DEVELOPMENT OF A GIS-BASED MONITORING AND MANAGEMENT SYSTEM FOR UNDERGROUND MINING SAFETY

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ABSTRACT

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SYSTEM FOR UNDERGROUND MINING SAFETY

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Mine safety is of paramount concern to the mining industry. The generation of a Geographic Information Systems (GIS) which can administrate relevant spatial data and metadata of underground mining safety efficiently is a very vital issue in this sense. In an effort to achieve a balance of safety and productivity, GIS can contribute to the creation of a safe working environment in underground (U/G) mining. Such a system should serve to a continuous risk analysis and be designed for applications in case of emergency. Concept for safety should require three fundamental components, namely (i) constructive safety; (ii) surveillance and maintenance; and (iii) emergency.

The implementation has to be carried out in a Web-Based Geographic Information System. The process comprises first the safety concept as the application domain model and then a conceptual model was generated in terms of Entity- Relationship Diagrams. After the implementation of the logical model a user interface was developed and GIS was tested. Finally, one should deal with the question if it is possible to extend the method of resolution used to a national GIS infrastructure.

ÖZ

YERALTI MADENCİLİĞİ EMNİYETİYLE İLGİLİ COĞRAFİ BİLGİ SİSTEMLERİ TABANLI BİR İZLEME VE İŞLETME SİSTEMİNİN GELİŞTİRİLMESİ

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Madencilikte iş güvenliği en önemli unsurlardan biridir. Bu nedenle yeraltı madenciliğinde emniyet ile ilgili mekansal ve meta verinin Coğrafi Bilgi Sistemleri (CBS) oluşturularak idare edilmesi gerekli bir konudur. Bu çalışmanın amacı yeraltı madenciliği emniyetinde daha verimli olabilmek için, gerekli mekansal veri ve meta verilerin kullanımıyla bir CBS oluşturmaktır. Böyle bir sistem sürekli risk tahmini ve tehlike anında acil durum uygulanabilirliğine hizmet edebilecektir. Güvenlik kavramı üç temel unsuru barındırmalıdır. Bunlar, (i) emniyet; (ii) gözetim ve bakım; (iii) olağanüstü durumdur.

Uygulama internet tabanlı coğrafi bilgi sistemleri kullanılarak yapılmıştır. İlk olarak emniyet kavramı mekansal olarak modellenmiş ve daha sonra kavramsal model olarak varlık-ilişki diyagramı oluşturulmuştur. Mantıksal model kurulduktan sonra kullanıcı arayüzleri geliştirilerek CBS test edilmiştir. Son olarak da, şimdiye kadar yapılanların ulusal bir CBS altyapı sistemine genişletilebilmesi sorusuyla ilgilenilmiştir.

Anahtar Kelimeler: Yeraltı Madenciliği Emiyeti, Coğrafi Bilgi Sistemleri (CBS), Veritabanı İşletim Sistemleri, İlişkisel Veri Modeli, İnternet Tabanlı CBS, Acil Durum Güzargahı

To my adorable and sweetheart Mother and Father

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CHAPTER 1

INTRODUCTION

1.1 Background

Underground (U/G) mining is an industry which is usually prone to mining accidents since the very beginning. These accidents may cause fatalities, injuries and also significant economical losses as consequences. An accident cost can be so substantial to an employer and mine that the mining operations may become infeasible due to the cost of accident and disaster. For these reasons, some institutes are established such as National Institute of Occupational Safety and Health Research (NIOSH) or Mine Safety and Health Administration (MSHA) in the world and a governmental agency to observe and watch work accidents in Turkey.

1.2 Statement of the Problem

In promoting and maintaining high safety standards of U/G mining, the availability of suitable laws, safety rules and regulations are needed. At this point, the maintenance of safety standards plays the most important role. In this study, the promotion of the standards was achieved by using the Geographic Information System (GIS) which may carry out constructive safety, emergency and surveillance concepts. The application of GIS in natural resource industry i.e., ore exploration, has been increased in recent years, however, utilization of GIS for underground mining safety is very rare. The reason for this is stated in Hammond's work for some extent as the popularity of other computer aided applications and its interface with specialty mining software (Hammond, 2001).

The generation of a GIS which can administrate relevant spatial data and metadata of underground mining safety efficiently can serve as a more sophisticated tool to monitor the mine environment. The transition from computer aided systems such as Computer Aided Drawings (CAD) to the GIS is succeeded in a certain extent and GIS is capable of handling the drawback of other CAD systems by incorporating spatially referenced data and database management systems. Hence, a GIS system integrated to the U/G mining safety should serve to a continuous risk analysis and be designed for applications in case of emergency.

U/G mining safety related data may range from ventilation of the underground galleries, gas contamination, and humidity to support parameters containing rock mechanics applications, sound, and temperature. These parameters can be increased if the enough automation can be accomplished by the company and the data can be supplied in definite period times. When the U/G mining environment data is considered, handling, implementing and establishing queries become a critical point to be considered. At that point, the need of a system which manages the data in an organized way becomes a necessity. A well developed database management system can be used to solve the problem of handling the U/G mining data. After managing the data, the relation between the worker and its environment can easily be examined on the computer as a mini world.

1.3 Objectives and Scope of the Study

This study aims to serve as a tool to connect the underground mining safety related database to the GIS environment with the help of web and desktop applications. The objective is to enable end users to monitor and analyze the safety related parameters on spatially referenced maps and thereby help to survival of safety in working environment. The maps are helpful for analyzing attribute information of points visually on computer screen. Therefore, critical areas can easily be noticed and required precautions can be taken.

The prepared Web-GIS and desktop-GIS applications help to visualize information of the entities gathered from underground, enable analyze operations based on graphical representations and demonstrate query operations based on data tables and map objects.

1.4 Research Methodology

The research methodology comprises four main stages: At first, the safety concept was modeled as an attribute domain model which consists of core elements of the initial study. Secondly, a conceptual computational model was generated in terms of Entity- Relationship Diagrams. This process mainly focuses on the system role in the model namely system analysis is performed. The database was established using Microsoft Access. The third stage is to establish logical computational model which is deeply related with the system design. Queries have been implemented using standard query language (SQL) on GIS software (MapXtreme) and the necessary case specific tools were created using new interfaces. After the implementation of the logical model a user interface was developed by Visual Basic .Net and then complete application was tested.

1.5 Industrial Contributions

Optimizations of U/G mines are very rare in Turkey. The mechanization in ore extraction stages is available in some mines like Çayırhan Coal Mine and some parts of the Turkish Coal Enterprise (TKİ) Garp Lignite. However, when the occupational health and safety are considered, not the same mechanization or automation is established. For example, in these mines monitoring of the mine environment is not fully-automated. There are sensors underground for monitoring the mine environment but still some measurements are achieved by conventional methods. Moreover, these sensed data are just sent to computer screens as simple representations. The existing monitoring system has been used since 1998 and since then it has not been updated. The update operation is

conducted by international engineers who initially designed the system in their language.

The main novelty of this study is to develop a mine monitoring system which is easy to use and install for engineers. Since most of the application is Web-based, any personal computer which has an operating system and a web browser can connect the internet and enter the web page to use the application. In desktop applications, which require additional security, the MapInfo installation is the only extra necessary item for the software component.

This application is expected to serve as a complete system to monitor the mine environment for the sake of occupational safety and surveillance. Therefore, it is expected to be a main contribution to U/G mines for better and safer working environments.

1.6 Structure of the Thesis

The following chapters define the subject in a wide perspective. Chapter 2 is dedicated to a comprehensive literature survey about the stated problem and the provided solution methods. Namely, first the underground mining occupational health and safety issues in general are discussed and then information intertwined the application of GIS and DBMS to the mine and environmental sciences are given chronologically. Chapter 3 discusses the data used in the study, the data formats and characteristics. The research area is presented, and the data acquisition and pre-processing are explained in detail also in the Chapter 3.

In the Chapter 4, database management system and system analysis that was conducted during this study was evaluated. In this chapter, the design of the database of the underground mine will be discussed in addition to the explanation of provided data characteristics. Then, data analyses which are made by the help

of GIS applications are examined. A discussion with concluding remarks and recommendations for future studies completes the thesis in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Many researchers have contributed to the definition and application of information management systems whether it is entirely related to underground mining (U/G) safety or not. The studies discussed during this chapter are related to U/G mining safety concept, database management system (DBMS), and geographic information systems (GIS). Literature review chapter consists of four brief parts which summarize the general ideas resulting from previous studies. In sections 2.2 and 2.3, general U/G mining safety related problems are presented and the studies performed to rehabilitate the U/G Mining safety problems in Turkey are discussed. In sections 2.4 and 2.5, the necessary contributions that can be made by technological point of view are presented. In this sense, the technology of DBMS as managing the related U/G mine data and GIS as a computer aided system to analyze, manipulate and output the data are briefly explained.

The exploration, mining, processing and the extraction of mineral resources tasks throughout the world are associated with numerous health risks. Therefore, a regulation which comprises health and safety in U/G mines and its maintenance is an obligation. Effective safety at mines aims many aspects. Some of these aims are stated as (Akcil, 2005):

    i.   Avoiding injury to personnel and harm/damage to plant/equipment and the environment,

ii.   Integrating health and safety management with the management of all other major functions of the organization,

iii.   Ensuring that review of safety management is carried out, and that programs and initiatives are developed to ensure continuous improvement in the areas of safety and health.

For achieving these objectives, namely preserving regulations and precautions in U/G mines, a safety concept model should be prepared and its maintenance should be full-filled.

The reason underlying these regulations and precautions is that risks in occupational health and safety in U/G mines have undesirable results. To eliminate and minimize these results, risk assessment should be handled. Risk assessment is the using of whatever information, experience and intuition which is available to control value of risk related to a concrete situation and a recognized threat (Blockley, 1992). Therefore, the key point in risk assessment is hazard identification and management. A simple risk management process consists of identifying and evaluating the treatment options, developing implementation, preparing an implementation plan and monitoring and reviewing the risk (Figure 2.1). In this study, data acquired is used to identify the risk and helps to define and evaluate the treatment.

During the risk management, a well concentrated management system should be preserved to manage the related risk data. Gibert *et al.*, (2005) put forward that management of environmental databases with user-friendly and well-developed software is essential because it enables end-users to perform their task and use tools efficiently. Furthermore, available knowledge in the domain can be used by all implemented methods by the help of well-developed software. A case specific application fully meets the needs of the end users. Moreover, Gibert *et al.*, (2005) emphasized that dynamical environmental monitoring process produces remarkably high quantity of the information and implicit knowledge patterns which necessities a DBMS.
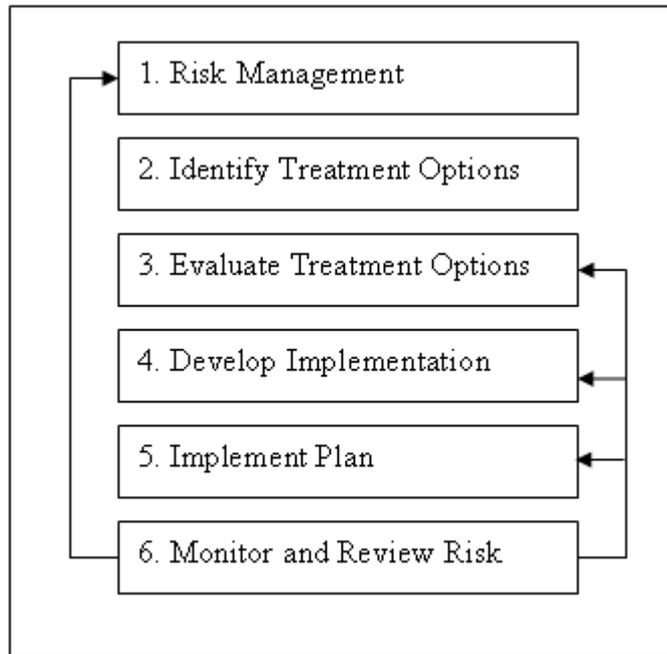
Figure 2.1 Simple Risk Management Process (Akcil, 2005)

2.2 Underground Mine Safety

According to the Mine Safety and Health Administration (MSHA) statistics most of mining accidents occur in underground mines and the highest rate occurred in coal and stone mines (MSHA, 2003). In 2003, 14,391 mining operations reported employed statistics to the MSHA. Almost half (49%) were sand and gravel mines, followed by stone mines (30%), coal mines (14%), non-metal mines (5%) and metal mines (2%). International Labor Office stated that 10,537,380 workers out of 2,164,739,590 have accidents and 57,468 of them were fatal accidents. That means every five people out of one thousand were killed by accidents occur in work (ILO, 2004). These accidents may be caused by different sources and have various outcomes. Figure 2.2 illustrates different aspects of U/G mining health and safety issue (Lui and Yang, 2004). It is a study evaluated by National Institute of Occupational Safety and Health Research (NIOSH). Among all stated

aspects, U/G mine ventilation is one of the biggest concerns for safety and effective working environment.

Engineering Controls	Diseases, Injuries, and Disorders
Equipment Design Maintainability Programmable Electronic Systems Ergonomics Ground Control Pillar Design Roof Support Ventilation Workstation Design Control Design	Hearing Loss Musculoskeletal Diseases and Disorders Respiratory diseases
Hazards	**Administrative Controls**
Contact with Electric Current Diesel Exhaust Dusts Emotional Stress Explosives Noise	Emergency Management Hazardous Materials Management Tasks and Activities Haulage Manual Materials Handling
Measurement and Analysis	**Accident and Emergencies**
Geologic Characterization Ground Monitoring Horizontal Stress Slope Stability Methane Monitors Training Education and Training	Explosions Falls Fires Rock falls
	Special Populations
	New Workers Older Workers

Figure 2.2 Safety and Health Topics in Mining (Lui and Yang, 2004)

Underground ventilation networks should be examined thoroughly on the basis of ventilation parameters such as tunnel sections, ventilation resistances, air pressure drop, tunnel slope, the supporting methods, integrity degree, and tunnel uses (Lui and Yang, 2004). Therefore, a comprise database management system for a perfect controlling and monitoring of the mine environment should consist of all related data stated.

2.2.1 U/G Mine Monitoring

Continuous and general monitoring have contributions to mine health and safety. A survey on mine monitoring and control system was completed in Deserado Mine (Mitchell *et al.*, 1986) in order to find out the overall cost and benefits of mine monitoring systems. In this prototype, all related items such as environmental parameters, electrical power, and operation of all mine equipment and controlling the entire conveyor haulage system were monitored. A plan view of wireless electromagnetic signaling and warning system in Lake Lynn Laboratory's U/G mine is shown in Figure 2.3. A mine monitoring system used in Deserado Mine was expected to be compatible, reliable, flexible and capable of managing the information. Mitchell *et al. (1986)* claimed that a good system becomes a state of art after adding some user interfaces and graphics into it (Mitchell *et al*, 1986).

Information that is provided by monitoring is needed to be managed. In that sense, a supervisory computer is needed to provide data storage, analysis, and reporting. In addition, it can help to combine the mine complex by accepting data from both the mine monitoring system and the prep plant system. Moreover, the designed system should be user friendly, so any personnel could modify the system when it is desired. Mitchell *et al.*, (1986) pointed out in their article that the system requirements should consist of mine monitoring controller, hot backup, supervisory computer, software, telemetry system, and sensors to monitor the mine at its current state of development. When the monitoring of mine environment is considered, it includes belt fire monitoring, power center

monitoring, environmental monitoring and underground belt monitoring. In underground mines, environmental monitoring includes gas measurements based on sensors or manual devices.
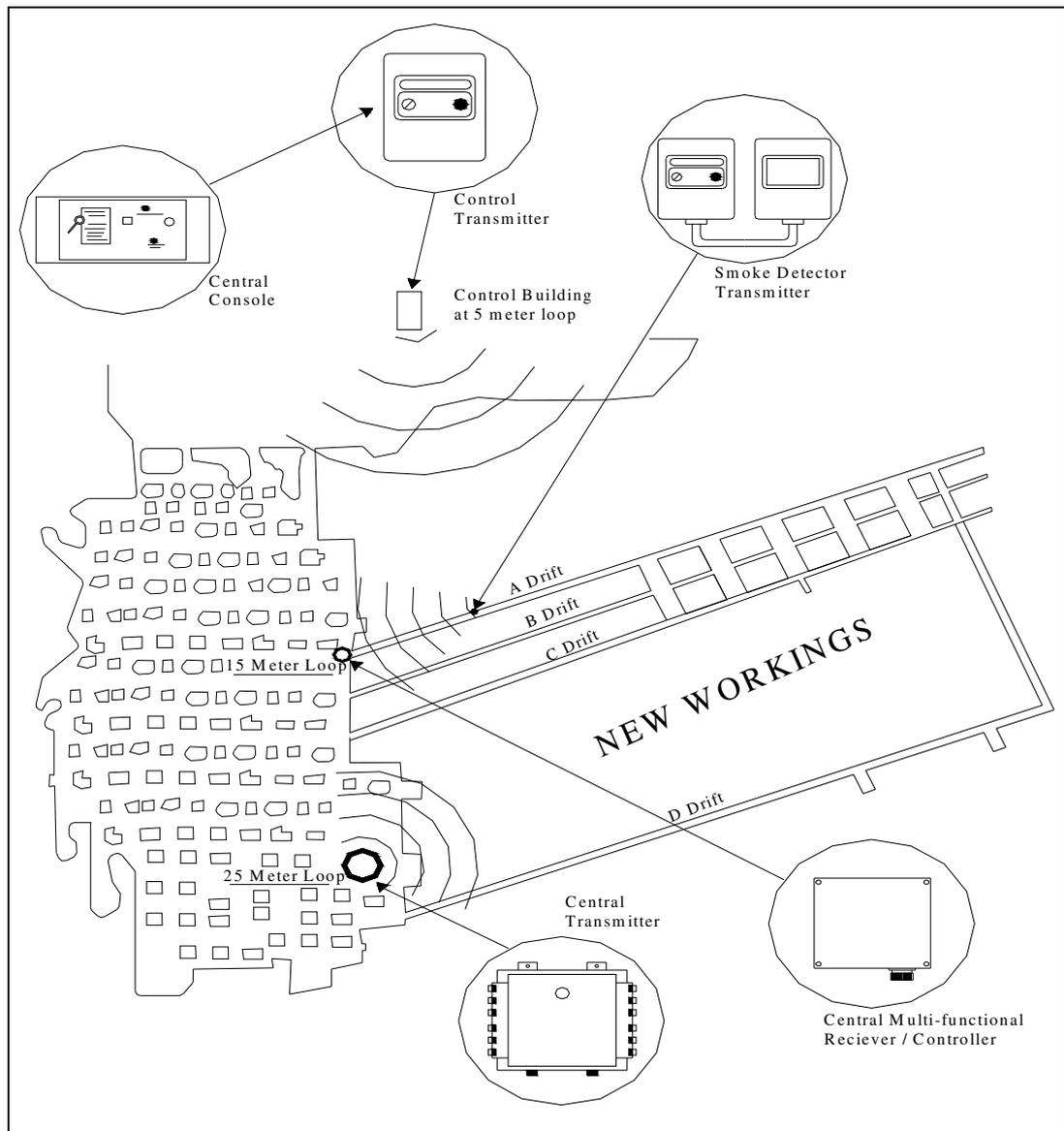
Figure 2.3 Plan View of Wireless Electromagnetic Signaling and Warning System in Desorado Mine (Conti *et al.*, 1998)
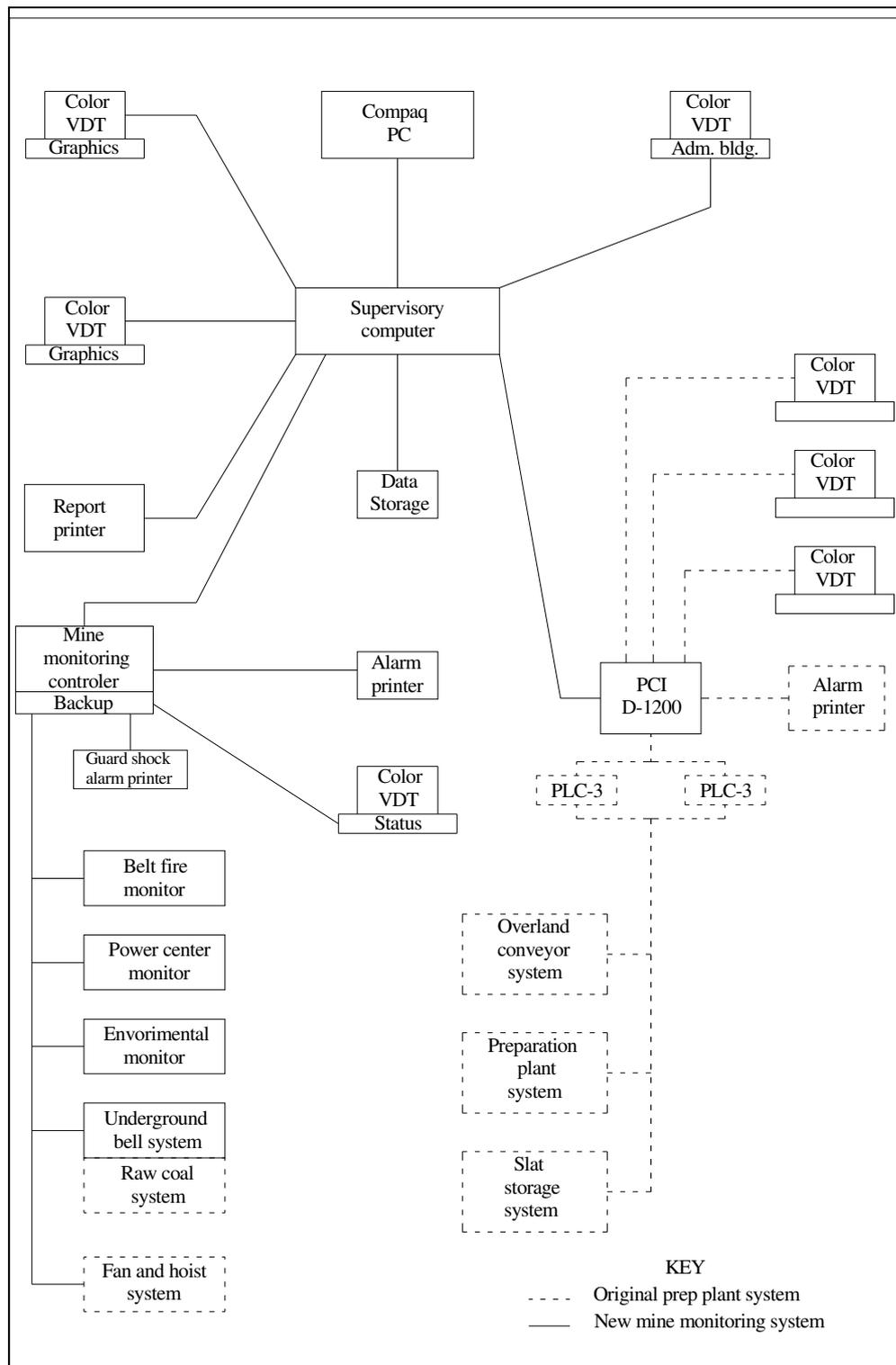
Figure 2.4 Monitoring System Architecture in Desorado Mine (Mitchell *et al*., 1986)

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The monitoring system architecture used in Deserado Mine is presented in Figure 2.4. The system is monitored through a color VDT monitor and the results can be outputted by a printer. Operator can notice alarm points through monitors and print.

