DEVELOPING A SPATIAL DECISION SUPPORT SYSTEM FOR TELECOM
WIRELINE INFRASTRUCTURE FOR ANKARA CITY

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DEVELOPING A SPATIAL DECISION SUPPORT SYSTEM FOR TELECOM WIRELINE INFRASTRUCTURE FOR ANKARA CITY

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ABSTRACT

DEVELOPING A SPATIAL DECISION SUPPORT SYSTEM FOR TELECOM
WIRELINE INFRASTRUCTURE of ANKARA CITY

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This thesis covers database creation, system design and application development for wire line telecom infrastructure within Geographical Information Systems (GIS) and concentrates on spatial decision support applications and serving wire line subscriber coordinates for emergency calls in Ankara. The main mission of the Telecommunication in the past was to serve for voice communication activities. Currently voice, internet, data and video communications are available. These new services need better bandwidth capacity and/or renewal of infrastructure with Fiber Optical cables. Telecom has a complex wire line infrastructure, both in physical and logical topology. It is important to manage this complex infrastructure to give better services with new installation and update activities. Due to these requirements Telecom infrastructure needs to be managed with GIS, which visually provide physical and logical relationships.

In this study it's aimed to build a GIS system for Turk Telekom (TT) including digitization of wire line cable infrastructure, geocoding subscribers and serving the coordinates of subscribers. The data layers are stored in Oracle Spatial Data Option (SDO) and spatial data information is kept in MapInfo MapCatalog. The data schemes for 81 provinces are created. The applications are developed with Borland Delphi version 7 and Microsoft Visual Studio 2008 .NET Framework. There are several GIS applications developed so far for the infrastructure of TT, since TT needs

to know the location and quality of the infrastructure already present in the field and needs spatially to decide on areas that need maintenance including improvement, replacement, and new installations to improve the service. This study is presented as an alternative spatial decision support system for the improvement of the current infrastructure and services given to the customers, by using digitized network and geocoded subscriber data that is stored in GIS system. This study is carried out with customer participation and on site development with Telecom staff.

Keywords: Telecom, wire line, GIS, Spatial Decision Support System.

ÖZ

TELEKOM KABLO ALTYAPISI İÇİN MEKANSAL KARAR DESTEK SİSTEMİ
GELİŞTİRMESİ, ANKARA ÖRNEĞİ

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Bu tez telekom kablo altyapısı için Coğrafi Bilgi Sistemleri (CBS) ile veritabanı oluşturma, sistem tasarımı ve uygulama geliştirmeyi kapsamakta ve mekansal karar destek uygulamaları ve haritalandırılmış sabit telefon abonelerinin koordinatlarının acil çağrılar için sağlanması üzerine de yoğunlaşmıştır. Eskiden Telekomunikasyonun ana görevi ses iletişim aktivitelerini sağlamaktı. Günümüzde ise ses, internet, veri ve görüntü iletişimi yapılabilmektedir. Bu yeni servisler daha geniş kapasiteli altyapı döşenmesini ve/veya varolan altyapının Fiber Optik kablolarla değiştirilmesi gerktirmektedir. Telekom hem fiziksel hemde mantıksal ilişkileri ile çok karmaşık bir altyapıya sahiptir. Yeni yatırımlar ve değişiklik aktiviteleri ile daha iyi servis verebilmek için bu altyapıyı iyi yönetmek önemlidir. Bu ihtiyaçlardan dolayı tlekom altyapısı görsel olarak fiziksel ve mantıksal ilişkileri gösteren CBS ile yönetilmelidir.

Bu çalışma, Turk Telekom (TT) için kabloların sayısallaştırılması, abonelerin harita üzerine yerleştirilmesi ve koordinatlarının servis edilebilmesini içeren CBS sistemi kurulmasını amaçlamaktadır. Harita verileri Oracle Spatial Data Eklendisi (SDO) ile tutulmakta, mekansal veri bilgileri ise MapInfo MapCatalogda tutulmaktadır. 81 ilin veri şemaları oluşturulmuştur. Uygulamalar Borland Delphi versiyon 7 ve Microsoft .NET framework ile geliştirilmiştir. Şimdiye kadar TT için sahada mevcut altyapısının yerini ve kalitesini bilmesi ve servislerini iyileştirebilmek için nerelerin

değiştirme, iyileştirme ve yeni inşaata ihtiyacının olduğuna mekansal olarak karar verebilmesi için birçok uygulama geliştirilmiştir. Bu çalışma, mevcut altyapının ve müşterilere verilen hizmetlerin iyileştirilmesi için CBS ortamında sayısallaştırılan şebeke ve haritaya yerleştirilen abone dataları kullanılarak alternatif bir mekansal karar destek sistemi olarak sunulmuşur. Çalışma müşterinin yerinde ve Telekom elemanları ile birlikte geliştirilmiştir.

Anahtar Kelimeler: Telekom, kablo altyapı, CBS, mekansal karar destek sistemi.

To my son

ACKNOWLEDGEMENTS

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ABBREVIATIONS

BT: British Telecom

CAD: Computer Aided Drawings

DBA: Database Administrator

DSL/ADSL: Digital Subscriber Line/ Asynchronized Digital Subscriber Line

FTTH: Fiber To the Home

F/O: Fiber Optic

FTTX: Fiber To the Home/Business etc

GIS: Geographical Information System

GSM: Global System for Mobile Telecom

IP TV: Internet Protocol TV Broadcast

ISP: In Site Plant

OLE: Object Linking and Embedding

OSP: Out Site Plant

PSTN: Fix line Telecom Subscription

SDO: Spatial Data Option of Oracle Database System

TMS: Telecom Management System

TT: Turk Telekom Company

TTGIS: Turk Telekom Geographical Information System, also named as TTCBS

VOD :Video On Demand

CHAPTER 1

INTRODUCTION

Computer and related technologies, especially communication technologies, are growing with a tremendous speed since beginning of the 21st century. Because the barriers existed about three decades ago became to be solved in the last decade they become possible to solve. It also became possible to access many of the services by today's communication technologies.

