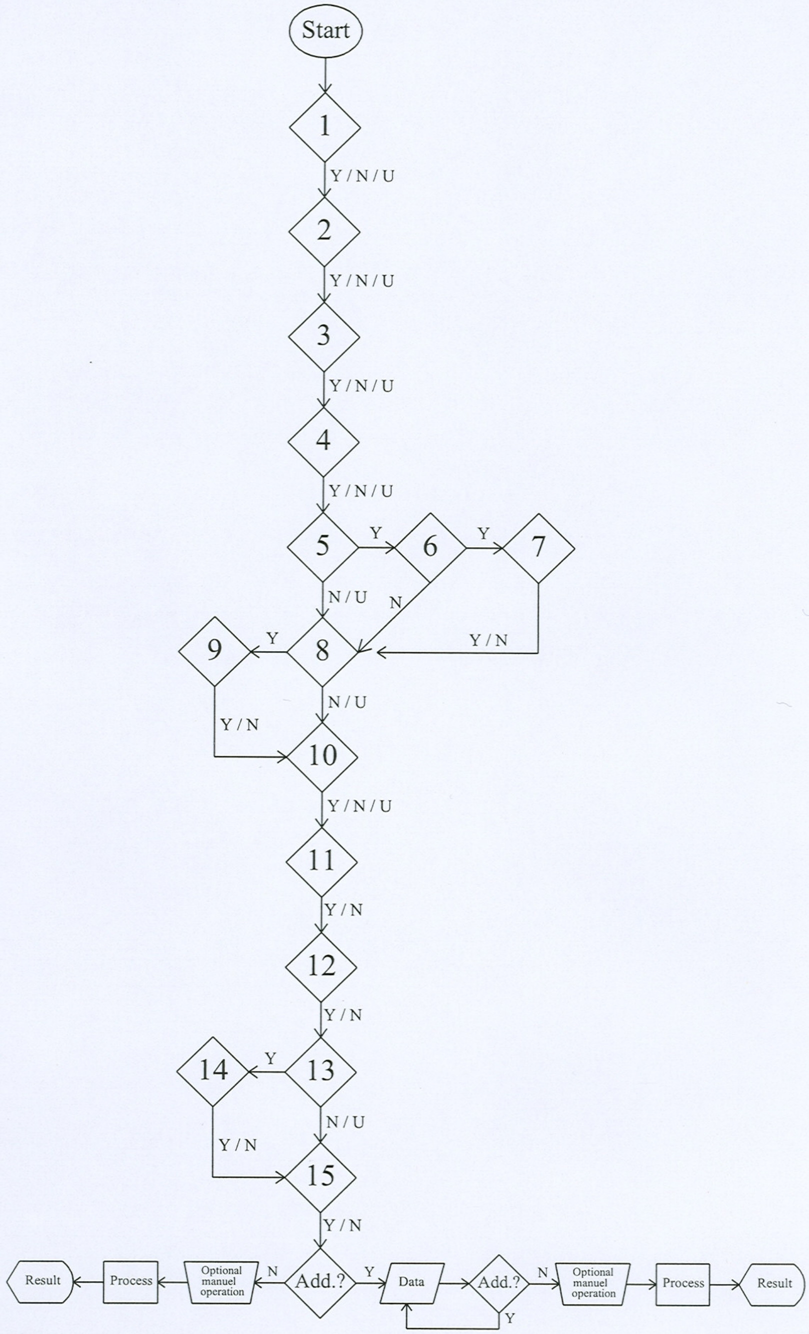


Figure D.6.1 Flowchart of the falls from roofs.