An alarm horn and light responding to carbon monoxide (CO) alarms are at each underground outstation. System control, color graphics generation, extensive data analysis and data archiving are accomplished by the supervisory computer. It afterwards, can report the document in run time, production and environmental status, alarm summaries, historical logs, trend analyses, and equipment availability.

Supervisory computers in continuous monitoring of mine environment have some benefits in creating a safer working environment. However, it has been said that many potential benefits have not yet been realized since the supervisory computer has not been completely operational. For example, it has some drawbacks on comparing the reports, such as electrical power consumption versus coal production, which may lead to reduction in operating costs (Mitchell *et al*, 1986). Other expectations from the software are to generate historical data and trend analysis to help improving mine efficiency, lower electrical costs, and improving maintenance troubleshooting. Moreover, provision of real time operating data, which would help improve efficiency and safety aspects, would be beneficial for the upgraded system (Mitchell *et al*, 1986).

Sensors are the backbones of the continuous monitoring systems. In a sensor network (Figure 2.5) each sensor is responsible for a different attribute which is related with the objects surrounding. The elements forming the network should be capable of filtering and making decisions about the data which passes through the stream and is ready to be stored. Furthermore, fluctuations resulting from the high-stream data should be accommodated by these monitoring networks (Pokorny, 2005).

Up-to-date data management visualizing and gaining information from the mine environment has become one of the paramount steps to be taken for mining safety in the United States due to the fact that this leads to development of mine safety in a very broad mean and help progress in environmental impact issues for mining like assessment and remediation of abandoned mine land problems, fair and equitable taxation.
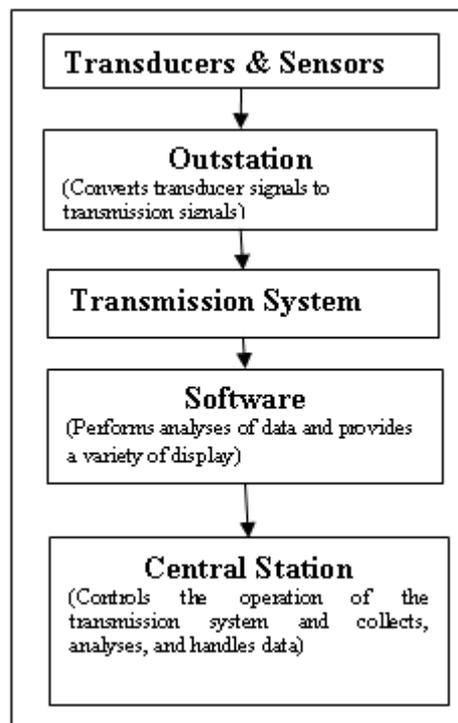
Figure 2.5 Sensor Network Flow Diagrams (Pokorny, 2005)

GIS technology helps to create an efficient storage environment for data and resource map besides it enables the manipulation and control for focused analysis. GIS outcomes for a coal mine can be very extensive such as structural contours and outcrops, net coal, total bed height, and percent partings isopach maps, and many others. These kinds of information can be meaningful for unintended cut-

through thereby insuring miners' safety. Moreover it permits monitoring water-filled abandoned mines and assessing the blowout potential for assessing mine subsidence risks (Fedorko, 2004).

2.2.2 U/G Mine Rescue Optimization

The safety concern has become a significant issue in mining industry and for that purpose some trials were carried out to control the emergency situations. For example, some mine rescue training simulations were conducted in NIOSH Pittsburgh Research Laboratory (Conti *et al.*, 1998) to have better emergency responses when in an urgent situation. Periodically, sessions were prepared which included the wearing and using of breathing apparatus, use, care, capabilities, and limitations of auxiliary equipment, advanced mine rescue training and procedures, mine map training and ventilation procedures. This is a sign of how much importance and care has been paid on safety in developing world (Conti *et al.*, 1998).

In rescue operations, time and efficiency are the key parameters. Locating the best possible emergency route will possibly save time and make the rescue operation more effective. According to Conti *et al.* (1998), in ideal case, sensors should be placed in underground for monitoring the gases and smoke in the passageways during the fire. This monitoring will help the locating best possible emergency exit. Moreover, by examining mine ventilation network, nodes and loops best rescue and safety route should be constructed in possible accident locations in U/G mines. After determining the best escape route, the appropriate strobe lights could remotely be turned on by interfacing these data with computer. GIS can serve on optimizing the network systems by using spatial properties of objects. Establishing an appropriate GIS can offer reliable evidences for mineral rescue based on science and efficiency (Lui and Yang, 2004).

Automated monitoring systems provide computer capability to process large quantities of data, indicate when alarm levels are reached, and provide shift

reports and analyses (Güyagüler and Karaman, 1993b). For emergency concept working zones must be evacuated immediately and workings at the effected zones must be stopped as quickly as possible (Güyagüler and Karaman, 1993b). Thus a well-developed mine safety surveillance system is beneficial for emergency concept.

The GIS serves as surveillance and training for emergency concept in mines in many aspects. Mining injury and illness data are examined using the GIS by observing the spatial distribution of mining injury and illness data. GIS maps are used to identify the illness locations and potential mining fall ground zones are demonstrated as well. In addition to these, some clustering regions are formed according to the data about the regions and districts like hospital catchments areas vs. mine locations. These help to facilitate rescue efforts and limiting the consequences of severe injuries by means of shortest path analysis (Coleman, 2007). For example, for the Lake Lynn Laboratory's U/G mine, which is a case study area for NIOSH, the wireless electromagnetic signaling and a warning system was generated. This could be a model for a GIS map, and it could be improved for further applications.

2.3 Underground Mining Safety Situations in Turkey

In Turkey, continuous mine monitoring is used to monitor toxic gases, temperature increase, and ore haulage on belt conveyors in some mines. These monitoring systems are used as an early warning system in emergency cases and tied to underground with sensors placed in definite galleries. Monitoring operations are conducted by the computers which are capable of showing the measured quantities of the specified parameters. Any further analysis is not provided by the system installed in the computer but the data is stored for backup. However, there are still conventional monitoring methods exist and some mines continue to make the necessary measurements with hand devices.

According to safety regulations in Turkey, before shift starts, each working place should be checked and controlled for harmful gases and unsafe working conditions. This procedure may become very difficult and time consuming for large mines which continue to use the conventional methods. Conventional methods are not only uneconomical but also ineffective to measure continuously harmful gases which could become dangerous beyond permissible limits. Another disadvantage of conventional methods is that in an emergency case, where mine air is contaminated by harmful gases, breathing apparatus is needed to reach measuring stations. In addition to this, the measuring devices are delicate and may lose its accuracy quickly in underground conditions. Due to aforementioned reasons, it is obvious that monitoring systems has superiority on conventional measuring techniques as far as economy and safety is concerned (Güyagüler and Karaman, 1993b). Continuous monitoring provides a better method of observing the trend of a specific gas in mine atmosphere as compared to spot measurement. The observed gases contamination and oxygen amount gives an idea about the ventilation of the U/G. This can help to make improvements in critical zones.

Data generated from both continuous monitoring and conventional methods may cause data abundances. Keeping and updating this data can be very cumbersome and time consuming. However, in urgency, reaching the related data should be accomplished as quickly as possible. Therefore, a well developed database management system should be preserved. GIS technology and a well designed DBMS are beneficial for many aspects in U/G mining and have prosperities to build a well designed automated system for mining organizations to the surveillance of mine safety.

2.4 Definition of GIS and Database Management System

A geographic information system is a computer-based information system which is able to capture, model, store, retrieve, share, manipulate, analysis and present geospatial data (Worboys and Duckham, 2004). In other words, the GIS has the

capability to deal with four items about geographically referenced data which are (Aranoff, 1989):

      i.   Input
     ii.   Data management (data storage and retrieval)
    iii.   Manipulation and analysis
    iv.   Output

Spatially referenced mine environmental data should be structured in an ordered manner so that it could be integrated into a GIS system to be managed, manipulated and analyzed. The output can be used for safety surveillance and mining safety preservation. This is required for the developing a database management system.

Database management system is a method for structuring data in the form of sets of records or tuples so that relations between different entities and attributes can be used for data access and transformation. Data stored in GIS consists of two dimensional tables where multiple relationships between data elements can be defined and established in an ad-hoc manner (Croswell, 1991). This data model is called relational data model and as stated in Worboys and Duckham (2004) relational database structure is very simple which makes it powerful.

2.4.1 Advantages of GIS

GIS provides many favors to the user by using graphics representations of spatial objects from their attached attribute information. This helps to manage the attributed data set to be reclassified and integrated by the user. When dealing with huge amount of data and plenty number of attributes, this function enables to manage the database in a regular way and organize the data normally. When manipulation, management and processing of the data considered, one of the most important achievements of the GIS is its capability to provide predictive models and functions to tackle the data stored. GIS can also provide spatial decision

support system. The system can display the output, manage the spatially stored data and provide interface functions. Traditional tabular data format cannot be expressed by means of certain relationships and trends. Therefore, geographic context will be much easier to convey which is an advantage of GIS. GIS analysis is helpful for locating where and why things occur. Moreover, occurrences of instances can be analyzed based on the relationship among each others. This is enabled by topological structure of GIS. This sometimes advances to gain unavailable information which is derived from the existing ones.

2.4.2 DBMS integration with GIS

GIS can be integrated with DBMS to tabulate, manipulate, query and retrieve the spatial data. According to Martin *et al.*, (2004) data redundancy, error and computational lag times can be reduced by efficiently constructed databases.

Any GIS containing a large variety of data, requires organization and management of the data files. When information is kept redundantly in several places and in several formats, the data update operation becomes difficult without concurrent control (Raheja *et al.*, 2008). Analyzing data categorically using spreadsheets is also difficult, since it is kept in daily or monthly based where the problem can be solved very easily by querying on the system (Carleton *et al.*, 2004). To manage the abundant data which can come from different sources, DBMS can be utilized. A DBMS is a collection of programs that enables to create and maintain a database. Its general purpose is to provide the facilities for defining, constructing and manipulating databases for various applications. A DMBS is essential when comparing individual data sheets or expecting a common task to be performed when analyzing the data. Beside its effectiveness in storage and querying, DBMS began to skilled in requiring a vastly wider range of techniques and integrating other approaches to various types and amounts of data.

GIS functionalities can be browsed on a standard internet medium, which provides data share and distribution between users. Data on the distributed

computing models like internet, intranet, extranet, the Web, net-work-centric can help to distribute computing services by the help of network services and computer processors for the client. This also removes the need of installation the data set on end-user side, the user can reach everything by means of a web-browser. The share of geographic data could be easier and operating cost could be decreased. This would consequently improve customer satisfaction (Jere, 2008).

2.5 Use of DBMS and GIS in Environmental Studies

GIS has begun to being used in environmental studies especially for monitoring purposes and spatial analysis. GIS is not only a map viewer but also it has been used as an integrated tool to manage data from many source, since it has abilities of capturing, storing, checking and manipulating spatially referenced data (Elbir, 2004). Furthermore, as stated in Carleton *et al.*'s study, user interface applications like quality assurance/quality control (QA/QC) calculations, retrieval of desired data for advanced analysis, and data comparison simplifies both remedial and advanced tasks related to environmental data. A web connected local area network can be supported by a database engine for that purpose.

Air pollution, spill management, mineral exploration, watershed hydraulic functions are some of the examples that GIS and DBMS can be used to monitor and to analyze the systems in environment and these applications are investigated under the general name of environmental management information system (EMIS). GIS is also used to determine the eligibility for project funding for the abandoned mines. The GIS enables users to store, manage, verify, protect, retrieve and archive environmental data as datasets, databases, documents, models, multimedia, projects and spatial information (URL 1).

Emergency management information system (EMIS) is a decision support system that includes all the urgent responses and management phases. In case of emergency, essential possibilities are evaluated and possible solutions for safer

locations, shelters, other emergency management facilities and resources are determined. The next step that is pioneered in EMIS is the improvement of user friendly visualizations for hazard situations and evacuation scenarios to support safety (Kwan and Lee, 2005). Therefore, environmental professions are focusing on the computerized solutions for management systems for standardization. Tracking activities, tracking wastes, monitoring emissions, scheduling tasks, coordinating permits and documentations, even in some cases conducting cost/benefit analysis can be performed by means of EMIS.

In environmental monitoring sensor technology plays a very important role for examining the changes, differences, variations from normal values. Sensors are widely used in environmental studies for monitoring purposes and they produce large amount of data economically. These devices should also be used as much as possible in U/G mines for various purposes such as temperature and gas measurements. One important point must be considered in the usage of sensors is the handling of the data. The data they produce is different from any ordinary enterprise data. Since they are retrieved in high-speed streams, their process should be in online fashion to meet the real-time responses. However this difference causes the need of metadata to understand the semantics of the data to perform basic SQL queries on the database (Pokorny, 2005).

For example, in characterization of urban air quality, GIS has been used as a management system. The chance for success depends basically on the data, which should be up-to-date, timely, affordable and in manageable formats, so that it can be shared between various governmental entities and the public. GIS gives the best solution for data management especially it would be much handier when it is combined with geographic imaging tools (Puliafito *et al.*, 2002).

Short response time is important in disaster management. Web-based GIS gives the ability to manage and analyze the data resultant from emergency management in an effective manner. It forms the bridge between the data and user by graphical

displays. Intelligent mapping enables users to understand the "location of the knowledge" (Raheja *et al.*, 2008). What web-based GIS provide is directly related with the user. It increases user's interaction and accessibility to spatial information, which is crucial for disaster analysis.

2.6 Summary

A comprehensive literature review has been done in order to gain an overview of research initiatives in GIS, DBMS, U/G mine monitoring, and incorporating new technologies into the conventional monitoring techniques. Previous researches conducted in risk assessment and environmental health and safety in U/G mines is criticized in this chapter. Database management concept is discussed and the integration of DBMS to GIS is also provided. GIS applications in mines are mostly focused on exploration or production stages in surface mining. The U/G mining GIS applications for occupational safety is very rare and these cases are limited with pilot studies as in Desorado Mine. Therefore, while the literature study was being made, other discipline examples are chosen to demonstrate the usage of GIS.

The aim of the formation of the occupational health and safety in mining is to avoid injuries of personnels, plant and environment. While avoiding the accidents, continuous improvement in the working environment is also expected. New technologies must be introduced for the welfare of the enterprises to improve the standards. These technologies must meet the requirements of the solutions of the problems occurred and they can be modified upon the requests of the users. When all these necessities are considered, as it was highlighted by all researches, GIS becomes more and more popular to solve drastic problems about risk assessment.

While spatial data has becoming more popular, it is begun to be used in different disciplines in everyday life. Especially, Web-GIS applications are turning into

solutions for different needs for even ordinary computer users. In this study, advantages of Web-GIS are employed to solve the problems in mines. Namely, intelligent maps on which different analysis are made possible are served for the safety engineers. Moreover, based on these maps, mining operations related problems can also be solved. For example, while selecting suitable fan location, air velocities in galleries can be examined spatially by using the application created in this study.

In Deserado Mine example, it is put forward that used supervised computers have some drawbacks. For example, it has some drawbacks on comparing the reports, such as electrical power consumption versus coal production, which may lead to reduction in operating costs (Mitchell *et al*, 1986). Other expectations that have been mentioned in the paper from the software are to generate historical data and trend analysis to help improving mine efficiency, lower electrical costs, and improving maintenance troubleshooting. Moreover, provision of real time operating data, which would help improve efficiency and safety aspects, would be benefits of the upgraded system (Mitchell et *al*, 1986). These drawbacks can be compensated by the integration of the GIS into this monitoring and surveillance system.

On the way to establish systems based on spatial information, attribute data of the elements must be well defined. The data needed for U/G mining safety is gathered by continuous or conventional monitoring methods as stated in section 2.2.1. The validation of the analysis and the reliability depend on the collection of the data. Therefore, to ascertain standards before starting to build the GIS, data acquisition process must be preserved. In the Chapter 3, the data acquisition and production standards are discussed.

CHAPTER 3

DATA ACQUISITION AND PRODUCTION FROM GARP LIGNITE UNDERGROUND MINE

3.1 Introduction

This chapter covers the data used in the study, the data formats and characteristics. This chapter also includes the details about monitoring system used in the research area and the existing operations. In section 3.2, the research area is presented, and the data acquisition and pre-processing stages are explained in detail in sections 3.3 to 3.5.