The main mission of telecom's infrastructure was to serve for communication activities. One of the main problems to overcome in the telecom history was to connect Europe with America. Mr. Gisborne from Atlantic Cable (Atlantic Telegraph) Company, was looking far away and saying "When we can whisper mutual words of friendship through the mystic voice of electricity, even though ocean rolls between us" (Cookson, 2003). Later, the continents were connected by wires successfully and this was a revolution in the human history.

Currently, telecom infrastructure is also used for many different services such as Dial-up Internet, Cable TV, High Speed Internet and Internet Protocol TV (IP TV). New technologies need bigger data transmissions both in size and speed. More data transmissions need improved infrastructure and management. It is needed to use information systems, especially Geographical Information Systems (GIS) in the current technology era. Due to these facts, telecom companies are encouraged to build GIS not to only answer the most of the current requirements but also potential ones, and also to maximize savings for maintenance of the existing infrastructure.

Since telecom has infrastructure maps and customer location data, they should

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use the telecom technology in life saving emergency services and location-based services in different ways. Whenever a telecom company can serve the coordinates of the customers to the emergency agents, there would be more chance to save lives and assets. Location information can be served for many different location based customer inquiries such as "Find me the nearest facility to me" or business inquiries like "Where are my customers located?" It is not enough to locate subscribers on the map; additionally, such data needs to be updated as cancellations, moving, and new subscriptions are common in the domain of telecom.

The research question of this study is searching the possibility of building a live GIS system in Turk Telekom (TT), supporting the decision of the new infrastructure installations and spatially serving the geocoded subscriber data for emergency studies. The scope of the study is to design the system applicable to the whole country and develop applications for Ankara, the capital of Turkey. A proper database was created and the applications indicating the use of GIS in editing/updating the system and supporting the decision-making on new investments were developed

The thesis is organized as follows:

- Chapter 1 gives a short introduction of the thesis along with the purpose, scope of the work and introduces the research question.

- In Chapter 2, the requirements for the GIS and the usage of it in the telecom sector are explained. Similar GIS applications are examined from other countries; moreover the telecom sector in Turkey and GIS history of TT are given.

- In Chapter 3 the database and the system design for TT are explained. Working with multiple users on the same projects that utilize both spatial and non-spatial data, and cataloging of the spatial data are presented.

- The GIS applications developed for TT, are explained in Chapter 4. As-built and cable digitization applications of the current inventory are described. The project applications for updating the system, monitoring and spatial decision

support applications for managers, ADSL capacity calculation for Telecom engineers are presented. Moreover, geocoding of subscribers and serving their coordinates for emergency system are offered.

- In Chapter 5, the results obtained from the developed applications are discussed.

- Conclusions and recommendations are given in Chapter 6.

CHAPTER 2

GIS IN TELECOM

2.1 Importance of Geographical Information System for Telecom

2.1.1 Importance of Geographical Information System for Telecom

Importance of Geographical Information System (GIS) can be explained in terms of problems due to complexity of telecom network infrastructure, competition in the market, effectiveness and having a modern system for a better vision. According to Albrecht (2007) "there are two main reasons why geographical data cannot be adequately represented by simple geometries used in popular CAD programs. The first is that projects covering more than few square kilometers have to deal with curvature of the earth. The other reason is that even for smaller areas, where curvature could be neglected, the need to combine the data from different sources, especially satellite imagery – requires matching coordinates from different coordinate systems".

Ciciora (1999) says, "The primary emphases of cable telephony and internet access services via cable, as well as digital video transmission. Factor making cable an attractive medium, include economy, speed and connectionless service". Telecom network management must be organized in a good system due to the requirements of having economical, fast and connectionless services.

Geographic Information Systems are computerized systems for managing data

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about spatially referenced objects. GIS differ from other types of information systems in that they manage huge quantities of data, require complex concepts to describe the geometry of objects and specify complex topological relationships between them (Mitrovic, 1993).

Bartlett (2000) says, "Fiber Optical technology as applied to Cable TV system was just what was needed and at the right time. Cable systems were expanding their bandwidth with the upper limit approaching one GHz. … Because more cable plant devices and connectors caused increased signal leakage problems, all contributing to increased plant maintenance and escalating costs. A coaxial cable with one of the lowest losses of 1000 MHz has 43 Db/km loss, but a F/O has 0.2 Db/km. It is imperative that Cable TV systems considering staying in the business along time, must add fiber optic technology to their systems in order to compete in the telecommunications enterprises during the next century".

Raghavendran (2003) defines the importance of Broadband technologies. "Broadband technology has not only given a new meaning for information exchange, but has also been the building blocks for the so-called Information Superhighway. Besides fostering a new class of consumer and business related services such as IP based telephone and video conferencing services, Video On Demand (VOD), home networking etc., it has also resulted in increased cable modem penetration and deployment of cable telephony services, making cities digitally intelligent".

The need for GIS system in telecom was emphasized by Deshpande (2003) as "Unlike the map and survey data, Telecom network inventory and connectivity involves complicated logical relationships, which are difficult to capture on CAD platform. Migration of such data to GIS platform is also very complex, error prone and does not lead to cost, efforts or time reduction. Therefore, network inventory is created directly on selected GIS platform, using telecom application."

Some of the main requirements expected to be met by the GIS / Telecom

application are:

- Plan, design and engineer network and expansion
- Modeling of OutSide Plant (OSP) and InSide Plant (ISP) items up to port level
- Placement of Trenches, Cables, Structures and facilities in the OSP
- Facility layouts, equipment placement and port-to-port connectivity
- Inventory management including equipment assignment
- Repository of As Built and survey data
- Provide network data to OSS / BSS systems
- Answer service activation / provisioning queries
- Cable fault localization
- Several Sales, Marketing and Service fulfillment related functions (Deshpande, 2003)

Like many other similar companies, TT has complex infrastructure and it is difficult to maintain. TT has many paper maps of the infrastructure. The maps have many versions for the same area and inconsistencies between each other. Bartlett (2000) says that, "As cable systems age, the cable system trunk and distribution system changes along with the subscriber growth in the community. More cables, passive, amplifies and power supplies are added. When the plant expands, it becomes hardly recognizable from the original build".

Desphande (2003) has also reported that "Building on migrated data: OSP Survey data with trench, man-hole and hand-hole details, number and alignment of ducts is migrated from AutoCAD platform. Correct models of span and ducts are populated. Cables are also drawn using models developed on telecom application. Further, cross-sectional views of the trench are added and cables are associated with ducts. Cable splicing / connection and slack loop addition are carried out and lastly, as built data of cable optical and run length is entered."

It is also important to improve the quality of the system. Quality of the system is a relative concept, according to Albrecht (2007). Albrecht says "Nothing is or has innate quality; rather quality is related to purpose. Spatial data quality is therefore described along characterizing dimensions such as positional accuracy, or thematic precision. Other dimensions are completeness consistency, lineage, semantics and time".

According to Stojanovic, (1996), Stoimenov et al. (1993), Daosheng, (1995) following parameters determined the quality estimation criteria of the system.

- Geographic accuracy
  - discretization accuracy
  - raster map layer correctness,
  - position accuracy,
  - displayed vector entity precision
  - distance precision
- Attribute accuracy
  - attribute precision,
  - attribute completeness,
  - attribute (uniformity).
- Logical consistency
  - geographic consistency
  - correction of topological relation
- Graphic's quality
  - raster map graphic quality
  - vector data quality
  - symbol and annotation quality

The TT company is privatized for 30 years, and each year the Contractor company must make investments on it. They can prove the installations easily by using GIS. As Campbell (2001) stated, "maps have credibility, someone consulting a

map expects an objective representation of the regions it cover and the topic it presents".

Brown (2006) says "Google Maps and Google Earth are so useful, it enables you to create applications that combine mapping or earth information with your own set of data so that you can build customized views of information. To make the best of this functionality, however, you need to change the way you think".

TTGIS system supplies the following information and more as theoretically GIS systems are designed for:

- Spatially store, query, analyze, update and print out the graphical and non graphical assets
- Unique, seamless, consistent and secure database for entire organization
- Having proper functions for operator, analyst and managers to update and monitor the system
- Integrating with other systems
- Using multi user environment and relational database
- Storing countywide network elements up to the most detailed sections, including the subscriber location.

2.2 Methodology

This study has been done by the following methodologies. First of all the papers have been examined. After that the congress and books have been searched. For a wider research and finding the current developments, internet has been searched. After all of the above researches, direct participation has been done with the TT engineers and managers on the site.

In literature, it has been found that there was no study carried out for telecom

GIS system in Turkey. This study has been done since GIS is applicable to telecom wire line infrastructure.

2.3 Telecom Sector in Turkey

Change in the communication technology affects our life. In all around the world there are huge changes in telecom sector, especially in mobile world. With respect to International Telecommunication Union's (ITU) report, the mobile subscription and broadband connection will be more than the fixed subscription (Bitdünyası 1). This prediction has already happened in Turkey. The mobile subscribers in Turkey increased approximately to 65 million whereas wire-line subscribers decreased from 24 million to 16.8 million by 2009 (Bitdünyası 2).

The number of mobile telecom subscriptions increased but fixed line subscribers and number of new DSL subscriptions declined in Turkey in recent years. Moreover 3G wireless networks are also started to operate since June 2009, which may cause a decline in number of fixed wire-line DSL subscriptions. Finally there is no more compulsion to have a fixed line subscription for having a DSL connection.

The mobile telecom companies in Turkey, use GIS for planning, field tests for their cellular network coverage and network quality. Also they are giving services for "Where am I?" (such as Turkcell NEREDEYIM 7777) and "Where is the nearest facility to me?" (such as Acaba NEREDE 5255, Avea KimNerede?). The precision of mobile locating will be discussed in Chapter 5.

Turkey, like the rest of the world, was economically and socially affected and will be affected more due to these new communication technologies spread all over the world as it is also stated by Bouras et al. (2009): "Before the implementation of the broadband network the local economy was based mainly in the lead mining and forestry. The development of the broadband network contributed to the creation of

new jobs. The faster and better communication infrastructure attracted many car manufactures to create their winter testing facilities in Arjeplog. The above had a significant result in the reduction of the unemployment in Arjeplog." Change in communication means is changing the opportunities for people, public and government sectors and for telecom companies.

According to European Union (EU) report dated January 2009, in Europe, 200 out of 1000 subscribers have broadband connection, whereas it is 90 per 1000 in Turkey (Bitdünyası 1). This means that, there is an opportunity of doubling this number. Moreover amount of F/O cable infrastructure of Turkey is nearly 10% of the average Europe F/O infrastructure (Table 2.1).