3.2 General Information about Research Area

Garp Lignite Enterprise (GLİ) underground mine is chosen as the study field in this research. It is located in Tunçbilek town of Kütahya city, which is approximately 350 km far from Ankara. The mine is 9 km far from Tunçbilek town as illustrated in Figure 3.1. GLİ has been working under the ownership of Turkish Coal Enterprise (TKİ) since 1985 and has been conducting both underground and surface mining operations (Figure 3.2). The extent of the mine area is around 5 km wide. The annual lignite productions from the surface and U/G mining are 5,000,000 tons and 700,000 tons respectively (URL 2).
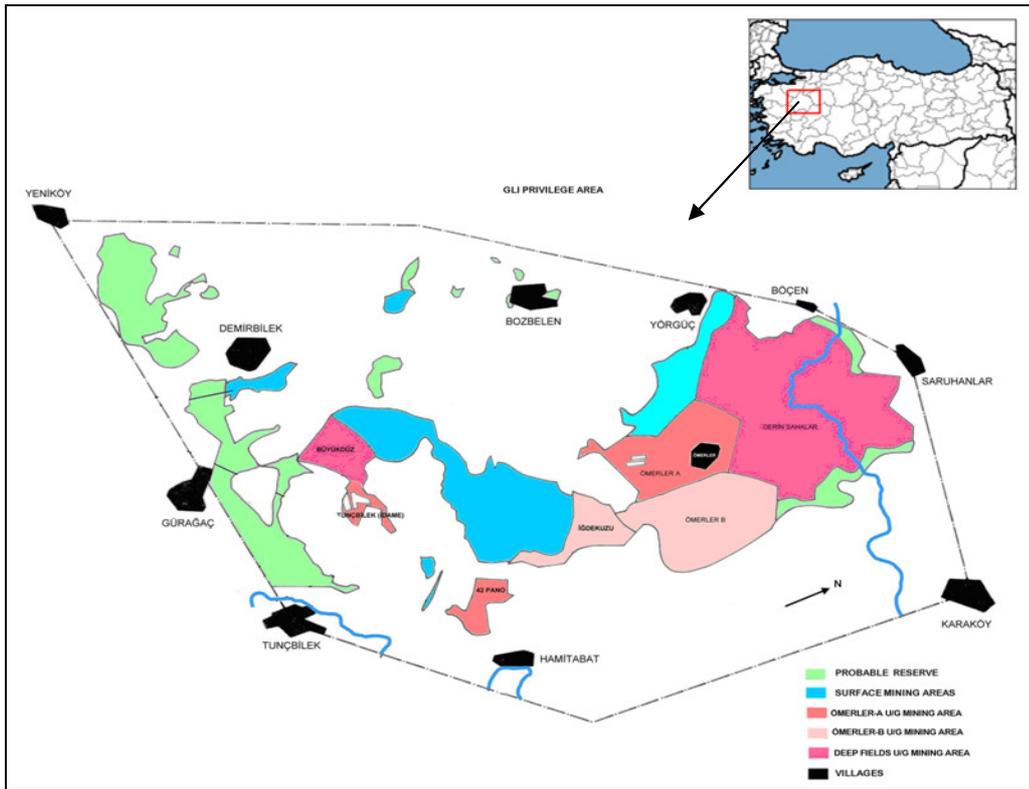
Figure 3.1 Representation of Boundary of Research Area

Figure 3.2 View from Surface and Underground Mine Areas

3.3 Underground Mining Operations in GLİ

In GLİ, the underground galleries are opened by drilling and blasting methods and the coal is extracted by longwall mining method. The operation is carried out by three 8-hour shifts. Coal cutting operation is performed by double drum shearers. The support system is established by concrete at the entrance of the galleries for 100 m. For the rest of the galleries, rigid ties are used to strengthen the maintenance.

Transportation of the coal is achieved using belt conveyors, coolie cars, and monorail systems. Coolie cars are used to carry equipment during the mounting and during the production stage. They serve as coal and man transportation mechanism. There are 629 workers who work for U/G mine divided in three shifts. Seven mining engineers work for the enterprise and one health and safety engineer is responsible for the preservation of the safety of the working environment in GLİ.

3.4 Monitoring System for U/G Working Environment

Underground mine environment can be monitored from surface stations in GLİ. There are sensors to monitor the galleries continuously. These sensors are specific for methane (CH_4), carbon monoxide (CO), carbon dioxide (CO_2), air velocity, pressured air, temperature, humidity, and oxygen. A system called Conspec Control Inc. Senturion 500 Graphics System Version 2.00 © is used to monitor these gases and activities of the conveyors. This system has the ability to alarm in case of an emergency. In the surface stations, the gas measurements and conveyor movements are observed and checked from computer screens by different user inter-phases. Figure 3.3 and Figure 3.4 shows the user inter-phases for gases. In Figure 3.3 CH_4, CO, CO_2 values can be monitored and conveyor belt carriage tonnage can also be observed.
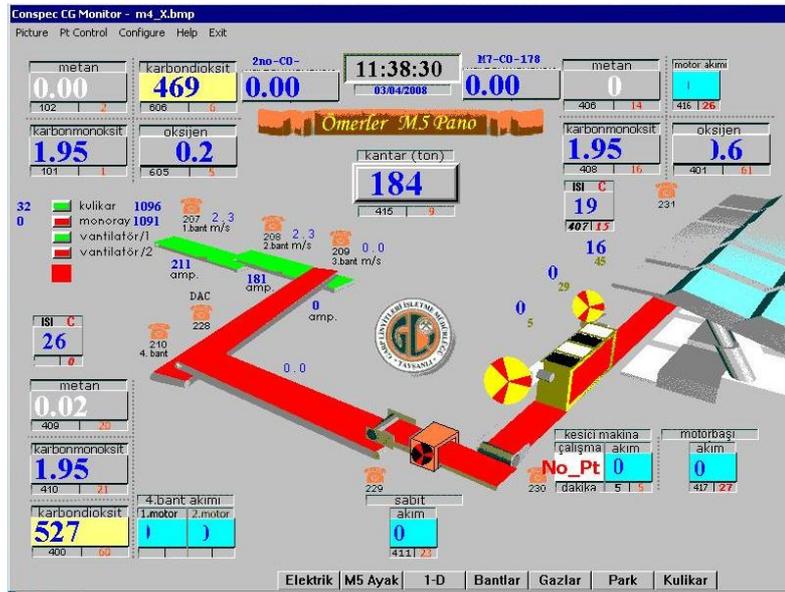
Figure 3.3 Measurements Monitoring Screen for CH$_4$, CO, CO$_2$

Figure 3.4 Monitored CO$_2$, CO, CH$_4$ Values Measured From Specific

Locations

3.4.1. Sensors Used Underground Mine

There are sensors for CH_4, CO, air velocity, pressured-air pressure, pressure difference, temperature, and humidity underground mine. CH_4 sensor called P 2039 is a type of sensor which exits in the Senturion® system. It is used in underground gallery, on the long wall mine panel. The measured methane's standard sample size can be adjusted and also maximum and minimum warning systems can be arranged according to the allowable values. The sensor sends CH_4 information to the central station.

CO sensor called P 2030T is another type of sensor which exits in the Senturion ® system. Like CH_4 sensor it is used in underground galley, on the long wall mine panel. This sensor can be adjusted such that it can serve for local alarm systems. To eliminate user dependent mistakes, it can be programmed with a specific address and password.

Air velocity sensor AFG-1C is used for the safety and protection purposes for the underground workers. It has a varied monitoring range. The maintenance and preservation is easy when it is compared to the other sensors. It is mounted at the entrance or the exit of the galleries in underground. It should be placed such that it can represent the air velocities' of the all galleries.

The pressured-air pressure sensor, called P 2053, is a site device working in Senturion® system. It is used underground gallery panel. The pressure difference sensor P 2054, like pressured-air pressure sensor, is a site device working Senturion® system. It monitors the air pressure in ventilation equipments. It is used in underground ventilation system.

The temperature sensor, called P5003, is used to measure the temperature on the coal surface. It is one of the site devices working in Senturion® system. The humidity sensor, KG 69301 uses its electro chemical principle to monitor the humidity in underground and it can work under hard conditions.

3.4.2 Limitations of the Sensors

Some of the limitations of the sensors used in underground mines are stated in Güyagüler and Karaman's (1993a) study. It is underlined that monitoring system cannot completely be compatible to electrical equipments used in the mine. Moreover, it is criticized that system should have the facility to adjust measuring range of toxic gases monitor directly from the central station.

The dust, high temperature and 100% relative humidity tolerances are other factors which affect the accuracy of the sensors. Those factors should be considered and the life of the sensors should be noted and checked regularly (Güyagüler and Karaman, 1993a).

The system Senturion® has been used since 1998 in GLİ. All the maintenance and update operations have been controlled by the producer firm, which disables any modification on the program, since the installation of the program. Therefore, each engineer is supposed to learn the system. Moreover, system files are software specific or program dependent. In the monitoring stations, only observations of the measurements are enabled. No more analysis or comparison is possible. Additionally the data sent to the general office consists of conventional method measurements done by workers. For more efficient utilization of the sensors, the existing monitoring system should be updated and the sensors data can be saved and backed-up in a format which can be read by other known program types.

3.5 Data Formats and Characteristics

Since the study is related to underground mines, all necessary and related data are included in the database. Every spatial data in the database has its own attributes, which can be spatial, temporal, and thematic information about the data. Some of the objects can have all three types of attributes, but in some cases in practice spatial or temporal attributes are neglected. However, spatial attribute

information is so important because it includes location, topology, and geometry information of spatial objects. Therefore, the distinction between GIS and other database systems is drawn (Bonham-Carter, 1995). In this study, generated spatial data is related to spatial information and based on primary observations and some measurements and their attributes are attained. In some of the further processes, data are derived using secondary processing and calculations.

Temporal attributes like the workers personal information, accident statistics, accidents types and occurrences, time of data collected or measurements are also kept in the database. Thematic attributes are other kinds of properties of objects that are neither spatial nor temporal, such as gallery length, worker's name, month based values of measured quantities of CO, CO_2, etc. can be considered as the example of thematic attributes. These thematic attributes are gained form the enterprise. The data which has a spatial mean is the gallery map, which contains the galleries, fans, and first aid stations locations. By the help of this information, the non-spatial data can be linked and related with the spatial information. For example, since the locations of fans are known, the fan properties can be assigned to that point as a non-spatial attribute.

3.6 Data Acquisition and Pre-Processing

Gathering the essential information in GIS is a paramount step because it provides data for new planned systems. Beside it enables the data to be more accurately and precisely produces. In this sense, the field studies strengthen the integration of the data to the system with more controlled and up to date manner. Although they provide more accurate information, field studies are more expensive and time consuming. Consequently, digitizing can be considered as an alternative which enables existing maps to serve as data sources. The field studies conducted can be used to strengthen the digitized map's accuracy by using ground control points.

3.6.1 Image Registration

Spatial information of objects is recorded either in geographic or geodetic latitude and longitude coordinates, in coordinates of one of the standard cartographic projections, or in arbitrary rectilinear coordinates with a local origin. Therefore, to get a spatial information form an image, first any point on the image should be registered to a projection system (Bonham-Carter, 1995). The base map which is the scanned version of gallery map of GLİ is formed in MapInfo ® program which is the software enables programmers to analyze, query and form different data sets based on layers. The image is registered according to known coordinates of the region which is scripted on the map. These known coordinates are collected chosen from the grid points and they are based on UTM projection system with ED50 ellipsoid with the given zone 3.

The Transverse Mercator Projection is very widely used, and is particularly appropriate for regions with a large extent in north-south direction but narrow extent in east-west direction. The transverse mercator is also the basis of a worldwide projection system known as Universal Transverse Mercator (UTM). This system divides the world up into 60 zones of longitude, each of width 6°. The zones are numbered from 1 starting at a longitude of 180°E, and increase eastwards. Turkey lies between zones 35N to 38N and for the maps which has a scale of 1/25000, 6° zoned systems are used. For the standard topographic and standard topographic cadastral maps with a scale of 1/5000, 3° zoned systems are used (Iliffe, 2003).

The given UTM coordinates on the map must be arranged before using for the transformation. For example, the hundred thousandth digit of the X coordinates and millionth digits of the Y coordinates were omitted by GLİ during the preparation stage of map. Therefore, the derived coordinates of the control points in the map should be rearranged by adding 400,000 to the X and 4,300,000 to the Y coordinate in order to transform into UTM projection. After converting the

coordinates, image registration is performed by using MapInfo ®'s image registration menu as seen in Figure 3.5.
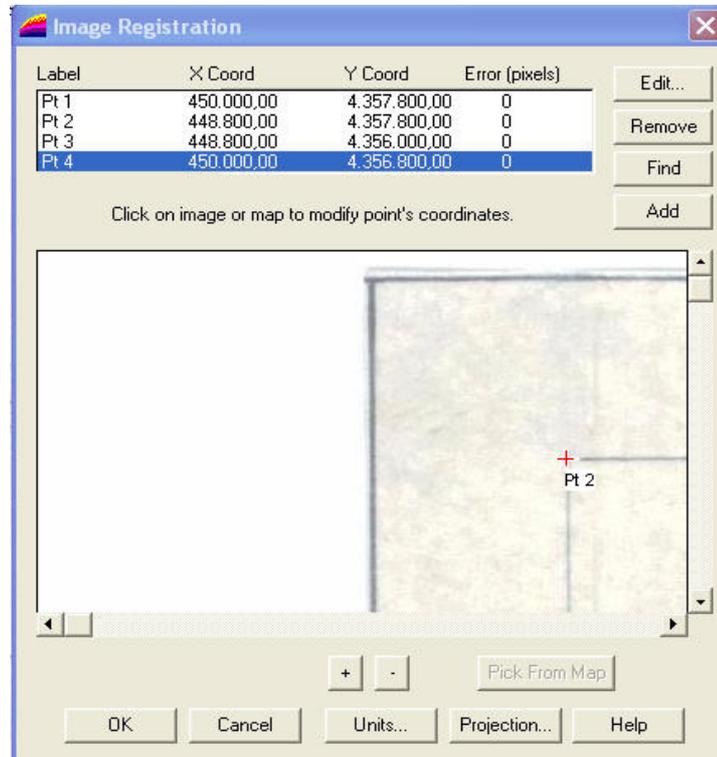
Figure 3.5 Ground Control Points for Image Registration in MapInfo

3.6.2 Image Registration Validation

Image registration is accomplished by choosing five ground control points on the map. These points are chosen as good as possible to represent the image coordinate set. Four of the points are the corner points of the image and one point is at the center of the image. MapInfo uses the control points to perform affine transformation, whereby digitized objects are skewed, shifted and scaled to fit the control point locations.

Table 3.1 Ground Control Points' Error Values for Image Registration

	MAP X (m)	MAP Y(m)	IMAGE X (pixel)	IMAGE Y (pixel)
Pt 1	450,000.00	4,357,800.00	5,033	128
Pt 2	448,800.00	4,357,800.00	318	134
Pt 3	448,800.00	4,356,000.00	317	7,199
Pt 4	450,000.00	4,356,000.00	5,033	4,053
Pt 5	449,400.00	4,356,800.00	2,672	4,058

The affine transformation model uses two different scale factors for the X and the Y directions, respectively. Besides, the affine transformation allows changes in the orthogonality between the two axes of the coordinate system. The general form of the two-dimensional affine coordinate transformation is conducted using equations (3.1) and (3.2) (Chen and Lee, 2001).

$$\mathbf{X} = a + s_X (\cos\alpha)x + s_Y (\sin\alpha.\cos\beta - \cos\alpha.\sin\beta)y \tag{3.1}$$

$$\mathbf{Y} = b - s_X (\sin\alpha)x + s_Y (\sin\alpha.\sin\beta + \cos\alpha.\sin\beta)y \tag{3.2}$$

where X and Y are directional coordinates of the new system and x and y are the coordinates of old system. a and b are translations of the origin along the X and Y directions. α corresponds to rotational angle from x axis to the y axis, s_x and s_y are scale factors in the x and y directions respectively. Last parameter β is the change in the orthogonality of the axes of the x-y system.

Equations (3.1) and (3.2) can also be expressed as in equations (3.3) and (3.4):

$$\mathbf{X} = a + cx + dy \tag{3.3}$$

$$\mathbf{Y} = b - ex + fy \tag{3.4}$$

where a,b,c,d,e and f are another form of the six transformation parameters. Existing maps may have shrunk or expanded differently along the two axes of the

map. Therefore, affine transformation is used in transformation of digitizing maps since it have different scale factors for different axes.

In this study, validation of the MapInfo affine transformation is conducted by using selected ground control points. The parameters of the affine transformation are calculated by using equation (3.5):

$$\hat{\boldsymbol{\beta}} = (\mathbf{X}^T * \mathbf{X})^{-1} . \mathbf{X}^T * \mathbf{P} * \mathbf{y} \qquad (3.5)$$

In equation (3.5) the coefficient matrix, $\mathbf{X}$ matrix composed of the partial derivatives of the X and Y values of image coordinates with respect to the parameters and $\mathbf{X}^T$ stands for the transpose of $\mathbf{X}$ matrix. Since the points as observations $\mathbf{y}$ have the same quality and uncorrelated, the weight matrix $\mathbf{P}$ is assumed to be an identity matrix. After calculating partial derivatives for each coordinate in equation (3.1) and equation (3.2) and forming $\mathbf{X}$ matrices $\hat{\boldsymbol{\beta}}$ can be calculated as in equation (3.6):

$$\hat{\boldsymbol{\beta}} = \begin{bmatrix} 448718.3447 \\ 4357832.714 \\ 0.254830960 \\ 0.000144067 \\ -0.000187016 \\ -0.254473693 \end{bmatrix} \qquad (3.6)$$

By using these parameters, the residuals of the measurements are calculated as in equation (3.7). Residuals of the parameters show the difference between the measured and estimated coordinates. In other words, it is a sign of how the observation differs from its expected value.

$$\mathbf{e} = \mathbf{\hat{y}} - \mathbf{y} = \begin{bmatrix} 0.00273644 \\ -0.00193713 \\ -0.00083334 \\ -0.00142671 \\ 0.00298123 \\ -0.00235674 \\ -0.00059755 \\ -0.00184273 \\ -0.00428677 \\ 0.00756332 \end{bmatrix} \tag{3.7}$$

Since the residuals (**e**) are tolerable in mm accuracy, the transformation of the program can be used. Seeing as the residuals are acceptable, there is no need to increase the number of control points.

3.7 Data Production

After getting each layer into digital format with both tabular and graphical information, quality control over data is applied. There are four distinct layers which are related to fans, first aid stations, galleries and air measurement stations.

   i.   Point based fans

  ii.   Point based first aid stations

 iii.   Point based air measurement stations

 iv.   Line based galleries

These files are kept in MapInfo Professional format. Each layer has its own attribute information which is explained in detailed in section 4.2. Line based galleries are important data layer for ventilation analysis. The pressure drop in underground mines can be calculated based on the length of the airway, cross-section of the airway and also depends on some friction factors results from the mine environment. The flow of air in underground mines can be effected by

viscosity and frictional resistance caused by the rubbing of the air against the side walls of duct, and shock losses.

Gallery length calculation and gallery air pressure drop values are derived according to the previous data taken from the mine environment. For the calculation of the air pressure drop in each gallery, first friction factor should be defined. The shape of the airway namely whether it is curved or straight can have affects on friction factor. Also, the rock type irregularities and formation can result in varied friction factors. Table 3.2 is composed of friction factors which differ for different type and shape of airways.

For coal formations or sedimentary rocks, average friction factors are range from 10.20 to 17.62. Since information about galleries are not supplied thoroughly slightly curved and slightly obstructed parameters are chosen from the table and corresponding k value equals to 12.98. After deciding the friction factor, pressure drop can be calculated using equation (3.8) and stored in the database (Güyagüler and Güngör, 1999).

$$P = \frac{k \times C \times L \times Q}{A^3} \tag{3.8}$$

In equation (3.8) P is pressure loss in Pascal, k is friction factor in Ns^2/m^4, C is perimeter of the gallery in meters, L is length in meters, Q is air velocity in m/s, A is cross-sectional area of the gallery in m^2. The lengths of the galleries are calculated in MapInfo program by adding an extra column to galleries table and assigning the spherical length formula in update column property.

The reason to assign the spherical length is because spherical calculations measure distance according to the curved surface of the Earth. The data is first converted to Latitude/Longitude and then a calculation is performed. Lat/Long data always use spherical calculations. Whereas the Cartesian method performs calculations on data projected onto a flat plane.

Table 3.2 Friction Factor (K) for Mine Airways (in SI Unit) (Güyagüler and Güngör, 1999)

Values of K x 10³												
	Straight			Curved								
				Slightly			Moderately			High Degree		
Irregularities	Clean	Slightly Obstructed	Moderately Obstructed	Clean	Slightly Obstructed	Moderately Obstructed	Clean	Slightly Obstructed	Moderately Obstructed	Clean	Slightly Obstructed	Moderately Obstructed
Minimum	1,86	2,78	4,63	3,71	4,63	6,49	4,63	5,56	7,42	6,49	7,42	9,27
Average	2,78	3,71	5,56	4,63	5,56	7,42	5,56	6,49	8,34	7,42	8,34	10,20
Maximum	3,71	4,63	6,49	5,56	6,49	8,34	6,49	7,42	9,27	8,34	9,27	11,13
Minimum	5,56	6,49	8,34	7,42	8,34	10,20	8,34	9,27	11,13	10,20	11,13	12,98
Average	10,20	11,13	12,98	12,05	12,98	14,84	12,98	13,91	15,76	14,84	15,76	17,62
Maximum	12,98	13,91	15,76	14,84	15,76	17,62	15,76	17,62	18,55	17,62	18,55	20,40
Minimum	14,84	15,76	17,62	16,69	17,62	19,48	17,62	18,55	20,40	19,48	20,40	22,26
Average	17,62	18,55	20,40	19,48	20,40	22,26	20,40	21,33	23,19	22,26	23,19	25,04
Maximum	19,48	20,40	22,26	21,33	22,26	24,11	22,26	23,19	25,04	24,11	25,04	26,89
Minimum	16,69	17,62	19,48	18,55	19,48	21,33	19,48	20,40	22,26	21,33	22,26	24,11
Average	26,89	27,82	29,68	28,75	29,68	30,60	29,68	30,60	32,46	31,53	32,46	36,17
Maximum	36,17	37,10	38,95	38,05	38,95	40,81	38,95	39,88	41,73	40,81	41,73	43,59

Type of Airway

Cartesian coordinates (x, y) define the position of a point in 2-D space with respect to two axes which are perpendicular to each other. In fact since the mine's area has a relatively small boundary, the earth curvature does not affect the result whether choosing Cartesian or spherical. However, in this study spherical lengths were used for more accurate results.