Table 2.1 The ratio of usage of broadband technology in EU and Turkey
(EU 14th Monitoring Report, 2009)

	EU Average (%)	Turkey (%)
DSL	79,4	98
Fiber Cable	15,3	1,6
Other	5,3	0,4

These numbers show that in Turkey we have reached half of the subscribers with ten percent investment, also the amount/quality of infrastructure per subscriber is very low in Turkey. According to the telecommunication reports documented in Bitdunyasi web page, given in Table 2.2, the increase rate of new ADSL subscription was 293% in 2005. As it is given in Table 2.3 it is declined to 29% in 2008, and became less than %1 in the second quarter of 2009 (Bitdünyası 3). The ratios of investments and results in return of investments are supporting each other.

The new services, such as IP TV and other value added services are rarely available since the F/O infrastructure is very low in Turkey. To give better services

TT needs to install F/O cables and it is not easy to decide which locations should have better infrastructure first in order to implement these new services.

Table 2.2. The annual change in subscriber numbers between year 2004 and 2008 in ADSL Subscribers of TT (Bitdünyası 3).

	2004	**2005**	**2006**	**2007**	**2008**
ADSL Subscribers	452.398	1.539.477	2.813.143	4.545.795	5.894.522
(%) Increase		% 293	%82	%61,5	%29,6

Table 2.3. The quarterly change in subscriber numbers between year 2008 and 2009 in ADSL Subscribers of TT (Bitdünyası 3).

	2008-1	**2008-2**	**2008-3**	**2008-4**	**2009-1**	**2009-2**
ADSL Subscribers	5.009.135	5.292.840	5.616.697	5.894.522	6.000.174	6.056.519
(%) Increase		%5,6	%6,1	%4,9	%1,7	%0,9

With respect to OECD 2008 statistics given in Table 2.4 and Figure 2.1, the number of ADSL subscribers is around 25-30 % of similarly populated countries with Turkey such as Germany, France and UK.

Table 2.4: Broadband Subscriber in OECD Countries (OECD Broadband Stats)

Rank	Country	Broadband Subscribers, total
1	United States	77,437,868
2	Japan	30,107,327
3	Germany	22,532,000
4	France	17,725,000
5	United Kingdom	17,275,660
6	Korea	15,474,931
7	Italy	11,283,000
8	Canada	9,577,646
9	Spain	9,156,969
10	Mexico	7,604,629
11	Netherlands	5,855,000
12	Turkey	5,736,619
13	Australia	5,368,000
14	Poland	3,995,458
15	Belgium	2,962,450
16	Sweden	2,905,000
17	Switzerland	2,533,643
18	Denmark	2,021,404
19	Austria	1,792,406
20	Czech Republic	1,769,684
21	Hungary	1,696,714
22	Portugal	1,692,306
23	Finland	1,616,900
24	Norway	1,607,750
25	Greece	1,506,614
26	New Zeland	914,961
27	Ireland	896,346
28	Slovak Republic	618,671
29	Luxemburg	141,584
30	Iceland	99,883
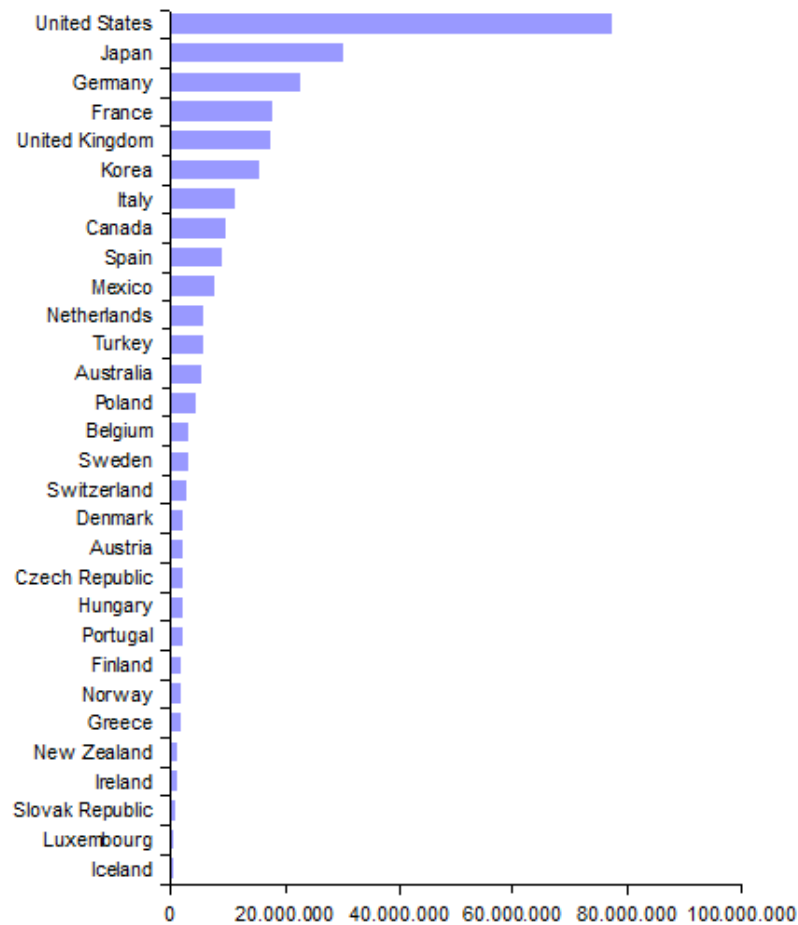
Figure 2.1 Total Broadband Subscribers by Country for year 2008 (OECD Broadband Stats)

TT needs to use many layers for GIS system. These are base maps which contain city plans, as built drawings and building information called "spot maps", principal and local infrastructure maps which contain manholes, poles, trenches, and copper cables, fiber optical cable (F/O) maps. TT has also subscriber database, which contains logical network data. Most of the network consists of copper cables and there is a huge need to replace them with F/O cables due to the fact that F/O has better capacity. High-speed broadband services cannot be supplied to subscribers with far from TT central buildings.

Due to these requirements, TT started to build a Geographical Information

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System (GIS) for digitizing her infrastructure on paper or Computer Aided Design (CAD) environment. With a proper GIS system and database, these data can be used in TT in a variety of applications, services and decision support system. After digitizing the data TT will have ability to control, improve and locate her inventory easily.

Turk Telekom (TT) was the only telecommunication company in Turkey until the monopoly ended in 2004. TT was the sole owner of the voice, data and video communications. However, there are new competitors in the market. TT can make better competition with other new companies if her engineers and managers know their assets installed already in the field and they can easily decide the locations for new installations. Currently these replacements and new installation are due with organizational knowledge, without a spatial decision support system. TT has already have F/O cable network but the major part of the network consists of copper cables.

By the year 2009 some companies, such as Türksat A.Ş and Superonline, started to serve high-speed (100MB) Fiber to the home (FTTH) internet, initiated in the largest cities such as Istanbul, Ankara and Izmir. Superonline had spent millions TL to increase F/O cable infrastructure from 4,000 km to 10,000 km in the last year. TT must use new technologies to compete with them.

Valuable information is gathered from GIS System. The digitization process will continue until whole network is created in the sub provinces and villages and the updates will be made on this system. The different departments in telecom can use these valuable data. For example the field team can use it for faster failure fixing similar to British Telecom (BT).

GIS technology can also help TT in digitizing the inventory of the network, to maximize the utilization of the current capacity, to minimize the inactive elements, better planning, to increase the satisfaction of customers both in failure response times and calculation of available ADSL speed, helps to give more services (such as

yellow pages) and locate the emergency calls in map by supplying coordinate of the caller to the emergency hotline (Police, Ambulance, Fire etc.). GIS will also help to decrease the expenses and increase the revenues.

Some of the advantages of using GIS technology in TT infrastructure are listed as below:

- Many paper and CAD formatted infrastructure investment and the replacements were occurred during the last 30 years. They will be digitized and stored in a geographically intelligent database system, which will also help to correct and to update the edge matching and inconsistent data problems during the digitization.

- It will be easy to calculate and tell the correct speed and service quality for Asynchronized Digital Subscriber Line (ADSL), Internet Television (IP-TV) or similar services.

- It will be easy to report the location and the path for new installations or replacements of Fiber Optical (F/O) cables.

- Digital Maps will be helpful to maintenance teams for fixing failures.

- The route from subscriber to the central can be traced, which will decrease the time required to fix a failure or will help to understand the problems in the voice quality and internet speed. These kinds of services will make the subscribers happier.

- The coordinate of the customer could be provided with a service in case of emergency, without asking it to the customer.

- It will be easy to report the empty, unused or unnecessary cables and infrastructure laid down in the field. It will be easy to report the empty holes in the trench in case of new requirements of installing new cables, no need to dig new areas.

- Also it will help to serve value added services of voice, data and video for subscribers and advertisers such as games, entertainment, security, education, health, etc.

2.4 Sample Telecom GIS Applications in Other Countries

There are many Telecom Companies in the world built GIS systems, or developing several applications for different departments. Some departments need infrastructure data for services, planning, operations, installations, marketing and sales department. Similar telecom GIS systems were built in different countries.

BT implemented a nationwide program to equip its 17,000 field service engineers with a comprehensive location based solution using GIS technology in 2001. It enables them to respond to and rectify network problems faster than ever before and is part of an overall initiative aimed at reducing the amount of time spent locating customers premises and in pinpointing faults, culminating in a predicted £23 million saving over the next five years.

BT staff was often called to a location, but did not necessarily have the relevant information to hand to solve the problem. This resulted in them having to drive back to one of BT's exchanges to obtain a copy of the network diagram, which was time consuming. They were also relying on local street maps to locate customers, which did not always provide the detail they needed.

The location-based solution enables engineers to first locate a property and then progressively zoom in to view road networks and local plant and network details, the location of underground ducts and finally the individual cables within these. In addition, engineers can see the proximity of the network to the customer, search by customer's address and postcode and plot the shortest route to get there, all saving further time and effort.

A similar GIS system was built by IMMCO Company in India, and the system is named as Intelligent Broadband Information System (iBISS). The system is developed for the following departments of telecoms:

- The **Network Operations Center (NOC)** use IBISS for trouble ticket dispatch at a quicker pace
- The **Engineering department** plan before they dig up, as the network plant data is made available overlaid with appropriate GIS land-base layers in IBISS.
- The **Accounting department** for the inventory report on its valuable assets out in the field has to simply pick the fields on which they wish to generate the reports and the powerful report generation option in IBISS does the rest.
- The **Marketing and Sales department** can use IBISS to locate their "Best Customers" based on specific criteria.