3.8 Summary

In this chapter, production and acquisition of the data used in this study is explained. First, the study is explained and then the monitoring system used in the research is discussed. After drawing the profile of the study area, the data formats and pre processing stages are clarified. Sensor systems used in GLİ is very useful and meaningful in safety studies. However, the usability of the data and the variety of the data can be extended by considering the other parameters effecting mine safety. During data pre-processing and data production stages accuracy is important because the analyses are made on the basis of these data. For example, the air pressure value in each gallery depends on the right selection of the friction factor. Therefore, provided data must be consistent and accurate as much as possible. Management of the data is the next step after collecting and producing necessary data. The next chapter elucidates database management system. Afterwards, the analyses conducted for the study is explained in detail.

CHAPTER 4

DEVELOPMENT OF THE SYSTEM FOR THE UNDERGROUND MINE SAFETY

4.1 Introduction

In this chapter database management system and system analysis that was conducted during this study was evaluated. In this study, two major phases were appraised to form a GIS application and produce some accurate spatial information about an underground mine. These phases are (i) designing of the related web and desktop applications which is integrated with GIS; (ii) associated analysis and evaluation of mine safety and surveillance based on the spatial data. In some cases, the data entries derived from the mine do not have spatial attributes themselves. Therefore, a relational bond should be constructed between the spatial attributes and the non-spatial attributes through a well-designed database. In this chapter, the design of the database of the underground mine is discussed in section 4.2 in addition to the explanation of provided data characteristics. Then, system development and components are presented in section 4.3. Afterwards, data query operations are explained in detailed through 4.4 and in section 4.5 data analyses by using GIS applications are examined. In section 4.6 the desktop application Accident and Worker Information Management System is discussed. Safety regulations, which are mentioned in the application and metadata base management system formed, are explained in section 4.7 and 4.8. Finally, what is accomplished in chapter 4 is summarized in section 4.9. The research framework of the application in the study is summarized in Figure 4.1.
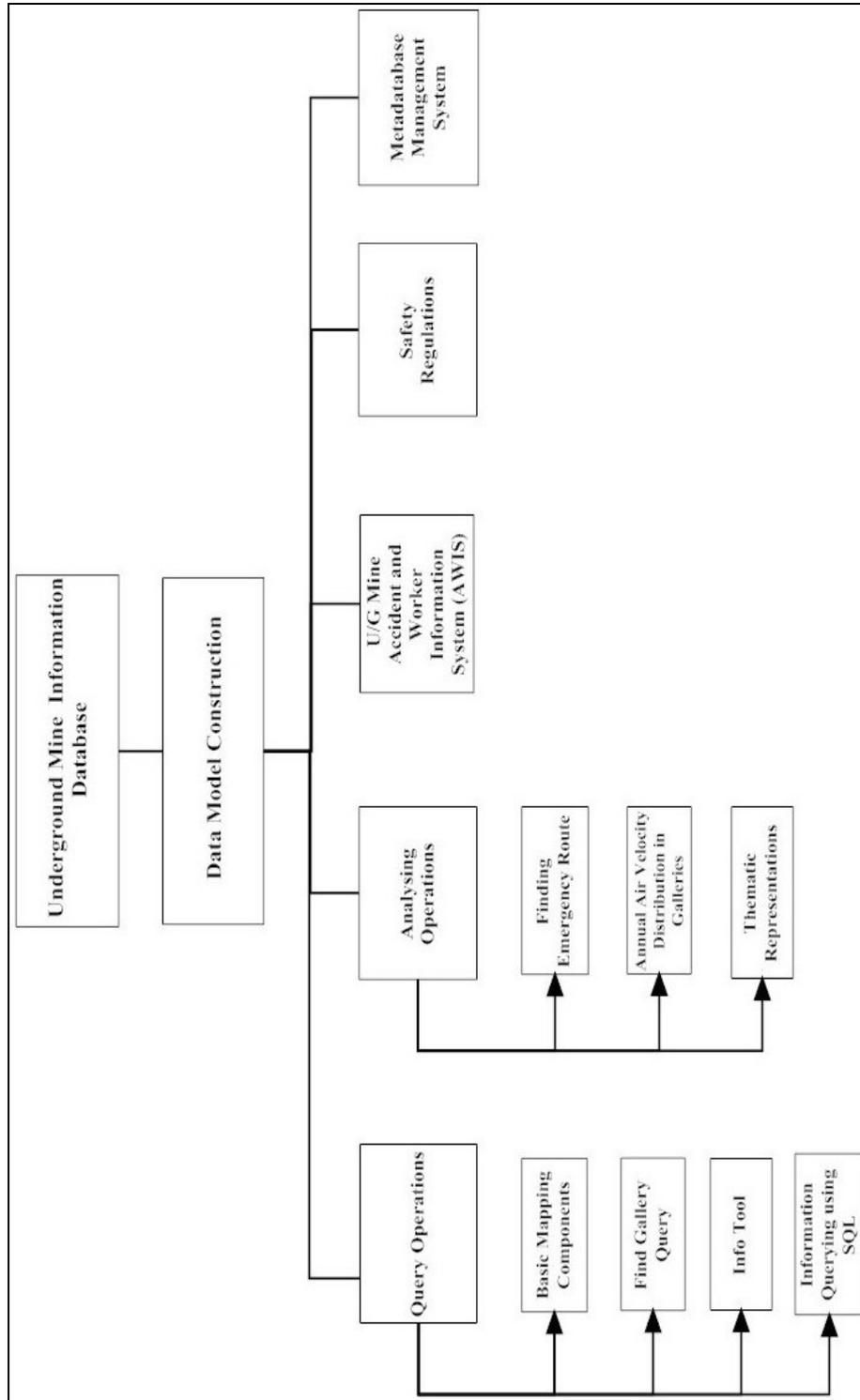
Figure 4.1 Research Framework of the Study

4.2 Database Design and Management for the GLİ Underground Mine

Database design and management for an organization has several stages to be accomplished. Before designing a database, at first, the strategy of the business should be decided and then the analysis of the problem and the related data should be examined thoroughly. As the stages of the database design are illustrated in Figure 4.2, after analysis of the model, design of the database can be managed. Finally management of the database system is ended by building the main frames of the system. When the database is gratifying, it holds promise to flexibility for re-sizing and modification. As a result, poor data element specification and database integration is noticed and eliminated.
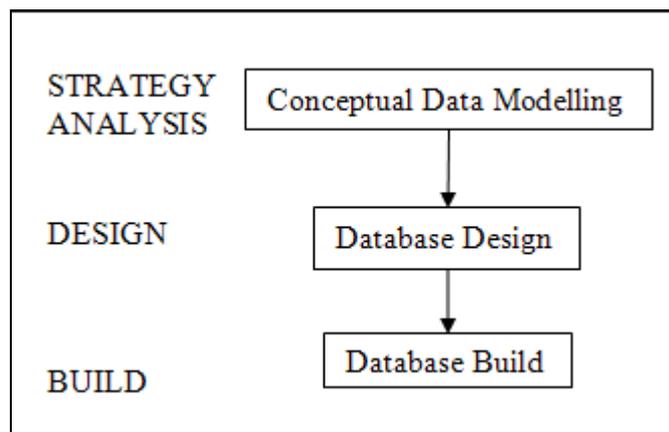
Figure 4.2 Phases of Database Design (Miller and Shaw, 2001)

Conceptual data model forms the body of the GIS. The model represents real-world situations as a mini-world representation. The data models are composed of three major components which are entity types, general integrity rules, and operators. Entity types are the basic building blocks for the database. In this study, every member of the mine environment is regarded as an entity. The second component is integrity rules which control the occurrences of entities in

the database. The final component of data model includes operators that can be applied to the entities in the database (Miller and Shaw, 2001).

Data modeling involves three different levels of abstraction: conceptual, logical and physical levels. Conceptual data models describe the organization of data at a high level of abstraction, without considering implementation aspects. The entity-relationship and the extended entity-relationship models are the most widely used conceptual data models. These models provide a series of concepts such as entities, relationships, attributes, capable of describing the data requirements of an application in a manner that is easy to understand and independent of the criteria for managing and organizing data on the system. A logical data model translates the conceptual model into a system-specific data scheme, while low-level physical data models provide the details of physical implementation (file organization and indexes) on a given logical data model (Fisher, 2004).

U/G mine database may have various members depending on the problem. Accidents, workers and all the related things happening in their working environment can be included in the mini-world. Each data table, which is basically the entities of the database, represents a layer in the GIS. The attributes which are connected with these entities are showed in the Figure 4.3. According schemas the primary keys and foreign keys are chosen as uniquely identifier attributes of tables and the relations between tables. There are also relational schemas for "*involve in*", "*result in*", "*works in*", and "*happen in*" relations. In these relational schemas, the primary keys of tables of the relations included as foreign keys.

Accident Entity Database Schema

Accident ID	Cause	Result	Date	Definition

Cause Entity Database Schema

Cause	Definition

Result Entity Database Schema

Result	Definition

Contacts Entity Database Schema

Contact SSN	Address	Phone	E-mail

Workers Entity Database Schema

SSN	Name	Surname	Job Describtion	Work Place	Age	Blood Type

Gallery Entity Database Schema

Gallery ID	Spherical Length	Cross Section	Air Velocity	Dust	Depth Of The Station	Fnode	Tnode	Air Pressure Drop

First Aid Entity Database Schema

First Aid Station ID	Place	Equipment No	Equipment

Fans Entity Database Schema

Fan ID	Name	Power	Operating voltage	Frequency	Air Circulation (RPM)	Location

Figure 4.3 Database Schemas

Accident table includes Accident ID, cause, result, date, and definition columns.

i.   Accident ID is the primary key for accidents table. Accidents are recorded based on a numerated system and each accident type has its own code. Accidents are classified into groups and sub-groups according to the type or cause of the case. Accidents occurred while carrying the material on

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haulage roads like traffic trucks accidents, electricity accidents, accidents resulted from machinery, accidents resulted from work machinery, accidents resulted from hand tools and other type of accidents are divided into groups and each main group has its own subgroups where the explanation about the accidents become more clear as in Table A.1 (see Appendix A).

ii.   Cause field contains the causes of accidents that occurred in the mine with the given Id as in Table A.2 (see Appendix A).

iii. Results of the accidents are kept in the database in this field therefore the accidents result can be examined through the program as in Table A.3 (see Appendix A).

iv.   Date gives information about when the accident occurred. Therefore some yearly based statistics and analysis can be hold promise.

v.   Definition attributes helps to clarify the accident type. Namely since the accident Id's composed of some numbers which define some specific cases and do not give wide information about how the accidents occurred, a broader definition of accidents should be kept in the database in accident table.

In cause and result tables related definitions are stored based on the Id numbers. These previously stated definitions can be seen in Appendix A.

Contacts table consists of Contact_SSN, Address, Phone and email columns.

i.   Contact_SSN is the primary key for the contacts table which directly relates the table with the workers table.

ii.   Address, phone and email fields contain related information of workers and they can be queried based on the SSN of the specified person.

Worker table includes Social Security Number (SSN), name, surname, job description, work place, age and blood type information in separate columns.

i. SSN is the primary key for the worker table. SSN field contains the Id's of workers which is established by the government and unique for each worker.

ii. Name, surname, job description, age fields contain the related information of the worker works in the mine.

iii. Work place field has the information of the gallery where the worker works. It is the foreign key for the galleries table which connects the table with worker table. It has the same values in gallery Id in galleries table.

iv. Blood type is another field kept for each worker. This field is useful for reaching the necessary information about worker in an emergency case.

Gallery table includes Gallery Id, spherical length, air velocity, cross-section, dust, depth of the station, fnode and tnode columns.

i. Gallery Id is primary key for galleries table. Each road segment has been kept with an Id in the database therefore places are defined by these Id's.

ii. Each rod segment's length in galleries layer has been calculated based on spherical method and kept in Length Spherical field.

iii. The air velocity amounts based on months that pass from the specified gallery are kept in air velocity fields. In order to calculate the pressure drop in the galleries this field information is compulsory.

iv. Another parameter which is important to calculate air pressure drop in galleries is gallery cross section. This information is kept in galleries table in Cross-Section field in the database.

v. Dust data (based on mg/m^3) which is measured in the defined gallery is kept in Dust this field.

vi. Depth of the station is kept to show the elevation of the specified gallery.

vii. Fnode and tnode fields contain the network information which is necessary for the emergency route analysis. They represents from which node to which the gallery extends.

viii. Air pressure drop field contains air pressure drop values calculated based on air velocity, cross-sectional area, perimeter, and length of the gallery.

First aid station table is consists of first aid station Id, place, equipment no and equipment columns.

i. First Aid Station Id contains the Id's of first aid stations. It is the primary key for first aid stations table.

ii. Place is the foreign key of first aid station table and it has the gallery Id's of first aid stations. It has the same values in gallery Id in galleries table.

iii. Equipment No field has the information how many equipment exist in the defined first aid station.

iv. Equipment field has the information which equipments exist in the defined first aid station.

Fan table contains fan Id, name, power, operating voltage, frequency, air circulation (rpm), and location columns.

i. Fan Id contains the ids of fans in underground. It is the primary key for fan table.

ii. Power, operating voltage, frequency of the fan and circulation rounds per minute values are specific values which is important for fan efficiency and mine ventilation calculations. All of them are kept in the database in the related fields.

iii. Location is the foreign key of fan table and it has the gallery Id's of fans. It has the same values in gallery Id in galleries table.

4.2.1 Relational Data Model

A relational database model includes relationships between elements of the systems and their attributes. Therefore, the relationships between entities should be clarified before construction of the entity-relationship diagram. Analyzing the

relationships between entities in an entity-relation diagram is followed by the creation of the database schema model. Attributes that describes the entities should be examined and primary keys for the tables should be chosen. In a database management system every table has its primary key which uniquely identifies each row in the table. The primary keys for the tables used in this study are stated in database design section and all these primary keys are unique for that entry. It can be composite of multiple or only one column. The primary keys defined for this study are all one column keys. Moreover, null values cannot be assigned as primary key. A foreign key refers to a primary key in the same or another table. It should match an existing primary key. These foreign keys are important in order to establish a relation between two tables in case like a field that has been defined the same in both tables.

Relational database models have some advantages over other database models like hieratical or network model. It can be modifiable easily, namely new rows and tables can be added the database afterwards. It has the advantage of fast processing and flexibility. However it needs to be designed carefully and thoroughly because badly designed models can lead inefficient solutions. Therefore data analysis must be done clearly before the model construction.

The foreign key identifies a column or a set of columns in one (referencing) table that refers to a column or set of columns in another (referenced) table. The columns in the referencing table must be the primary key or other candidate key in the referenced table.

4.2.2 Normalization of the Database

Relational database model selection is followed by the normalization of the data tables. After deciding the relations and keys, the data should be normalized. Normalization is a process that improves a database design by generating relations that are of higher normal forms. Therefore it is a necessity for databases to

i. Separate data into meaningful groupings making it easy to maintain, update, modify and protect,

ii. Provides rules for organizing data into tables that relate to each other by common keys,

iii. Requires thorough knowledge of the data in its relationships,

iv. Assign each feature (point, line, or polygon) a unique code,

v. Allows a link to the tabular business data stored in relational database management systems.

Subsequent to consideration of these parameters, functional dependencies in which every dependency on the key are observed to create relations (Figure 4.4).
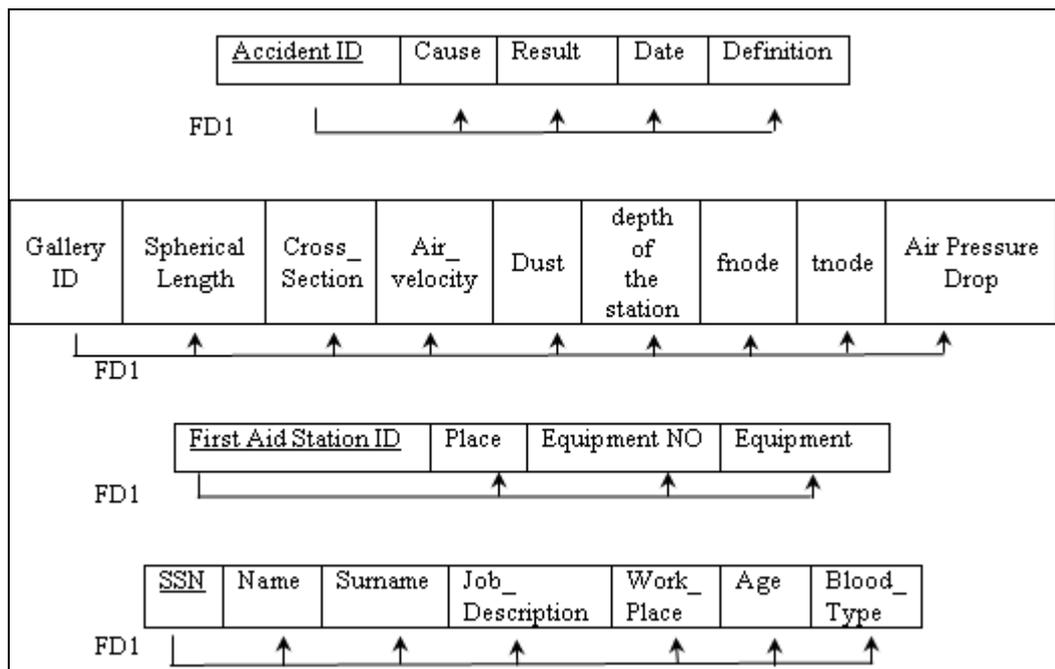
Figure 4.4 Functional Dependencies of Tables

According to first normal form, all attributes must be single valued. For our data set, this constraint is held and the attributes chosen as atomic. For the second

normal form, an attribute must be dependent on its entities entire unique identifier. Namely, full functional dependency is necessary to hold promise the 2nd NF. All attributes in an entity must depend on the whole primary key. The best advantage of normalization is that it disables the redundant values in tuples and anomalies in insertion, deletion, or modification in the relations.

The constraints between tables can be examined as:

Workers& Accident Relation: Accident table is connected with workers table by worker Id key. A worker can be involved in many accidents. (Many accidents can happen to that worker). An accident can be joined by many workers as well. (An explosion can happen and may affect many workers). Therefore the relation between workers and accident is M to N.

Cause-Accidents & Result – Accidents Relation: Every accident has a cause and a consequence. However, there can be many accidents caused or resulted by the same cause and result. Therefore the relation between cause and result table with the accident table is 1 to ∞.

Accident & Galleries Relation: Accident table is relational with galleries table gallery Id attribute. An accident can happen in a gallery also the same accident can happen in another gallery as well. Many accidents can be happened in many galleries as well). Therefore the relation between accidents and galleries is M to N.

Workers & Galleries Relation: Workers table is connected to galleries table on gallery Id namely place of the worker works. One or many workers can work on a gallery or many galleries can be work places for worker. Accordingly the relation between workers and galleries are M to N.

Workers & Contacts Relation: Every worker has only one contact information such as unique address and phone number and this table is tied with SSN key that the wanted contact information can be reach by this information. The relation between workers and their contact information is 1 to 1.

Galleries & First Aid Stations Relation: Galleries table is tied to first aid stations table with gallery Id attribute. One first aid station can exist in only one gallery, however, one gallery can contain first aid stations more than one. Consequently the relation between galleries and first aid stations is 1 to N.

Galleries & Fans Relation: Galleries table is tied to fan table with gallery Id attribute. One fan can exist in only one gallery however one gallery can contain fans more than one. Consequently the relation between galleries and first aid stations is 1 to N.