The IBISS system design depicted in the Figure 2.2 and the benefits of the system is shown in Figure 2.3, the integration of IBISS with other work management systems is displayed in the Figure 2.4.
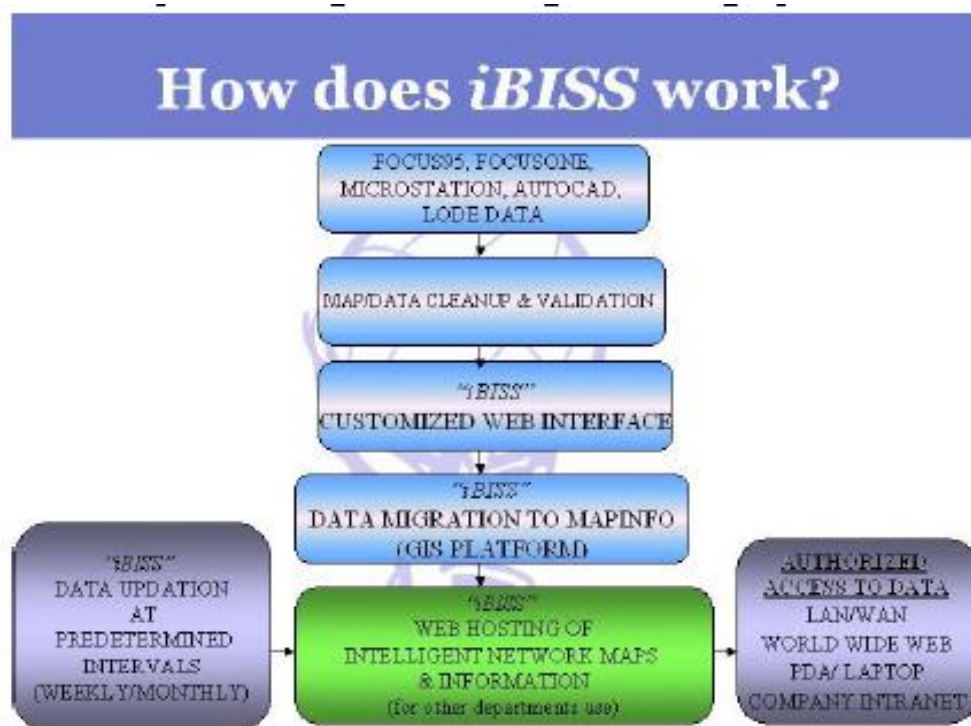
Figure 2.2: Configuration of a cable infrastructure GIS system of IBISS
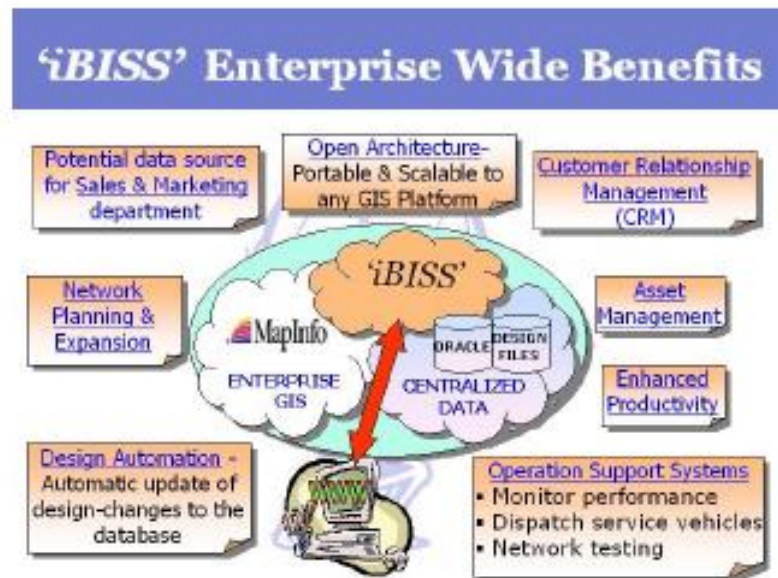
Figure 2.3: Benefits of GIS system and integration with other systems
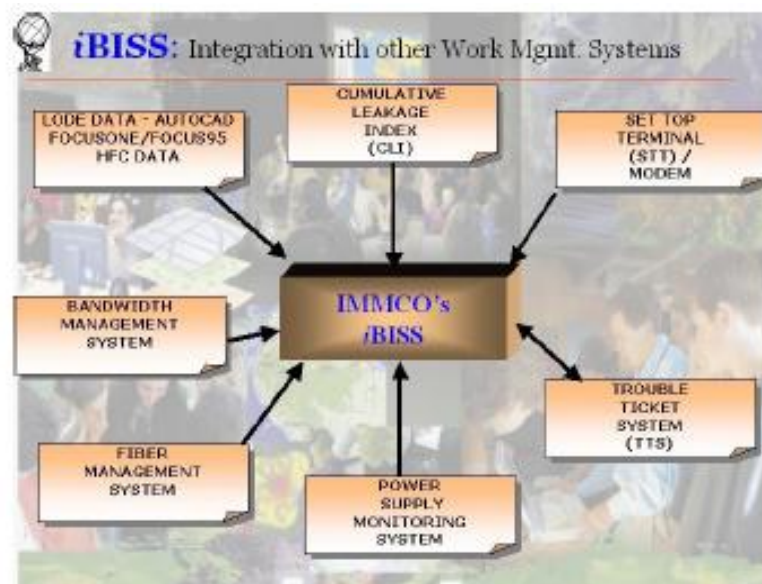
Figure 2.4. Integration of GIS with other work management systems.

Another example for wire-line GIS in Nis city of former Yugoslavia (Serbia), a GIS system, named as "GeoTT" was developed for Telephone and Telegraph department. GeoTT system with its spatial and active dimensions provides many advantages compared to the traditional solutions. Some of these advantages are:

• GeoTT gives control of the entire Yugoslavia TT network infrastructure up to the telephone cable pair.