The dependencies in result and cause tables with accident are represented with double line. That means total participation of accidents in cause and result table. Explicitly, every accident must have a cause and result. The same situation is valid for worker- contacts relation. The relation symbol also has double line which represents identifying relation. Moreover, since the relation between accidents and workers are M to N, the primary keys of these tables are added as a foreign key in e-r mapping. These are valid for each M to N relationship in the database; the foreign keys are kept in the relation tables. According to these relations an entity-relationship diagram can be drawn as illustrated in Figure 4.5.
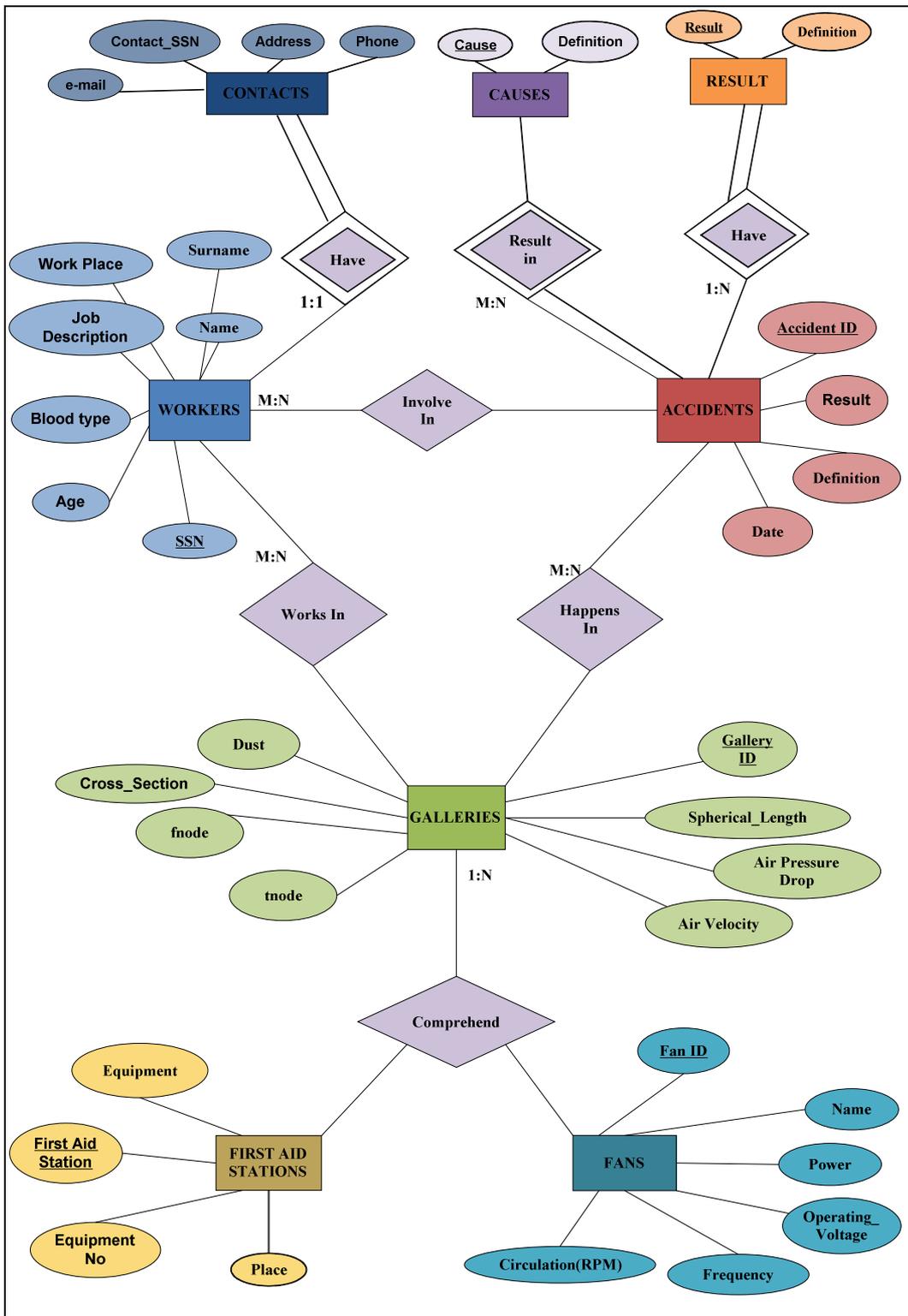
Figure 4.5 Entity Relationship Diagram

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4.3 System Development and Components used in Web-GIS

System development begins with selecting appropriate hardware and software. In this study hardware and software are selected as in Table 4.1.

Table 4.1 System Components

HARDWARE	SOFTWARE
Genuine Intel® CPU (1.60 GHz) 1 GB RAM Realtek RTL8169/8110 Family Gigabit Ethernet NIC VIA Chrome9 HC IGP	Windows XP Professional : Operating System Internet Information Services (5.1): Web Server MapXtreme 2005 6.6: Application (Map) Server Microsoft Visual Studio. Net 2005: Web Development Microsoft Access: Relational Database Development for Data Input MapInfo Professional 9.0: Data Preparation and Evaluation in GIS

As indicated in Plewe's book (1997), the technologies being developed to make Web-GIS applications possible include, servers (which store data and applications), clients (which use the data and applications), and network communications (which control the flow of information between servers and clients) (Figure 4.6). On the server (dissemination) side of the equation, issues include such things as the speed of query and transfer, the possibility of including full GIS functionality or just basic mapping, and the efficient storage of and access to large quantities of geographic information. On the retrieval side, issues include effective user access to and location of desired information, as well as means of viewing and analyzing the information, often with GIS software unfamiliar to the user. Web-GIS applications are related with servers (which store data and applications), clients (which use the data and applications), and network

communications (which control the flow of information between servers and clients) (Figure 4.7).
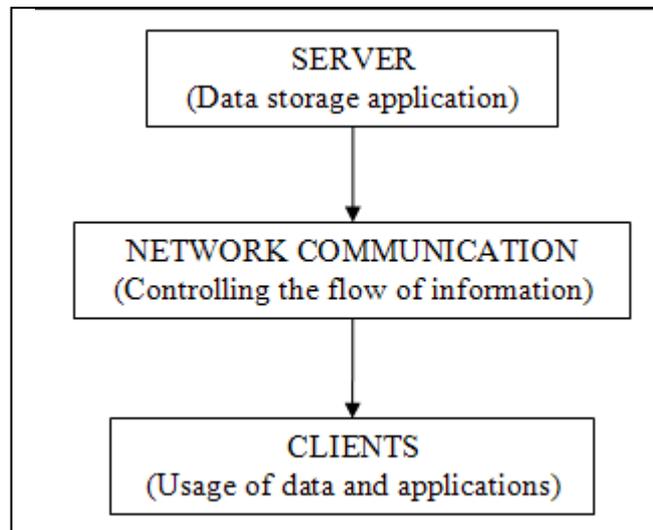
Figure 4.6 Server Client Bridge
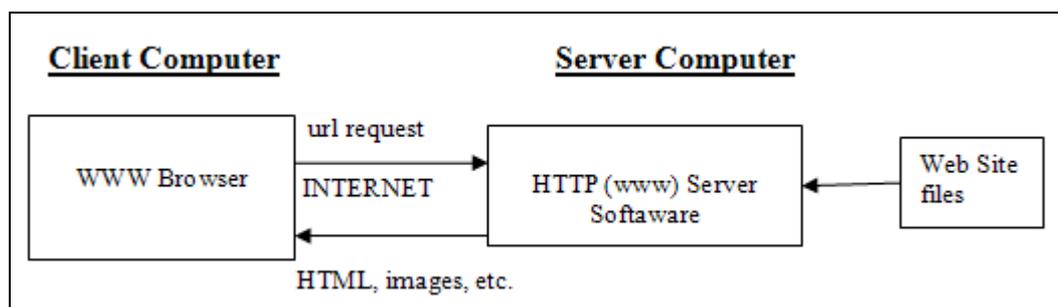
Figure 4.7 Client-Server Relation (Plewe, 1997).

In this study, server side Web-GIS program is MapXtreme ® 2005 as application (map) server and Microsoft ® Internet Services (IIS) as web server together performing online mapping functions. While server looks at the issue by serving

the data and application as good as possible (like considering querying and transferring speed and efficiency in storage and accessibility of large quantities), client part tries to manage the data in most accurate way, and as most possibly large quantities of data with full GIS functionality.

When someone makes a request for a map or other GIS product, the request message is sent over the Internet to the Web server. The server recognizes it as a Web-GIS request, and passes it to the Web-GIS program, which translates it into some type of internal code (e.g., queries or map drawing commands). This is passed to the GIS software, which processes the request, usually using custom scripts (programs interpreted by GIS software).
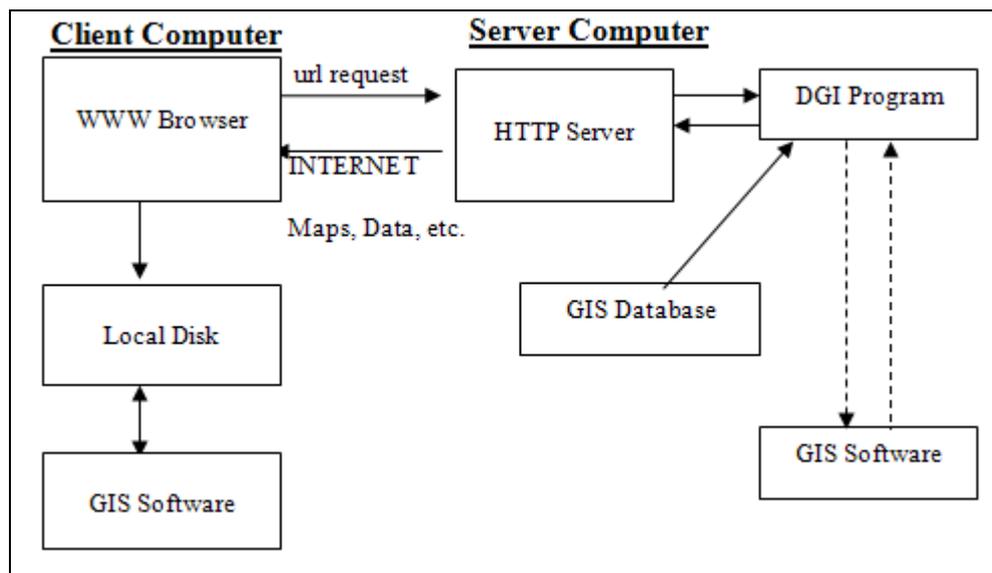
Figure 4.8 Web GIS Client Server Relation (Plewe, 1997).

MapXtreme is a vendor product of MapInfo Professional which contains object model for client/server and Web applications. By the help of MapXtreme, an application written for the desktop can be adjusted for subsequent web development with making minimal code changes. This product has core

components working incorporated in Microsoft visual .Net platform. By the help of this development, successful and powerful query operations can be run and some customizations on the web application are become valid.

The MapXtreme is made up of many namespaces. A .NET namespace is a type classification system that differentiates specific classes, methods, and properties from others with the same name (Figure 4.9). The used namespaces in the application are MapInfo.Engine, MapInfo.WebControls, MapInfo.Mapping, MapInfo.Geometry, MapInfo.Data.

i. The MapInfo.Engine namespace contains all classes directly related to the core functionality that drives all applications based on MapXtreme 2005. This includes the core session class which is the starting point for all MapXtreme 2005 applications.

ii. The MapInfo.WebControls namespace provides support for using Visual Studio .NET templates for a MapXtreme ASP.NET application. There are MapControl and LayerControl design-time enhancements available from this namespace, as well as web tools.

iii. The MapInfo.Mapping namespace contains classes, interfaces, and enumerations for creating, displaying, and exporting maps, layers, modifiers, and labels.

iv. The MapInfo.Geometry namespace is an extensible hierarchy based on OGC (Open GIS Consortium) standards, coordinate system interoperability, and object processing. The MapInfo.Geometry namespace contains classes, interfaces, and enumerations for creating and editing Geometry objects.

v. The MapInfo.Data namespace contains the classes and interfaces that implement the MapInfo Data Provider. The object model has several different classes to access data. Depending on the format in which your data is stored, there are specific classes to use to access it. Additionally, ADO.Net is implemented to access to any data that is contained in formats not covered by any other class (MapXtreme Developers Guide, 2005).
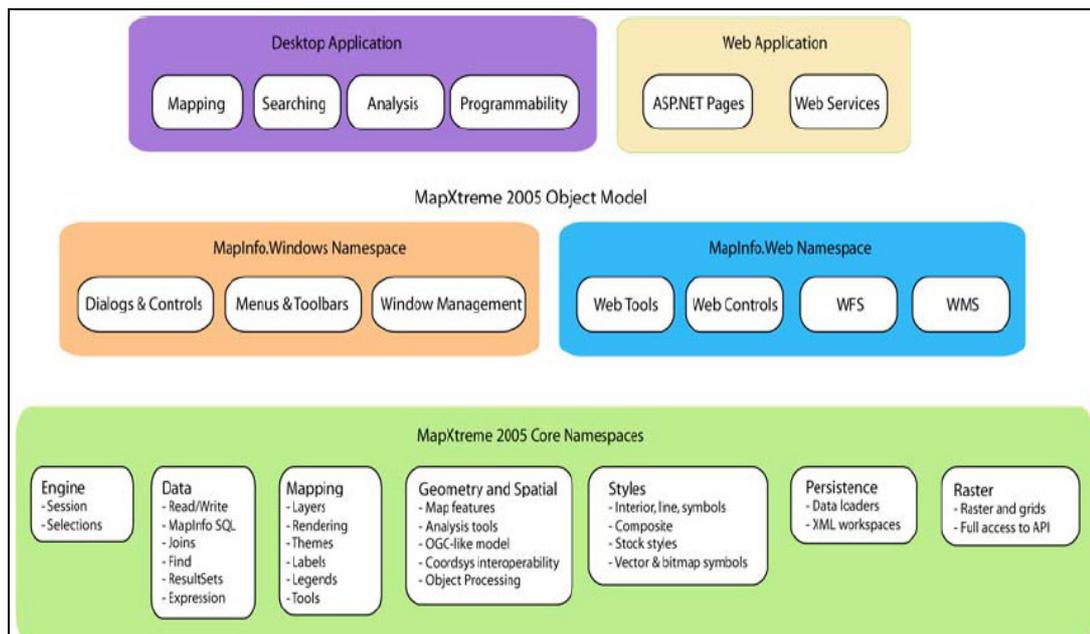
Figure 4.9 MapXtreme Namespaces (MapXtreme Developers Guide, 2005)

The study uses MapInfo web controls in .Net environment. The solution is created by Visual Studio. It includes MapXtreme Web User Interfaces controls as well as Global ASP.Net session protocols and Web Config references. While the necessary web application has being created, some necessary files are generated by default in the Web root folder. Some of these are system runtime and others are design time components.

4.4 Query Operations

The query operations can be run by the program is based on Structured Query Language (SQL). This language is a database computer language designed for the retrieval and management of data in RDBMS, database schema creation and modification, and database object access control management. Basically, user asks from program to perform some task according to the user's specifications. These queries in this study can be grouped into four parts, such as basic mapping

operations, find operation, info tool and information operation with using SQL statement.

4.4.1 Basic Mapping Components

A map displays the spatial relationship among map features therefore the details on the maps gain the most of the attention. The visibility of a map is the first thing that catches the eyes of the user. Moreover, the map visually orients user to where those features are and what they represent. Thus, basic map controls are the foremost tool to be considered. Basic mapping operations conducted in this study are operations related with navigation of the GIS map. Since the system is map based, the navigation on the map becomes a necessity. Therefore centering the map to its original position, zooming, and panning operations were added to the web page to make the map usage flexible. The basic mapping tools and their utilization are explained in the Table 4.2.

Table 4.2 Navigation Tool Definitions

Zoom In	The Zoom In button gets the user a closer area view of your map. After pressing the zoom in button, whenever the user clicks on the map, map redraws a closer area of view, centering itself at the point of click.
Zoom Out	The Zoom Out button gets the user a wider area view of your map. After pressing the zoom in button, whenever the user clicks on the map, map redraws at a wider area view, centering itself at the point of click.

Table 4.2 Navigation Tool Definitions (cont'd)

Pan	The Pan button helps to reposition your map without changing the zoom level. If you want to see another part of the map (upper or lower part that you are staring) while holding down the mouse button, one can drag the map to the desired position.
Center	The Center button centers the map point when you click on the map after you selecting the button.
Select1	Select button is used to select objects one at a time or to select all objects that are generally in the same area. In this application, First select tool is used to get the gallery id and it uses this information to find the related air velocity information of that gallery. Second select tool is used to select the starting node of the gallery which is used to find the shortest path to the exit, in the network analysis.

4.4.2 Find Gallery Query

The system formed for the study can also be used for finding the galleries on the map according to their gallery Id number. When the gallery Id is chosen from the dropdown list (Figure 4.10), the SQL statement written in the code matches that Id with the corresponding object in the map and zoom that gallery. The program also puts a symbol on the chosen gallery to specify it from the surrounding galleries as shown in Figure 4.11.

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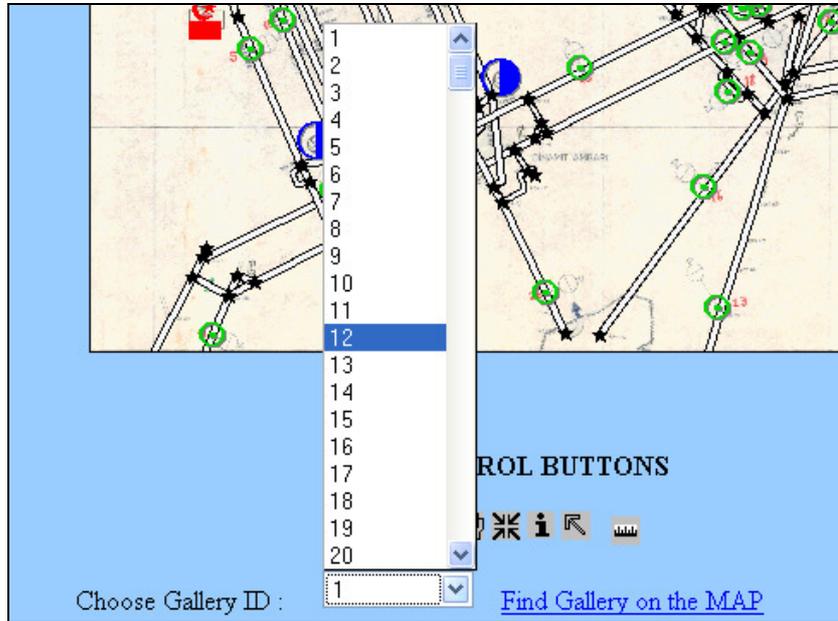
Figure 4.10 Finding Gallery Screen

Figure 4.11 Found Gallery Image

4.4.3 Info Tool

Monitoring the mine environment is crucial for surveillance of mine safety. The gas and dust contamination, temperature, noise and humidity are some of the parameters that can be monitored from the mine environment. Since the monitoring operation is limited to the available information obtained from underground, the data acquisition is the backbone of the information tool. The data in the database files are the sources of information used for the GIS map.

Info tool is used to show any information kept in the tab files. It achieves this by using previously opened layers in workspace. When the user chooses an object from a layer, it first gets the layer information of the object and then it retrieves the all the columns of the table that object intersect. The info table of the clicked object is displayed by sending the request using JavaScript to server without needing to refresh the whole page. Figure 4.12 shows a sample information table including technical specifications associated with the selected fan.

Selected Feature Info:

Layer Name	fans
fan_id	7
Name	Korfmann
power_kw	110
operating_voltage_volt	1100
frequency_hz	50
Circulation_round_per_minute	1485
location	Sector C

Figure 4.12 Info Tool Table for Fan 7

4.4.4 Information Querying using SQL

MIConnection is a connection which is established to the catalog that exists inside MapXtreme. By the help of MIConnection issuing commands and obtaining results is enabled. This is provided by using alias tables which are not available at the initial state session. Therefore at the initializing state, tables need to be opened or created before they can be accessed. When opened, alias can be associated with the table and used to resolve identifiers in the query engine.

The query operation is enabled after the connection is established. The query command is composed of a SQL statement. The program enables user to make selections from tables stored in the server. These selections are done by SQL statement written by the user. Therefore, the selection parameters depend on user needs, and they should be in the form of "*select* [COLUMN_NAME] *from* [TABLE_NAME]" clause. Figure 4.13 represents the query operation conducted by the statement "select * from workers_" example. In the example, all the worker information namely all the columns in the table selected by using "*" sign from table "workers_". After the statement written in the textbox and clicking on the apply button program executes the query and gets the result on the web page.

Figure 4.13 Query Result Screen

4.5 Analyzing Operations

GIS provides analysis abilities for safety concept in underground mines besides its query operations. Some basic maintenance and monitoring operations can be checked with the help of queries. However, some changes in the working environment should be analyzed and consequences of the situations should be drawn or interpreted based on these analyses. Location is one of the base parameters for GIS and it is beneficial for mapping, measuring distances, and trying different kinds of information together because they refer to the same place. GIS serves to perform analyses on spatial references. Spatial information helps to visualize the situation more easily. Therefore, in this study spatial analysis components were added to the program which can be useful to help the health and safety surveillance in U/G mines. These spatial analyses are explained in detailed through sections 4.5.1 and 4.5.3.

4.5.1 Finding Emergency Route

Taking precautions and monitoring the mine unfortunately does not always provide solutions for mine accidents. They can prevent mine accidents but may not totally eliminate all possibilities. Therefore, when accidents occur, the rescue operation should be planned and managed immediately to minimize the loss.

Since the underground galleries are look like labyrinths, it would be very hard to find the exits without any previous information especially in emergency cases. Some exits or some galleries can be collapsed or the dangerous situations can expand through underground areas. In those situations, best possible route optimization should be done.

The approach adopted almost universally is to represent a road network by a set of nodes and a set of links. The nodes represent points in space and the links tend to correspond to identifiable pieces of transport infrastructure. In this study links, are represented by the length of road segments. The network data model is the

most widely used conceptual model to represent a network within a GIS environment. The planar embedding of the node-arc data model guarantees topological consistency of the network. This model is established for the gallery network in this study of which data type is vector or poly line.

A logical spatial data model (the vector data model) that encodes nodes and arcs maintains the geometry and associated topological information, while the associated attribute information is held in relational database management (RDBMS) tables. Unique identifiers associated with each spatial entity (node, arc) provide links to records in the relational model and its data on the entity's attributes. This hybrid data management strategy was developed to take advantage of a relational database management system to store and manipulate attribute information (Longley *et al.*, 2001).

To establish the route optimization using the optimum route, first network model should be established in MapInfo tab files. A MapBasic code segment is used for this purpose to form a network model for each gallery road segment. After running this code, each gallery on the map gets an Id, starting and ending node numbers. In this network formation, the constraint parameter is chosen as gallery length. In emergency situations when there can be problematic case scenarios, the air velocity of the gallery, the oxygen amount of the sections can be added as impedance to the algorithm. The impedance selection optimizes the safest route for the desired location. While forming the network of the galleries in this study, the road conditions were added to the system. For example, if the road cannot be used or it is used as one-way it should be specified while preparing the network. Afterward, by means of defined nodes, an algorithm which is embedded in a dynamic link library (DLL) is used to find the shortest path between chosen two nodes. The algorithm is based on Dijkstra's shortest path algorithm and it stores the starting and ending nodes in buckets and tries the optimum possible solution.

Dijkstra's algorithm, conceived by Dutch computer scientist Edsger Dijkstra in 1959, is a graph search algorithm that solves the single-source shortest path problem for a graph with non negative edge path costs, outputting a shortest path tree. For a given source node in the graph, the algorithm finds the path with lowest value (i.e. the shortest path) between that node and every other node. It can also be used for finding costs of shortest paths from a single vertex to a single destination vertex by stopping the algorithm once the shortest path to the destination vertex has been determined (Cormen *et al*, 2001). According to the known Dijkstra's algorithm, a validation of the used algorithm in the program was made. For that reason, a small portion of the network is chosen and that sample network's segments are considered for the route selection (Figure 4.14).
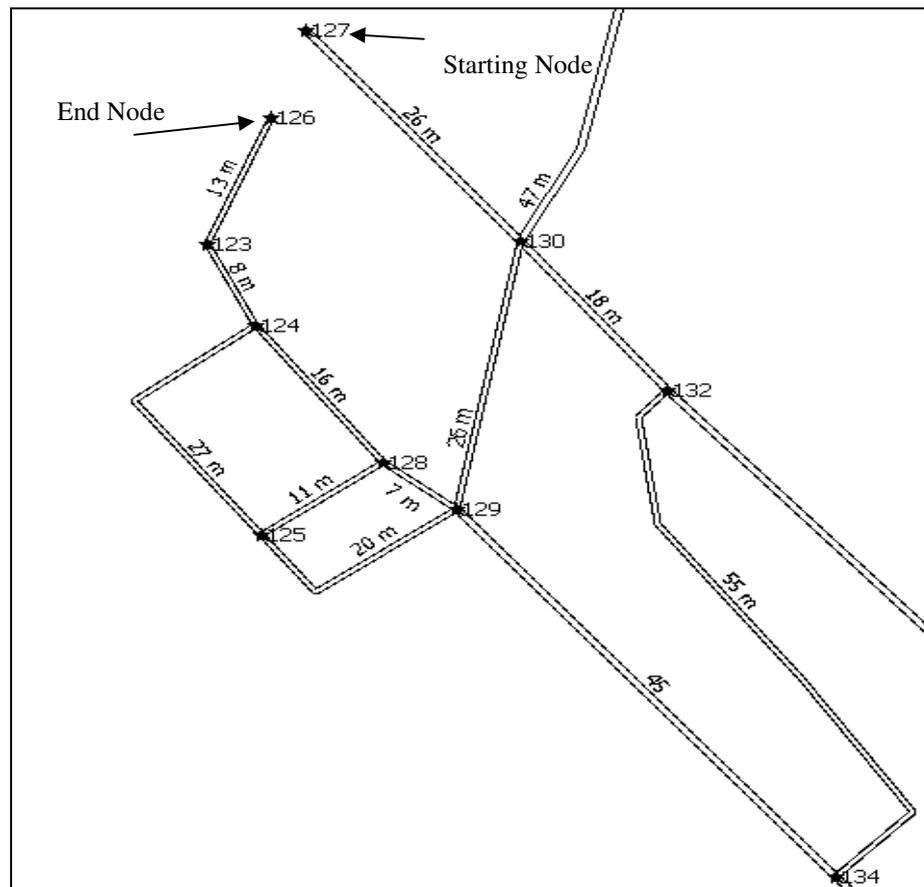
Figure 4.14 Shortest Path Example Area

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For the application algorithm, first distances of all road segments, from and to node information should be noted (Table 4.3). The starting node should be determined as the second step. In the application, this option is left to the user. User chooses the starting gallery with selection button, where the possible accident occurred. Then again user defines the exit node where he/she want to direct the victims. In this sample case, node 127 was chosen as the starting point and node 126 was chosen as the exit. From all the gallery intersections of the already marked routes, aim is to find the closest unmarked intersection closest to the starting point. It's the whole marked route to the intersection, plus the gallery to the new, unmarked intersection. Then marking that gallery to that intersection and drawing an arrow with the direction should be performed. This procedure should be repeated till the destination was reached (Table 4.3).

Table 4.3 Starting and End Nodes of the Galleries in the Sample Network

From	To	Distance of the road (m)
127	130	26
130	132	18
130	129	26
132	134	55
134	129	45
129	125	20
129	128	7
125	124	27
125	128	11
128	124	16
124	123	8
123	126	13
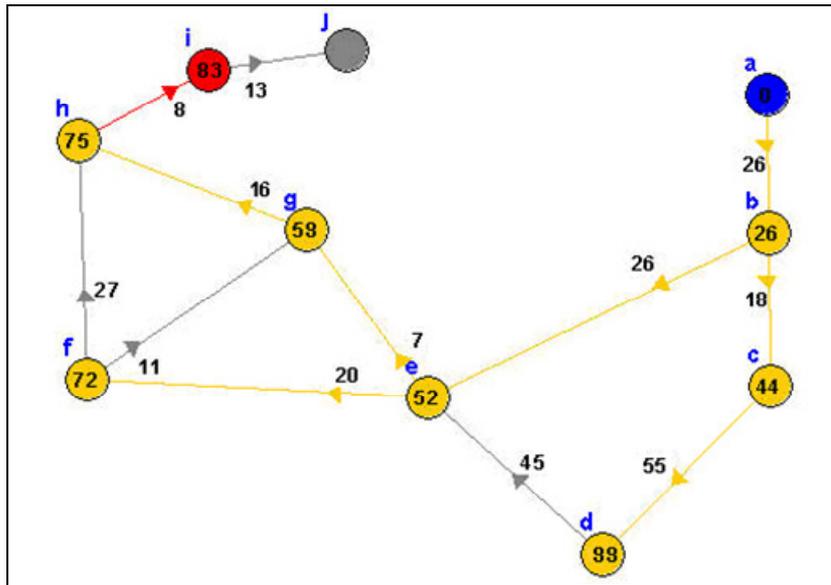
Figure 4.15 Solved Path for the Sample Area

The validation result was the same with the program output. Program highlights the shortest path with red color after running the algorithm (Figure 4.16). Furthermore the program calculates and writes the path distance to the textbox after calculating it.
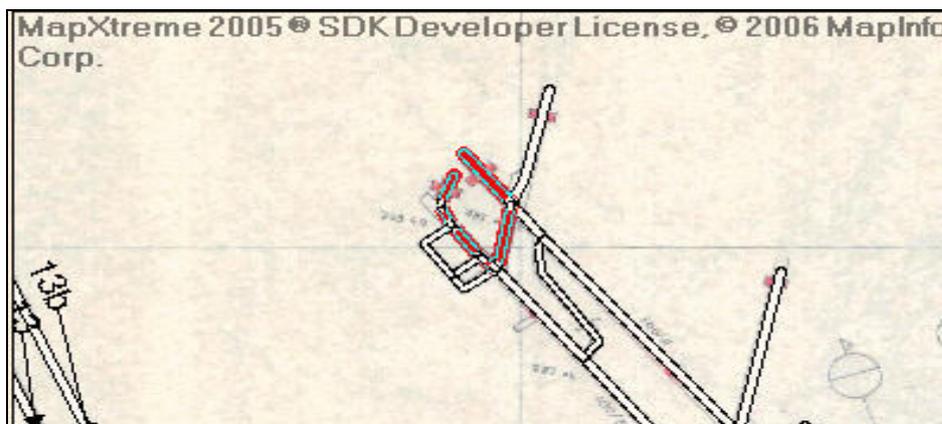
Figure 4.16 Shortest Path Web Representation

4.5.2 Annual Air Velocity Distribution in Galleries

Ventilation in U/G mines is another parameter for health and safety maintenance. Since the fan operating cost is one of the most expensive parameters in feasibility studies in mines, fans should be chosen to supply optimum air in the minimum cost. Besides observing fan characteristics, the air velocity changes should also be also monitored to identify critical locations underground. Therefore, monthly air velocity data of air velocity in galleries can be valuable during the life of the mine.

Air velocity values taken form GLİ was kept in the database in galleries table. Therefore, each of them has spatial information since they were related to the galleries. Whenever a gallery is selected with the select button, related information of that object is chosen from the gallery. This information is the gallery's monthly air velocities in the selection case. The velocity values are drawn against to months as X-Y graph. ZedGraph extension is used for to visualize the graphics. In Figure 4.17 example of a Air Velocity-Months graph is shown for Gallery with Id number 130.

This procedure can be extended and same graphical representation can be valid for other toxic gases. Then, the maximum allowable concentrate value can be added as a second equation and the observer can see the amount of the gas which goes beyond the threshold value.
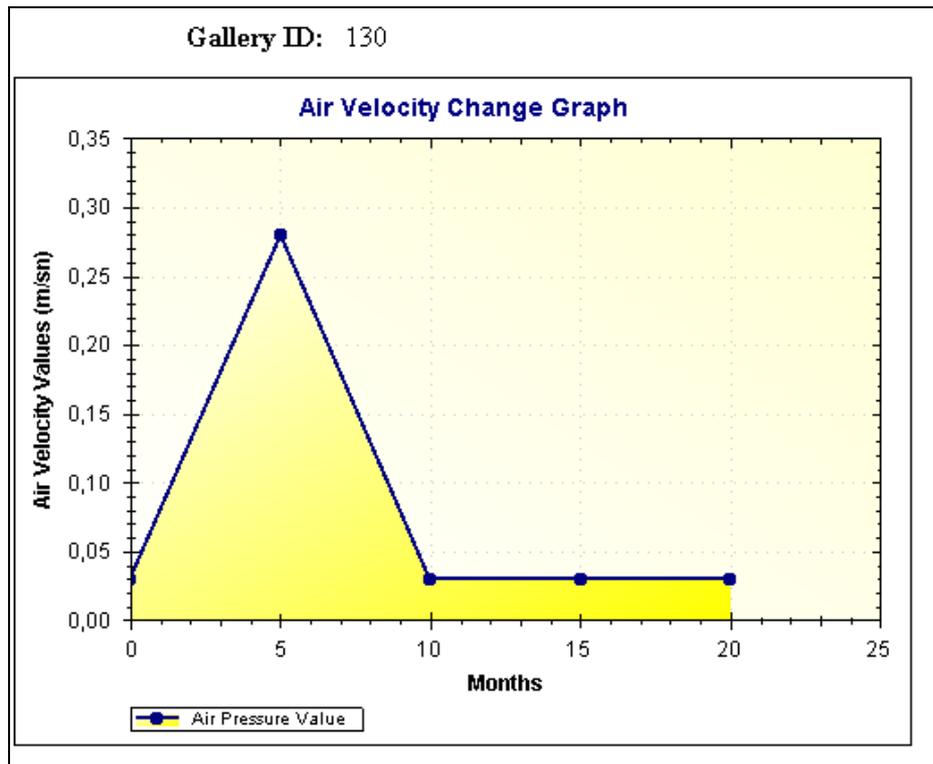
Figure 4.17 Graphical Representation of the Air Velocity Values

4.5.3 Thematic Representations

Thematic map is a type of map that uses a variety of graphic styles (for example, colors or fill patterns) to graphically display information about the map's underlying data. In contrast to reference maps which show many geographic features, thematic maps emphasize spatial variation of one or a small number of geographic distributions. Thus, a thematic map of dust concentrates for example might show one region in deep red (to indicate the region has a large number of concentrates), while showing another region in very pale red (to indicate the region has relatively few concentrates). Thematic map creation should begin with choosing right variable which serves best to the user's need. Therefore, prior to creating a thematic map, the elements that make up a thematic map and combination to form the map should be known. Thematic maps are varied

according to the type of set which is chosen to group the selected data. The data which is displayed on the thematic map is called thematic variable. Depending on the type of thematic analysis, one or more thematic variables can be shown. Ranges of values, grid shading, graduated symbols, dot density, and individual values maps examine one variable. With bar or pie charts, more than one thematic variable can be displayed at a time. The specifications of the different thematic map kinds are explained in Table 4.4.

In this study, thematic application is added to the system as a desktop application and the tab files which are stored in the server computer can be used for thematic mapping. All the thematic map types are valid for the application and the parameters can be chosen by the user. The program uses MapInfo to make the necessary analysis therefore the system should have the software installed. After installing the thematic application by downloading from the hyperlink in the main form, the user should choose the file which is desired to be mapped thematically. After opening tab file (program has gallery tab file existing in the set up), the theme can be added from the theme menu (Figure 4.18).

Table 4.4 Thematic Map Types Explanations

TYPE	DEFINITION
Pie Chart Map	A type of thematic map that displays a pie chart of thematic variables for each record in the table from which the map is based.
Bar Chart Map	A type of thematic map that displays a bar chart of thematic variables for each record in a table from which the map is based.
Ranged Map	A type of thematic map that displays data according to ranges set by the user. The ranges are shaded using colors or patterns.
Dot Density Map	A type of thematic map that carries information by showing a large number of tiny dots, where in each dot represents some specific unit quantity. For example, for a population dot density map each dot might represent 10,000 people.
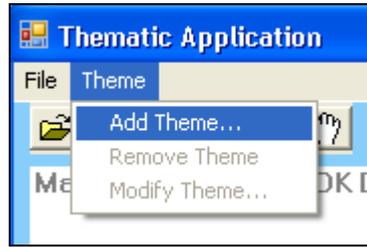
Figure 4.18 Thematic Opening Screen

The thematic map can be formed with three steps with the program. First step is to choose the theme type (Figure 4.19).
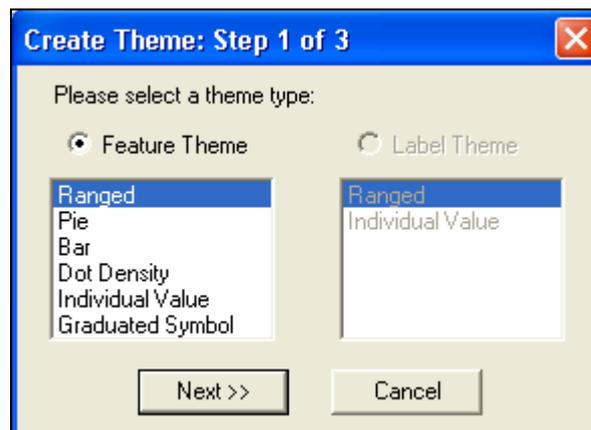
Figure 4.19 Theme Selection

Depending on the type one or more variable is chosen as the second step (Figure 4.20). A thematic variable can also be an expression. The expression selection enables to construct a statement that derives information from the data in the opened table.

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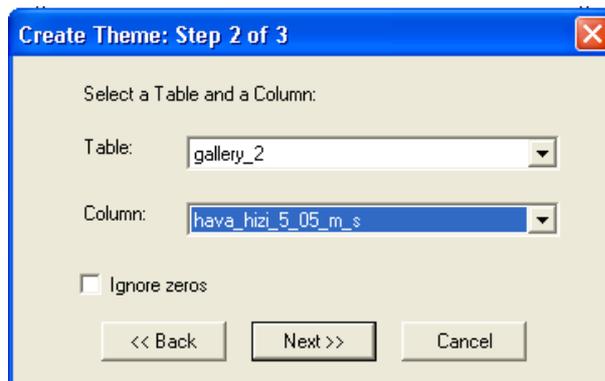
Figure 4.20 Theme Selection Screen (2)

Last step is to choose parameter that differs from method to method. User can change the parameters according to the desired end map (Figure 4.21). Finally, whenever the apply button is clicked, the thematic map is created according to the previously chosen parameters.
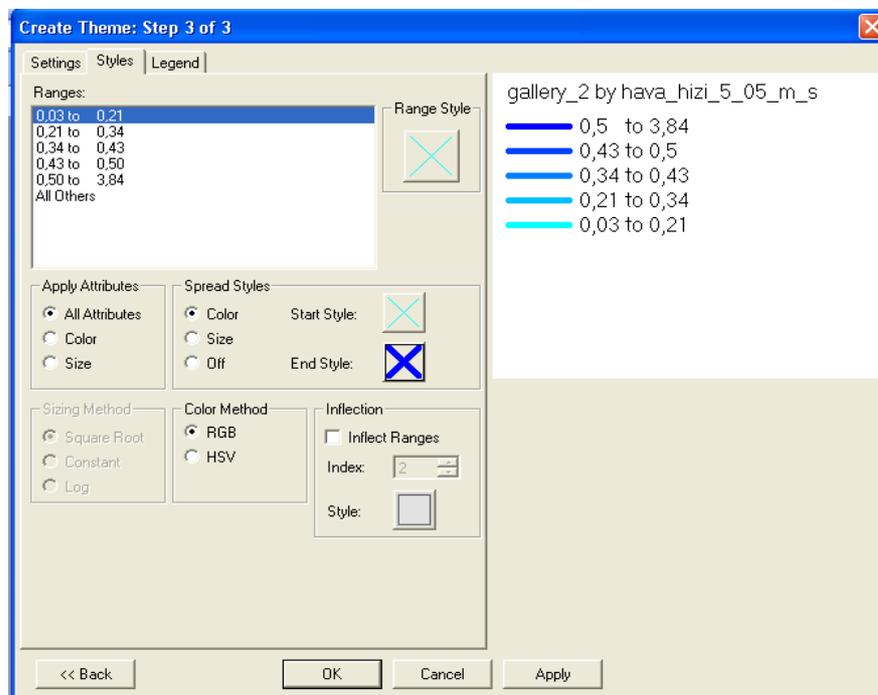
Figure 4.21 Theme Selection Screen (3)
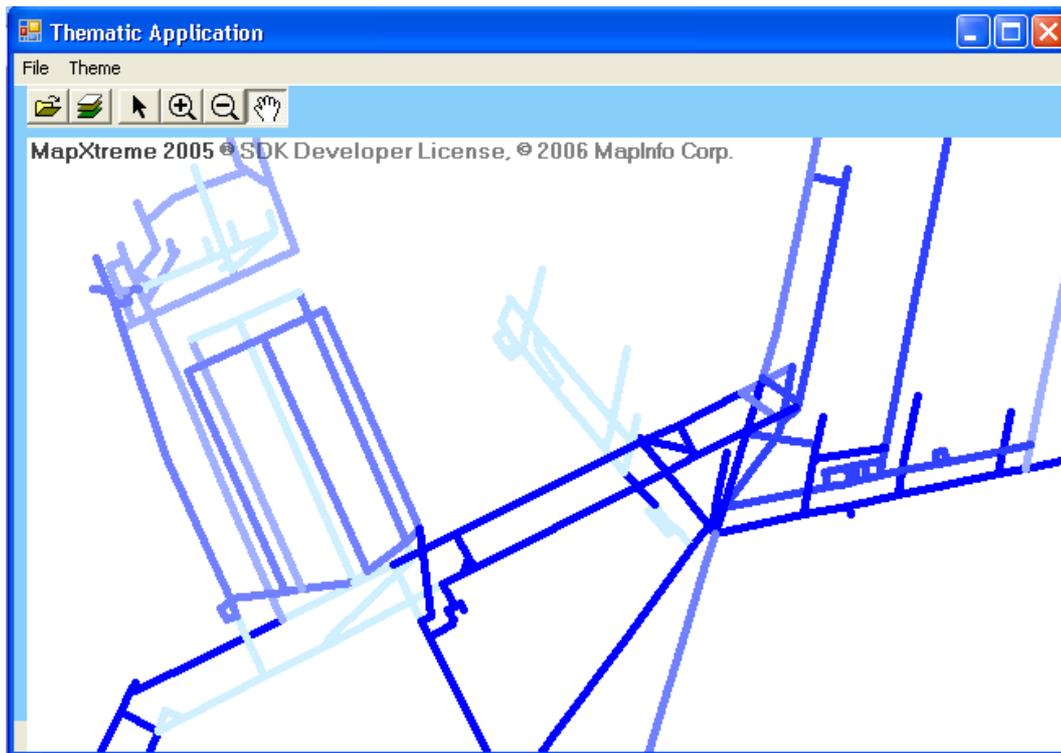
Figure 4.22 Formed Thematic Map

Thematic maps are sometimes referred to as graphic essays that depict spatial variations and interrelationships of geographical distributions. Location is as well important to provide a reference base of where selected phenomena are occurring. In Figure 4.22, the dark blue represents the galleries where the air velocity is high. The color scale represents the change in the air velocity.