• GeoTT integrates the most important technical estimates (distance calculating, coordinate translating and the other ones).

• GeoTT offers automated transfer of data from the acquisition device to the database.

• GeoTT offers precise data interpretation, graphics and many views on data.

• Data security is on the highest level.

• Data consistency is provided.

• Maintenance process is very simple and fast.

• GeoTT provides spatial queries and analyses. (Stoimenov et al., 1993)

Stojanovic et al. (1996) say "The full implementation of specific GIS must be preceded by the geographic data acquisition and conversion that can take a great part of complete system budget and time. Such digital geographic data organized and stored in the form of spatial database are the foundation of specific GIS implementation. The spatial database enables storing, processing querying, analyzing and displaying large amount of information about spatial properties of geographic entities (geometry, topology) along with their non-spatial, thematic attributes in the alphanumeric and multimedia (sound, image and video)". A sample application screen for multimedia is depicted in Figure 2.5.

The starting point of the phase for creating raster map database is preparing available paper maps at necessary scales. Each paper sheet is scanned all at once or in parts, depending on the scanner and sheets dimensions. Obtained set of files presenting the scanned parts of paper maps represent input (Figure 2.6) for dedicated software systems for creating raster map database (Djordjevic-Kajan et al., 1996).
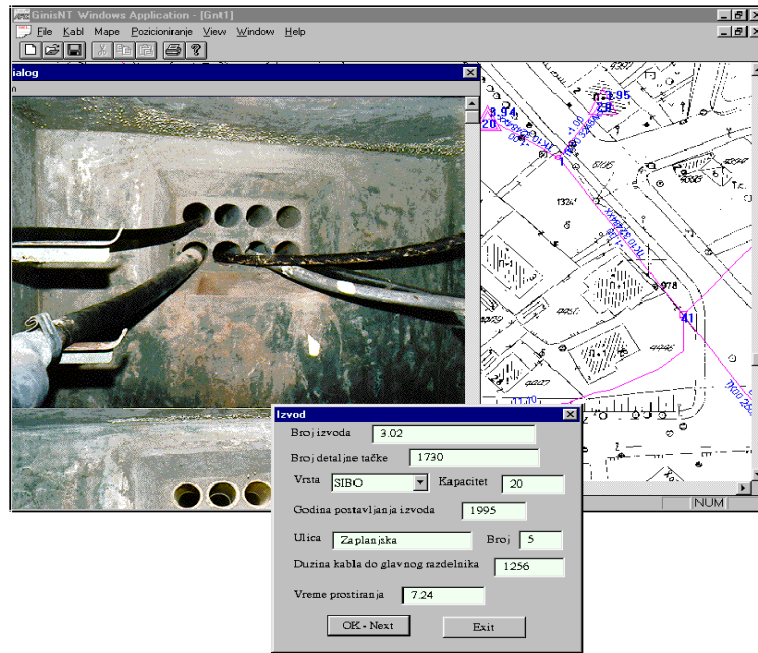
Figure 2.5. Vector and multimedia files displayed in GeoTT (Stojanovic et al., 1996)
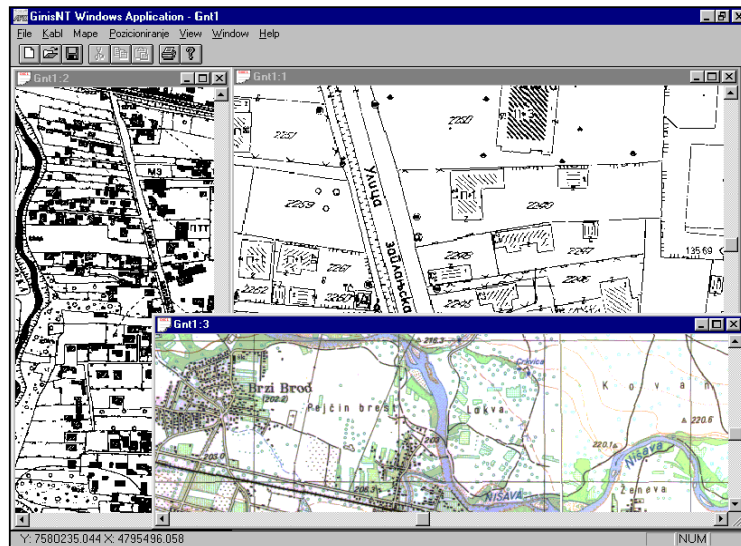
Figure 2.6 Raster data scanned from different scale maps displayed in GeoTT
(Stojanovic et al., 1996)

Name of some of the telecom companies and their web based GIS services are listed below.

- British Telecom (BT) Global Services (BRITISH TELECOM GLOBAL SERVICES)
- Telstra, Australia (Telstra)
- E.ON Netz ,Germany (E.ON Netz)
- TeleOS, Germany (TeleOS)
- Globalconnect, Denmark (Globalconnect)
- E-net, Ireland (E-net)
- E.ON Bredband, Sweden (E.ON Bredband)
- BKW FMN, Switzerland (BKW FMN)
- CityCom Graz, Austria (CityCom Graz)

2.5 About Turk Telekom

Turk Telekom has been presenting the contemporary communication media to its customers with excitement since 1840. Turk Telekom group provides integrated telecommunication services from PSTN, GSM to wide band internet. Turk Telekom group companies have 16.8 millions of PSTN customers, 6 millions of ADSL customers and 12.1 million GSM customers as of September 30, 2009. With its modern network substructure, covering the whole country, the group companies offer a wide range of services to its personal and corporate customers. Turk Telekom, who is the owner of the 99,9% of shares of the companies TTNET, Argela, Innova, Sebit A.Ş. and AssisTT, is also the owner of 81% of the shares of Avea, which is one of the three GSM operators in Turkey. Turk Telekom also supports Albtelecom in Albania. The 55% of the shares of Turk Telekom belongs to Oger Telekomünikasyon A.Ş. and the 30% of the shares belongs to Under secretariat of Treasure of Turkey. The remaining 15% of shares has been offered to public (Turk Telekom Web Page).