Thematic maps serve three primary purposes. First, they provide specific information about particular locations. Second, they provide general information about spatial patterns. Third, they can be used to compare patterns on two or more maps. When designing a thematic map, users must balance a number of factors in order to effectively represent the data. Besides spatial accuracy, and aesthetics, quirks of human visual perception and the presentation format must be taken into account (Mitchell, 1999).

4.6 U/G Mine Accident and Worker Information System (AWIS)

When the U/G mine safety and health are concerned, accidents that happen in U/G cannot be eliminated. The relation between working places and accidents should be examined carefully to observe the possible accident locations. Besides, a relational database system prepared for this purpose can serve as an emergency checkpoint by providing the workers contact information.

Accident and worker information system (AWIS) is composed of data elements. These elements were stored in tab files while creating layer. Yet to use the relations between tab files and other database files which are prepared in Microsoft Excel, the tab files should be exported to Microsoft Access. These tables can be gathered in one database file with the predefined names which are used in MapInfo.

Mine accident and worker information system application is prepared to control and observe data gathered from the enterprise. Information about workers and accidents kept in database files and can be seen and analyzed by the application. Workers, accidents, contacts, causes and results can be examined in different tabs at the first form. Each tab has specific values related with the title. Adding, deletion and updating operations are valid for each tab (Figure 4.23). Moreover, the relation between workers and accidents can be seen with the help of "See Accident Involved" button. In this case, if a worker has involved in more than one accident, all the accidents will be listed in a data grid. Same button is valid for accidents tab, where each worker who has involved the specific accident can be seen within a data grid.
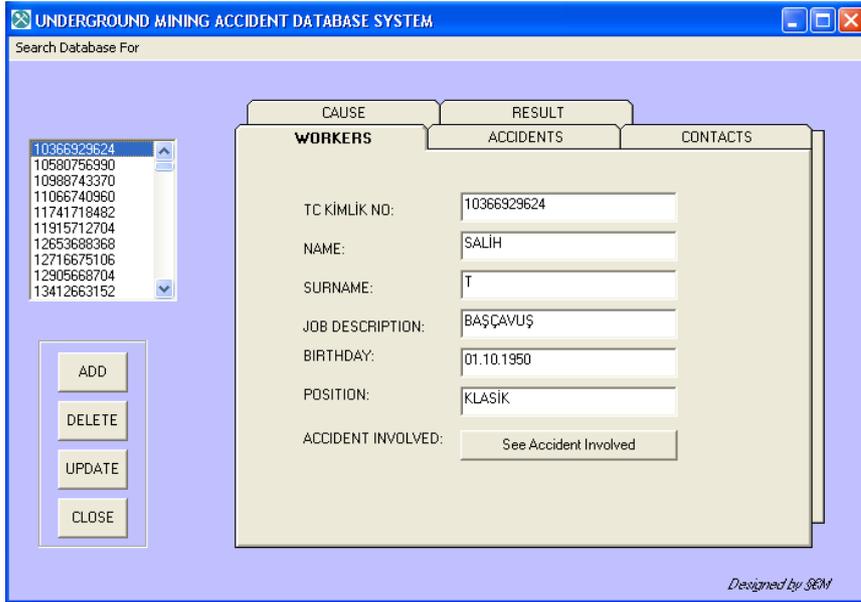
Figure 4.23 Accidents and Worker Database System Program Screenshot

The program facilitates also search function on accidents and workers. User can search the accidents according to accident Id or workers according to their name or surname. Moreover, program can find workers by using job descriptions as key points (Figure 4.24).
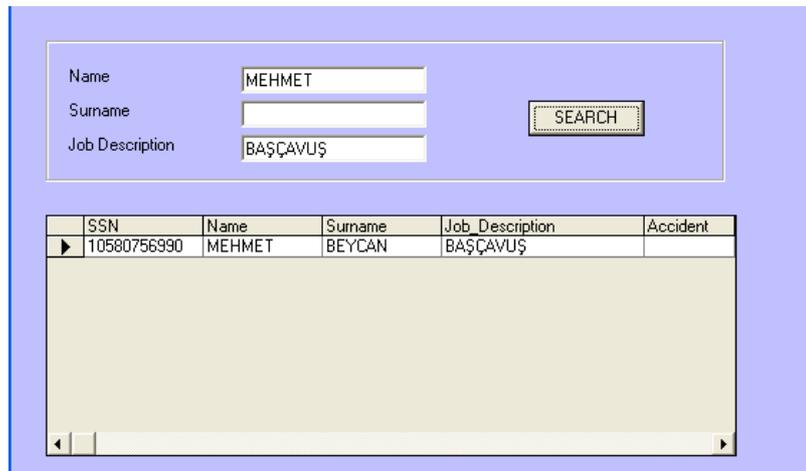
Figure 4.24 Worker Search Screen

In the main form, causes and results of the accident can be seen by the help of info buttons. These are predefined identities which correspond to the Id's stated before (Figure 4.25).
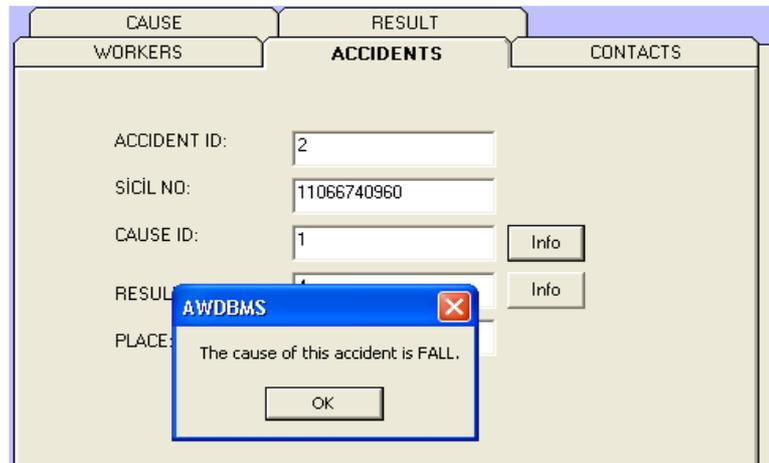
Figure 4.25 Accident Cause Message Box

4.7 Safety Regulations

The basic statues on labor protection are grouped in laws, regulations, instructions and standards. Safety in underground mines is preserved by some pre-defined law and regulations. Without understanding and comprehending the safety legislations thoroughly, stating them will be meaningless. These legislations ensure safe and healthy working environment conditions and promote safety layouts and devices that prevent accidents. Therefore, management has to organize the production processes in line with safety because it is a part of the process itself. Regulations which are written in different sources can be reached and checked by using the web link provided in the opening page of the site.

4.8 Metadata base Management Systems

Metadata is the descriptive information about data source and how accurate it is. Its documentation can be presented in a database system like data name, data create date, creator's name, data owner, data sensitivity, which groups can see the data, source of data, construction process of the data, record scale constraints, perspective, magnification, filters or definitions, record geodesic information (datum, projection), record accuracy and errors standards.

Metadata is the data about data, in the very general definition. It gives information about who, what, when, why and how of the data. A geospatial metadata record includes core library catalog elements such as title, abstract and publication data; geographic elements such as Geographic Extent and projection information; and database elements such as attribute label definitions and attributes domain values.

Metadata is stored in the previously formed layer's .tab file, instead of being stored as rows and columns. Each table can have zero or more keys. Each key represents a different information category. MapInfo Professional uses metadata to manage transactions between MapInfo Professional and the server database. Two of the most important kinds of information stored in the metadata include the connection string and the query built from the program.

The first column which is formed by the code from metadata file is column names. Then, column data type is scripted on the screen as the second column. This value matches previously defined information. Data type is the type of the column defined as Char (Width), float, integer, smallint, decimal (Width, decimal-places), date or logical; if not specified; type default as float.

The program retrieves metadata information about coordinate system from the .tab file based on the structure as;

CoordSys Earth
      [**Projection** *type*, *datum*, *unitname*
             [, *origin_longitude*] [, *origin_latitude*]
             [, *standard_parallel_1* [, *standard_parallel_2*]]
             [, *azimuth*] [, *scale_factor*]
             [, *false_easting*] [, *false_northing*]
             [, *range*]]
      [**Affine Units** *unitname*, *A*, *B*, *C*, *D*, *E*, *F*]
      [**Bounds** (*minx*, *miny*) (*maxx*, *maxy*)]

What written in the html document when the code executed for gallery_2 tab file is:

CoordSys Earth Projection 8, 28, "m", 15, 0, 0.9996, 500000, 0 Bounds (-7746230.6469, -9998287.38389) (8746230.6469, 9998287.38389)

Every element has a specific place in the table. The first element in the list is the name of the projection. The second element is the number that identifies the projection number. The number 8 matches the Transverse Mercator in our case. The third element in the list is the datum Id that identifies the appropriate datum projection. The next number, 28, is the key definition of European 1950 (ED50) international datum. The fourth element in the list is the units, which indicate the units of the projection. In our case unit is in meters corresponding symbology is "m" which stands for meter. The next number in some list is the coordinate system origin (Table 4.5). The coordinate system origin is the point on the Earth (specified as longitude and latitude degrees) from which all coordinate distances are to be measured. X equals to 0 and Y equals to 0 at the origin point, unless a false easting and/ or false northing are used. It is chosen to optimize the accuracy of a particular coordinate system. These coordinate values are generally called northing and easting. The terms "false easting" and "false northing" were used to remove these signs and refer to the absolute value of the X and Y coordinates. MapInfo Professional processes these computations, but these parameters still have to be accounted for in the projections that use them. For the transverse mercator projection, the origin's longitude defines the central meridian. The remaining elements are specific to particular types of projection. In this study,

there is a scale factor of 0. The scale factor is applied to cylindrical coordinates to average scale error over the central area of the map while reducing the error along the east and west boundaries.

Table 4.5 Metadata Explanation

Where	Refers to:
UTM	Name of Coordinate System
8,	Projection type used
28	Datum used
7,	Units used
15,0	Origin Longitude and Origin Latitude used
0.9996, 500000	False Easting, False Northing
0	Scale Factor used

Metadata helps users to utilize data easily and efficiently. In addition preserved data history can be re-used or adapted.   The metadata also instill data accountability by requiring one to state what is known about the data and realizing what is not known (URL 3).

As personnel change in an organization, institutional knowledge leaves the organization.   Therefore, undocumented data can lose their value.   Another problem can be the duplication of the effort resulted from lack of knowledge. It may seem burdensome to add the cost of generating metadata to the cost of data collection, but in the long run metadata are worth it (URL 3).

As stated in (Wayne, 2005), metadata management and usage can serve a critical role in geospatial data management. It enhances data the maintenance and update, recovery and reuse, accountability and liability. Once potential resources are

discovered, users can access the metadata to learn more about the data content, availability, and limitation and better assess the fitness of use of the data to meet their specific need. A well-written metadata record is also an opportunity to state what the data are not. To sum up, metadata utilization is an investment to time, tools and training.

4.9 Summary

In this chapter, database design and management is explained in detailed and then the analyses performed by the use of GIS are clarified in detailed. The applications made for the study are divided into query and analyses operations and each of them is explained in detail in different sub-sections.

In the database design process in section 4.2, data model selection is emphasized since it forms the body of GIS. The database model is the representation of the real world. The model consists of entities, their attributes and relations. While constructing the data model, storage conditions must be scanned. The size of the database clarifies the selection criteria for the program to manage the database. Another question rises throughout the time is the how the database grow. In this study, when the collected data is considered, MS Access ® is chosen as the software to manage the database. However, if the database grows and user number increases over time, software can be changed to meet the new requirements.

Safety data used in the study composed of tabular and graphical data. Graphical data is kept in the database in layers and other attributes are kept in tables. The relations between the stored tables are established to form the entity relationship diagram in section 4.2.2. This diagram is a guide for the mini world that is desired to be created.

In some cases sharing provided data is not desired thus quality control and assurance of the data can be maintained by privileged end users. For example, companies may not intent to share the worker or accident information with public therefore a full Web-GIS application may not be necessary. Therefore, some of the applications are kept in the desktop part to control the data share. The desktop applications are kept for the computer who works as server because server computer contains the database.

Described find gallery tool in section 4.4.2 can also be extended for the other objects on the map. Namely, according to the needs; fans and first aid stations can be other parameters to search on the object. In that case, the code should be updated with fans and first aid stations Ids.

Mapping nearest exit and identifying the shortest route from various working centers can be used for emergency operations and the workers underground can be guided to the nearest exit. For the surveillance of safety, thematic maps created for the desired attributes like dust concentrate or noise amount can be used to predict the problematic zones. Moreover, the graphical analysis based on the air velocities can be supportive while deciding on the fan locations.

The user can also check the safety regulations from the web page in case a conflicting situation. The beginner workers can as well be educated using this system and the galleries can be explained by GIS inter-phases. The data can be analyzed using queries whenever information is needed. For example in order to learn the operation voltage of a fan information tool can be used or an SQL sentence can be written to form the necessary query.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This research on integration of GIS with DBMS to health and safety in underground mines is mainly focused on the implementation of a flexible, user friendly and analyzing system to the specified data. The case study area is chosen as Garp Lignite Enterprise in Turkey. The applications conducted in the study have different scenarios. Thus in the summary part the outcomes and findings were grouped by the operations that are run by the program. Namely, query operations; navigation, find, info and query tools and analyzing operations; emergency route finding, annual "air-velocity" distribution analyses, and thematic mapping. Beside these operations accident worker information system, safety regulation links and metadata base management system performed in the study have some consequences.

In this chapter, the main conclusions drawn from this research study is based on the research findings and results. In section 5.2, conclusions of the results are made and in section 5.3 recommendations for the future works are discussed.

5.2 Conclusion

The main conclusions drawn from this research study are;

i. Navigation tools enable users to use the map provided by the web page easily. The buttons existing in the navigation panel are the first steps to

introduce the GIS map to the end-user thus their contribution to the system is necessary.

ii. Finding gallery tool is a query based operation which enables users to find the desired gallery on the map and zoom it to the center of the map. Selected gallery can be chosen so that further queries can be made on the selection.

iii. Info tool works for all open layers in the web page. When the user clicks on any item on the map it initializes and retrieves the related information of the object. This information is taken from the server and it is taken as tabular form and printed on the screen as information table.

iv. Query tool is used to write queries on the opened tables in the workspace. The possible selections made are based on the structured query language (SQL) and the outcome query is printed on the same browser as table. Each selected column from the selected table is represented.

v. Emergency route finding analysis is working based on the algorithm of Dijkstra. Shortest path from the chosen gallery to the exit is highlighted to enable users to see possible exit route. When the accessibility time to response to the emergency and rescue efforts increases the consequences of mine accidents and disasters can become much more intensified. Therefore, to decrease the time spent underground in the case of emergency is significant.

vi. An annual "air-velocity" distribution analysis is made based on the monthly entered data and the outcome is a X-Y plot. This plot represents the air velocity changes in the selected gallery and it helps to get an idea of the ventilation of the chosen gallery. This analysis can be upgraded and modified in such a way that it can be used for toxic gases or dust contamination. When it is used for different parameters, graphs can be used to monitor changes and model this change with respect to time. In such a case scenario a threshold value can be added as a second equation in the graph.

vii. Thematic mapping is another advantage of GIS application to analyze the tabular data in graphical views. The visualization can differ from the need of the user and comparison between the data can easily be accomplished by thematic maps. The result of the thematic analysis provides to focus on the action and helps to choose best options for solutions. The places where your criteria meet and the relationships between places can be analyzed by the help of spatial distribution of the data. For example dot density map can be used to find areas where things are concentrated.

viii. A well developed and managed U/G mine safety data as conducted in this study present a model for accident database management about accidents and workers. It helps to manage the large amount of data related to mine personnel and implement that data by the help of query languages. Maintenance of the workers and accidents information are provided by the desktop application which organizes data in a well-structured model.

ix. Safety regulation links provide easily accessibility to the user for any emergency case. When a contradiction occurs or the decision must be made the end user can check the regulation stated without searching for the entire internet search engines.

x. Metadata base management system is as important for data user as the data itself. Before updating or editing the data, the information about data can be needed and the application in this study provides this information after getting the stored information from MapInfo.

Since the application is web based it has some constraints through the stage from server to end user. Before integrating the system on the internet some considerations ought to be taken about the questions such as how many users going to use this application or what details change from one user to another. These questions are answered according to the needs of company. Since the TKİ has only one operation U/G mine, the end-user for this system depends on the engineers work in GLİ. However, when this scenario is applied to another

company, the number of end users can be increased and the performance criteria of the server should be revised.

5.3 Recommendations

Since the new era grows with technological improvement, every discipline should adopt itself to the enhancement of the science. Desktop mapping and GIS are making the spatial dimension of the world accessible and ties the objects with their surroundings to lead users to dig for more information.

The application of GIS in mining cannot be disregarded when the improvements are considered. The integration of the system with the operation can be extended in natural hazards subjects while locating the mine area and a ground survey can be done on population density, labor resources, housing in the preparation of the environmental impact assessment. The spatial data analysis can be implemented in these case scenarios and these applications can be tied via network systems through the internet and many mines can have and maintain information about their working environment.

The location of refuge chambers within a safe distance from production faces can be achieved with a GIS proximity analysis. A network of refuge chambers can be implemented that possesses adequate capacity and the correct number of first aid kits proportionate to the miner population. For small and medium budget companies, high expenses for GIS softwares can be an overburden. For that reason open source GIS design and low-cost alternatives like web-GIS can be developed. The Open GIS Consortium has proposed the Geography markup language (GML) which is an XML encoding for the transportation and storage of geographic information, including both the geometry and properties of geographic features. If such kind of a standard language is adopted by all then there would be probably be no need for conversion of data types. This will cause uniformity in the availability of data throughout the internet.

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APPENDIX A

UNDERGROUND MINE ACCIDENT IDENTIFICATIONS

Table A.1. Accident ID and Definition Table

Accidents	
Accident ID	**Definition**
01	**GAS RELATED CHOKING AND POISONING**
02	**GAS AND DUST EXPLOSION**
03	**SUBSIDENCE, ROCK OR COAL FALL**
031	On Food
0311	*While excavation*
0312	*While coal extracting*
0313	*While Supporting Or Taking Out The Support*
0314	*While Cleaning*
0315	*While Mounting*
032	On Preparation
0321	*While excavation*
0322	*While Supporting Or Taking Out The Support*
0323	*While Loading Coal and Rock*
0324	*Others*
033	On the Gallery Ways
0331	*While Repairing and Scanning*
0332	*Transportation, walking, waiting and others*
04	**FALL OF MATERIAL**
041	Fall of Support Material
0411	*While Mounting the Support*
0412	*While Taking Out the Support*
0413	*Falling of Mounted Support*
042	Fall Of Other Materials (Transportation, Except For: Repair, Maintenance, And Mounting)
0421	*Fall of a highly located material*
0422	*Fall of material held by the worker*
0423	*Others*

Table A.1. Accident ID and Definition Table (cont'd)

Accident ID			Definition
05			**CRUSHED BY A MATERIAL**
	051		Crush Of A Moving Object
	052		Crush To A Stationary Object
		0521	*Crush to a support parts underground*
		0522	*Crush to a transportation unit underground*
		0523	*Crush or hit to another stationary object*
	053		Others
06			**EXPLOSIVE MATERIAL**
07			**CARRY BY HAND**
	071		Fall Of Something Carried By Hand On Worker
	072		Fall With Something Carried By Hand On Worker
	073		Caught Of Part Of Body While Carrying Something With Hand
	074		Hurting Back While Carrying Something With Hand
	075		Others
08			**MECHANICAL CARRIAGE**
	081		Crush Or Hit Of Moving Parts Of Conveyors
	082		Crush Or Hit Of Coolie Cars Or Locomotives
	083		Other Transportation Unit Crushes
	084		Fall Of Something From Transportation Units
	085		Hurt Of Back While Lifting Fallen Locomotives
	086		Fall From Any Transportation Unit While Man Or Material Transportation
	087		Others
09			**TRANSPORTAION BY MOTORWAR (ROAD)**
	091		Heavy Duty Machines (Crane, Loader, Grader, etc)
		0911	*Overturned*
		0912	*Crush*
		0913	*Fire*
	092		Other Vehicles Except For Heavy Duty Machines
		0921	*Overturned*
		0922	*Crush*
		0923	*Fire*
	093		Others
10			**ELECTRICITY**
	101		Electricity Shock
	102		While Mounting, Maintaining, Carrying Electricity Devices, And Others
11			**MACHINERY**
	111		Fall Of Machinery Or A Part Of It

Table A.1. Accident ID and Definition Table (cont'd)

	Accidents
Accident ID	**Definition**
112	Crush Or Hit Of Machinery Or A Part Of It
113	Hit Of The Ventilation Or Hydraulic Pump
114	While Repairing The Instrument In The Atelier
115	Squeezing Of A Part Of Hands Or Legs
116	Hit Of Chip To The Parts Of Hands Or Legs
117	While Lifting Part Of A Machinery, Hurting Back Of The Body
118	Others
12	**HEAVY DUTY MACHINERY**
121	Fall Of Machinery Or A Part Of It
122	Crush Or Hit Of Machinery Or A Part Of It
123	Fall From Heavy Duty Machinery
124	Fall While Getting On A Heavy Duty Machine
125	Squeezing Of A Part Of Hands Or Legs
126	Hit Of Chip To The Parts Of Hands Or Legs
127	While Lifting Part Of A Machinery, Hurting Back Of The Body
128	Others
13	**HAND DEVICES**
131	Hit Oneself Accidently By Hand Devices
132	Hurt Oneself's Back While Working With Hand Device
133	Fall While Working With Hand Device
134	Others
14	**OTHERS**
141	Fall (While carrying by hand or mechanically)
1411	*Falling while walking*
1412	*Falling while using stairs*
1413	*Falling from an arbitrary height*
1414	*Other falls*
142	Squeezing of the part of body while mounting support
143	Squeezing of hand or foot to the gate
144	Hurting of one's back while mounting support
145	Twisting ankle
146	Hurt by pin
147	Others

Table A.2. Cause ID and Definition Table

Causes	
Cause	**Definition**
1	GAS RELATED CHOKING AND POISONING
2	GAS AND DUST EXPLOSION
3	SUBSIDENCE, ROCK OR COAL FALL
4	FALL OF MATERIAL
5	CRUSHED BY A MATERIAL
6	EXPOSIVE MATERIAL
7	CARRY BY HAND
8	MECHANICAL CARRIAGE
9	TRANSPORTAION BY MOTORWAR (ROAD)
10	ELECTRICITY
11	MACHINERY
12	HEAVY DUTY MACHINERY
13	HAND DEVICES
14	OTHERS

Table A.3. Result ID and Definition Table

Results	
Result	**Definition**
1	DEATH
2	SERIOUSLY INJURED
3	CHOKED
4	PERMANENT DISABILITY
5	TOTAL DISABILITY
6	SLIGHTLY INJURED

APPENDIX B

SAMPLE CODE

The developed models throughout the study were developed by generating codes in Visual Basic environment. An interested reader is provided with the part of the code as a sample as following:

WebForm1.aspx

```
Imports System.Web
Imports MapInfo
Imports MapInfo.Engine
Imports MapInfo.WebControls
Imports MapInfo.Mapping
Imports MapInfo.Geometry
Imports MapInfo.Data
Imports System.Runtime.InteropServices
Imports System.Math
Imports System.IO
Imports System.Runtime.Serialization.Formatters.Binary

Namespace InfoToolWeb

    Partial Class WebForm1
        Inherits System.Web.UI.Page
        <DllImport("C:\sp2.dll")> _
    Public Shared Sub SetStartNode(ByVal LineId As Integer)
        End Sub
        <DllImport("C:\sp2.dll")> _
    Public Shared Sub SetEndNode(ByVal LineId As Integer)
        End Sub
        <DllImport("C:\sp2.dll")> _
    Public Shared Sub FindShortestPath()
        End Sub
        <DllImport("C:\sp2.dll")> _
    Public Shared Function ResultCount() As Integer
        End Function
        <DllImport("C:\sp2.dll")> _
    Public Shared Function GetResults() As Integer
        End Function
        <DllImport("C:\sp2.dll")> _
        Public Shared Sub LoadNetwork(ByVal t As String)
        End Sub

#Region " Web Form Designer Generated Code "

        <System.Diagnostics.DebuggerStepThrough()> Private Sub
InitializeComponent()
```

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        End Sub
        Private Shared _findColumnName As String = "gallery_Id"
        Private Shared _findLayerName As String = "gallery_2"
        Private Shared _workingLayerName As String =
"WorkingLayer"


        Private Sub Page_Init(ByVal sender As System.Object, ByVal
e As System.EventArgs) Handles MyBase.Init
            InitializeComponent()
        End Sub

#End Region
        Private Sub Page_Load(ByVal sender As System.Object, ByVal
e As System.EventArgs) Handles MyBase.Load, Me.Load

            If Me.Session.IsNewSession Then

MapInfo.Engine.Session.Current.Selections.DefaultSelection.Style.L
ineStyle = New MapInfo.Styles.SimpleLineStyle(New
MapInfo.Styles.LineWidth(7, MapInfo.Styles.LineWidthUnit.Pixel),
2, System.Drawing.Color.Red)

                Dim controlModel As
MapInfo.WebControls.MapControlModel =
MapControlModel.SetDefaultModelInSession()
                controlModel.Commands.Add(New Info)
                controlModel.Commands.Add(New ZoomValue)
                controlModel.Commands.Add(New PointSelect)
                controlModel.Commands.Add(New ChartSelect)

            End If

            Dim conn As MIConnection = New MIConnection
            conn.Open()
            Dim comm As MICommand = conn.CreateCommand

            If AppStateManager.IsManualState Then
                Dim stateManager As New AppStateManager

stateManager.ParamsDictionary.Item(WebControls.StateManager.Active
MapAliasKey) = Me.MapControl1.MapAlias

stateManager.ParamsDictionary.Item("WorkingLayerName") =
_workingLayerName

WebControls.StateManager.PutStateManagerInSession(stateManager)
            End If
            Me.InitWorkingLayer()
            Dim myMap As Map =
MapInfo.Engine.Session.Current.MapFactory.Item(Me.MapControl1.MapA
lias)
            myMap.Zoom = New MapInfo.Geometry.Distance(0.5398,
MapInfo.Geometry.DistanceUnit.Mile)
            myMap.Center = New DPoint(449376, 4356799)
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            myMap.Size = New
System.Drawing.Size(CType(Me.MapControl1.Width.Value, Integer),
CType(Me.MapControl1.Height.Value, Integer))

            If AppStateManager.IsManualState Then

StateManager.GetStateManagerFromSession.RestoreState()
            End If


        End Sub
        Private Sub Page_UnLoad(ByVal sender As Object, ByVal e As
EventArgs) Handles MyBase.Unload
            If AppStateManager.IsManualState Then

MapInfo.WebControls.StateManager.GetStateManagerFromSession().Save
State()
            End If
        End Sub

        Private Sub shortest()
            If Session.Item("LastSelectedNode") Is Nothing Then
                Exit Sub
            End If

            Dim nodeid As Integer =
Integer.Parse(Session.Item("LastSelectedNode").ToString())
            Dim conn As MIConnection = New MIConnection
            conn.Open()
            Dim comm As MICommand = conn.CreateCommand
            Dim map1 As Map =
MapInfo.Engine.Session.Current.MapFactory(MapControl1.MapAlias)
            LoadNetwork("C:\GALERI\gallery_2.gr")
            SetStartNode(nodeid - 1)
            Dim endnode As Integer

            If CheckBox1.Checked Then
                endnode = 131
            ElseIf TextBox3.Text = "" Then
                MsgBox("please write the exit node!")
                Exit Sub
            Else
                endnode = TextBox3.Text
            End If


            SetEndNode(endnode)
            FindShortestPath()


            Dim i As Integer
            i = GetResults()

            Dim toplen As Double
            toplen = 0.0
```

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MapInfo.Engine.Session.Current.Selections.DefaultSelection.Clear()
        While (i > 0)
            i = i + 1
            comm.CommandText = "select * from gallery_2 where
ID=@id"
            comm.Parameters.Clear()
            comm.Parameters.Add("@id", Convert.ToInt32(i))
            Dim reader As MIDataReader = comm.ExecuteReader
            reader.Read()
            toplen = toplen +
Convert.ToDouble(reader("Spherical_Length"))
            Dim irfc As IResultSetFeatureCollection =
comm.ExecuteFeatureCollection

MapInfo.Engine.Session.Current.Selections.DefaultSelection.Add(irf
c)

MapInfo.Engine.Session.Current.Selections.DefaultSelection.Style.L
ineStyle = New MapInfo.Styles.SimpleLineStyle(New
MapInfo.Styles.LineWidth(7, MapInfo.Styles.LineWidthUnit.Pixel),
2, System.Drawing.Color.Red)
            irfc.Close()
            reader.Close()
            i = GetResults()

        End While
        Dim distance2 As MapInfo.Geometry.Distance = New
MapInfo.Geometry.Distance(0.5389, map1.Zoom.Unit)
        map1.Zoom = distance2
        conn.Close()
        TextBox2.Text = toplen.ToString()
    End Sub

    Private Function GetMapObj() As MapInfo.Mapping.Map
        Dim myMap As MapInfo.Mapping.Map =
MapInfo.Engine.Session.Current.MapFactory.Item(Me.MapControl1.MapA
lias)
        If (myMap Is Nothing) Then
            myMap =
MapInfo.Engine.Session.Current.MapFactory.Item(0)
        End If
        Return myMap
    End Function
    Private Function OpenTable(ByVal connectionName As String,
ByVal tableName As String) As MapInfo.Data.Table
        Dim nci As MapInfo.Data.NamedConnectionInfo =
MapInfo.Engine.Session.Current.Catalog.NamedConnections.Get(connec
tionName)
        If (nci Is Nothing) Then
            Return Nothing
        End If
        If nci.DBType.ToLower.Equals("file") Then
            Return Me.OpenNativeTable(nci, tableName)
        End If
        Return Me.OpenDataBaseTable(nci, tableName)
```

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        End Function

        Private Function InitWorkingLayer() As Boolean
            Dim map1 As Map =
MapInfo.Engine.Session.Current.MapFactory(MapControl1.MapAlias)
            If ((MapInfo.Engine.Session.Current.MapFactory.Count =
0) OrElse (map1 Is Nothing)) Then
                Return False
            End If

            Dim table As Table =
MapInfo.Engine.Session.Current.Catalog.GetTable(WebForm1._workingL
ayerName)
            If (table Is Nothing) Then
                Dim ti As New
TableInfoMemTable(WebForm1._workingLayerName)
                ti.Temporary = True
                Dim column1 As New
GeometryColumn(map1.GetDisplayCoordSys)
                column1.Alias = "obj"
                column1.DataType = 7
                ti.Columns.Add(column1)

                Dim column2 As New Column
                column2.Alias = "MI_Style"
                column2.DataType = 11
                ti.Columns.Add(column2)
                table =
MapInfo.Engine.Session.Current.Catalog.CreateTable(ti)
            End If

            If (table Is Nothing) Then
                Return False
            End If

            Dim layer1 As FeatureLayer =
map1.Layers(WebForm1._workingLayerName)
            If (layer1 Is Nothing) Then
                layer1 = New FeatureLayer(table,
WebForm1._workingLayerName, WebForm1._workingLayerName)
                map1.Layers.Insert(0, layer1)
            End If
            If (layer1 Is Nothing) Then
                Return False
            End If

            CType(layer1.Table, ITableFeatureCollection).Clear()

            Return True
        End Function
        Private Function GetServerToolkit(ByVal nci As
MapInfo.Data.NamedConnectionInfo) As MapInfo.Data.ServerToolkit
            Select Case nci.ConnectionMethod
                Case MapInfo.Data.ConnectionMethod.Odbc
                    Return MapInfo.Data.ServerToolkit.Odbc
                Case MapInfo.Data.ConnectionMethod.OracleOci
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                Return MapInfo.Data.ServerToolkit.Oci
        End Select
        Throw New ArgumentException("ConnectionMethod should
only be Odbc or OracleOci!", "nci")
    End Function


    Private Function OpenDataBaseTable(ByVal nci As
MapInfo.Data.NamedConnectionInfo, ByVal dbTableName As String) As
MapInfo.Data.Table
        Dim tableAlias As String = (dbTableName & "_" &
nci.Name.Replace(" ", "_").Replace(".", "_"))
        Dim table As MapInfo.Data.Table =
MapInfo.Engine.Session.Current.Catalog.GetTable(tableAlias)
        If (table Is Nothing) Then
            Dim tis As New
MapInfo.Data.TableInfoServer(("tableInfoServer_" & dbTableName))
            tis.ConnectString = nci.ConnectionString
            tis.Query = ("select * from " & dbTableName)
            tis.Toolkit = Me.GetServerToolkit(nci)
            tis.CacheSettings = New
MapInfo.Data.CacheParameters(MapInfo.Data.CacheOption.On)
            tis.Alias = tableAlias
            table =
MapInfo.Engine.Session.Current.Catalog.OpenTable(nci.Name, tis)
        End If
        Return table
    End Function

    Private Function OpenNativeTable(ByVal nci As
MapInfo.Data.NamedConnectionInfo, ByVal tableName As String) As
MapInfo.Data.Table
        Dim fileName As String = tableName
        Dim aliasName As String = (tableName & "_" & nci.Name)
        Dim table As MapInfo.Data.Table =
MapInfo.Engine.Session.Current.Catalog.GetTable(aliasName)
        If (table Is Nothing) Then

            If (tableName.ToLower.IndexOf(".tab") <= 0) Then
                fileName = (tableName & ".tab")
            End If
            table =
MapInfo.Engine.Session.Current.Catalog.OpenTable(nci.Name,
aliasName, fileName)
        End If
        Return table
    End Function


    Private Sub FindGallery()
        Dim find As MapInfo.Data.Find.Find = Nothing

        Try
            Dim map1 As Map =
MapInfo.Engine.Session.Current.MapFactory(MapControl1.MapAlias)

            If
(MapInfo.Engine.Session.Current.MapFactory.Count = 0) Then
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                    Return
              End If

              If (map1 Is Nothing) Then
                    Return
              End If

              Dim findLayer As FeatureLayer =
map1.Layers(WebForm1._findLayerName)
              find = New MapInfo.Data.Find.Find(findLayer.Table,
findLayer.Table.TableInfo.Columns(WebForm1._findColumnName))
              Dim result As Find.FindResult =
find.Search(Me.DropDownList1.SelectedItem.Text)
              If result.ExactMatch Then
                    Dim csys As CoordSys = findLayer.CoordSys
                    Dim geometry1 As New Point(csys,
result.FoundPoint.X, result.FoundPoint.Y)
                    Dim feature1 As New Feature(geometry1, New
Styles.SimpleVectorPointStyle(52, Color.DarkGreen, 32))

                    Dim workingLayer As FeatureLayer =
map1.Layers(WebForm1._workingLayerName)
                    If (Not workingLayer Is Nothing) Then
                        CType(workingLayer.Table,
ITableFeatureCollection).Clear()
                        workingLayer.Table.InsertFeature(feature1)
                    End If

                    map1.Center = New DPoint(result.FoundPoint.X,
result.FoundPoint.Y)
                    Dim distance2 As MapInfo.Geometry.Distance =
New MapInfo.Geometry.Distance(0.02, map1.Zoom.Unit)
                    map1.Zoom = distance2
              Else
                    Me.Label3.Text = "Cannot find the gallery"
              End If
              find.Dispose()
          Catch exception1 As Exception
              If (Not find Is Nothing) Then
                    find.Dispose()
              End If
          End Try
      End Sub
      Private Sub FillDropDown(ByVal tableName As String, ByVal
colName As String)
          Dim map1 As Map =
MapInfo.Engine.Session.Current.MapFactory(MapControl1.MapAlias)

          If ((MapInfo.Engine.Session.Current.MapFactory.Count =
0) OrElse (map1 Is Nothing)) Then
                Return
          End If

          Me.DropDownList1.Items.Clear()
          Dim fl As FeatureLayer = map1.Layers(tableName)
          Dim t As Table = fl.Table
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            Dim con As New MIConnection
            Dim tc As MICommand = con.CreateCommand
            tc.CommandText = "select " & colName & " from " &
t.Alias
            con.Open()
            Dim tr As MIDataReader = tc.ExecuteReader

            Do While tr.Read
                Me.DropDownList1.Items.Add(tr.GetString(0))
            Loop
            tc.Cancel()
            tc.Dispose()
            tr.Close()
            con.Close()
        End Sub
        Private Sub Page_PreRender(ByVal sender As Object, ByVal e
As System.EventArgs) Handles MyBase.PreRender
            If Not MyBase.IsPostBack Then
                Me.FillDropDown(WebForm1._findLayerName,
WebForm1._findColumnName)
            End If
        End Sub
        Protected Sub LinkButton1_Click(ByVal sender As Object,
ByVal e As System.EventArgs) Handles LinkButton1.Click
            Me.FindGallery()
        End Sub
        Protected Sub Button1_Click(ByVal sender As Object, ByVal
e As System.EventArgs) Handles Button1.Click

            Me.shortest()

        End Sub

        Protected Sub ApplyButton_Click(ByVal sender As Object,
ByVal e As System.EventArgs) Handles ApplyButton.Click
            If (Not Me.SelectClauseTextBox.Text Is Nothing) Then
                Me.SetDataGrid(Me.GridView1,
Me.SelectClauseTextBox.Text.Trim, False)
                Me.GridView1.DataBind()
            End If
        End Sub
        Private Sub SetDataGrid(ByVal GridView1 As GridView, ByVal
commandText As String, ByVal bShowSchema As Boolean)
            Dim miConnection As New MapInfo.Data.MIConnection
            miConnection.Open()
            Dim miCommand As MapInfo.Data.MICommand =
miConnection.CreateCommand
            miCommand.CommandText = commandText
            Dim miReader As MapInfo.Data.MIDataReader = Nothing
            Try
                miReader = miCommand.ExecuteReader()
                If bShowSchema Then
                    GridView1.DataSource = miReader.GetSchemaTable
                Else
                    Dim dt As New DataTable("Data")
                    Dim index As Integer
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                        For index = 0 To miReader.FieldCount - 1
                            Dim column1 As DataColumn =
dt.Columns.Add(miReader.GetName(index))
                        Next index
                        Do While miReader.Read
                            Dim dr As DataRow = dt.NewRow
                            For index = 0 To miReader.FieldCount - 1
                                dr.Item(index) =
miReader.GetValue(index)
                            Next index
                            dt.Rows.Add(dr)
                        Loop
                        GridView1.DataSource = dt
                    End If
            Catch exception1 As Exception
                Me.SelectClauseTextBox.Text =
(Me.SelectClauseTextBox.Text & " ***Wrong select clause, try
it.***")
            Finally
                If (Not miReader Is Nothing) Then
                    miReader.Close()
                End If
            End Try
        End Sub


        Protected Sub LinkButton2_Click(ByVal sender As Object,
ByVal e As System.EventArgs) Handles LinkButton2.Click
            Response.Redirect("WebForm1.aspx")
            StateManager.GetStateManagerFromSession.RestoreState()
        End Sub


    End Class
End Namespace
```