Turk Telekom (TT), made many Research and Development studies for Geographical Information System (GIS) since 1998. Sample projects were made by using MapInfo, Smallworld and ESRI. Speed of data production, easiness of usage, cost of total ownership, integration with other systems and customizability of software, multi user editing were analyzed. Several projects initiated such as data production in Ankara, İstanbul and Antalya, fiber optic (F/O) drawing and unknown numbers service (Dial 118) by using MapInfo Professional GIS product. In those projects the weak points of the architecture were analyzed. The main problems were storage of GIS data, integration with other applications and extending the applications within the TT departments.

Data transmission speed in network was also a major concern at the beginning of the project. Currently all of the cities are connected to the TT General Management Building and Computer Center with high speed connection, whereas in 1998 the speed was not suitable for GIS applications, but it was suitable for text based data transmission for example subscriber information.

In 2008 TT has made a contract to develop the current GIS applications and to get services for infrastructure digitization. In 2009, second phase of the project was initiated to get service for digitization of infrastructure, support for the existing applications and build new applications. However the system implemented so far does not support decisions on new implementations and service of the coordinates of subscribers.

CHAPTER 3

DATABASE AND SYSTEM DESIGN

In this chapter, the spatial and non-spatial data types, decision chart for the system design and database structure of TTGIS project are explained.

Some of the infrastructures were in paper format and those papers were scanned and digitized. Some of them were in CAD files and those files were converted into GIS format. The related information on the drawings was entered to the GIS objects. Standard types and categories were stored in look up tables.

According to Shi et al. (2009) "Geographic Information System manages the following: (a) spatial information, (b) temporal information, (c) attribute information and (d) topological relations. Spatial information describes the location and shape of geographic objects in which the user is interested. Attribute information describes the property, quality and characteristics of geographic objects. Temporal information describes the changes over time in geographic objects, while topologic relations describe the spatial relationship between geographic objects".

According to Stojanovic (1996), "the spatial components of digital geographic data consist of two kinds of spatial information: raster and vector. These geographic data completely describe spatial properties of geographic entities of interest including their geometry (shape, size, location) and topology (relationships with other entities). Also geographic entity is described by their non-spatial, thematic attributes describing their quantitative and/or qualitative properties and traits in the form of text, numbers, graphic symbols, sounds, images, video records and so on. In order to fully represent some important aspects of the geographic world, the spatial

database must be modeled and developed to include, store and appropriate organize all these data about geographic entities constituting this geographical aspect". Telecom GIS application was designed to store, spatial, attribute and topological information. The changes and time of change information were also logged in the system.

According to Vanikar et al. (1996) the spatial and non-spatial data should be kept together. "The telecommunications services have been computerized since about a decade and all this information was maintained in tabular form. The spatial information is being maintained in carefully hand drawn maps which are of several levels/kinds and innumerable. Whenever any changes are to be made in the telephone cables like diverting a telephone cable to another nearby pillar or erecting a new pillar, a lot of time is wasted in drawing the new maps or updating the already drawn maps. The personnel of the telephone department also have to take into consideration the existing telephone facilities that have been laid down i.e. they have to have the tabular information alongside while planning such changes. Hence, a need has been felt to explore the possibility of transferring the map information in digital format and to design and develop a software package to provide query based access using the available technology of GIS; where the spatial and non-spatial data could reside under a common umbrella".

The database tables were created in relational format. The logical database structure is designed for storing each different network element in a separate table and data of each province is stored in a separate schema. The users can connect to download and display their central region. In many provinces there are more than one user who may edit the same area. So a primary key field is defined and on each insert of database, this number is increased with a sequence numbering called within a triggering function. For multi user editing Oracle database is chosen. Oracle Management tools are used together with PLSQL Developer program for creating tables, relations, indexing and granting for tables. The desktop applications are developed on MapInfo with MapBasic, Borland Delphi and Microsoft .NET. Web

based applications were developed with Microsoft .NET on MapInfo MapXtreme.

3.1 Spatial and Non Spatial Data Types

In GIS projects several layers/tables are created. Vector, raster and text tables are used in the projects. The vector layers contain Point, Line, Region spatial objects types, but raster layers contain pixels/colors information. The text databases do not contain coordinates, but mostly contain coded or free type address information, whereas the spatial database contains both spatial and textual information in the same table.

3.1.1 Spatial (Vector) Layers:

In many GIS books, the standard vector objects are divided into three groups: Point, Line and Region. Due to the needs of the GIS sector, there are several new types recorded in Open GIS Consortium (Figure 3.1). Some of those types are listed below:

Point: X, Y, Style

Line: X1, Y1, X2, Y2, Style

Poly-line, Line-string: X1,Y1, ...XN,YN, Style

Surface/Region: X1,Y1, ...Xn,Yn, X1,Y1

Multipoint: Combination of 2 or more points

MultiCurve: Combination of 2 or more curves (line or line string)

MultiSurface: Combination of 2 or more polygons

GeometryCollection: Combination of Line, Region and Point objects or Block Object.

CAD files in local coordinate system are transformed by using affine parameters obtained from local municipality or Cadastral Departments.
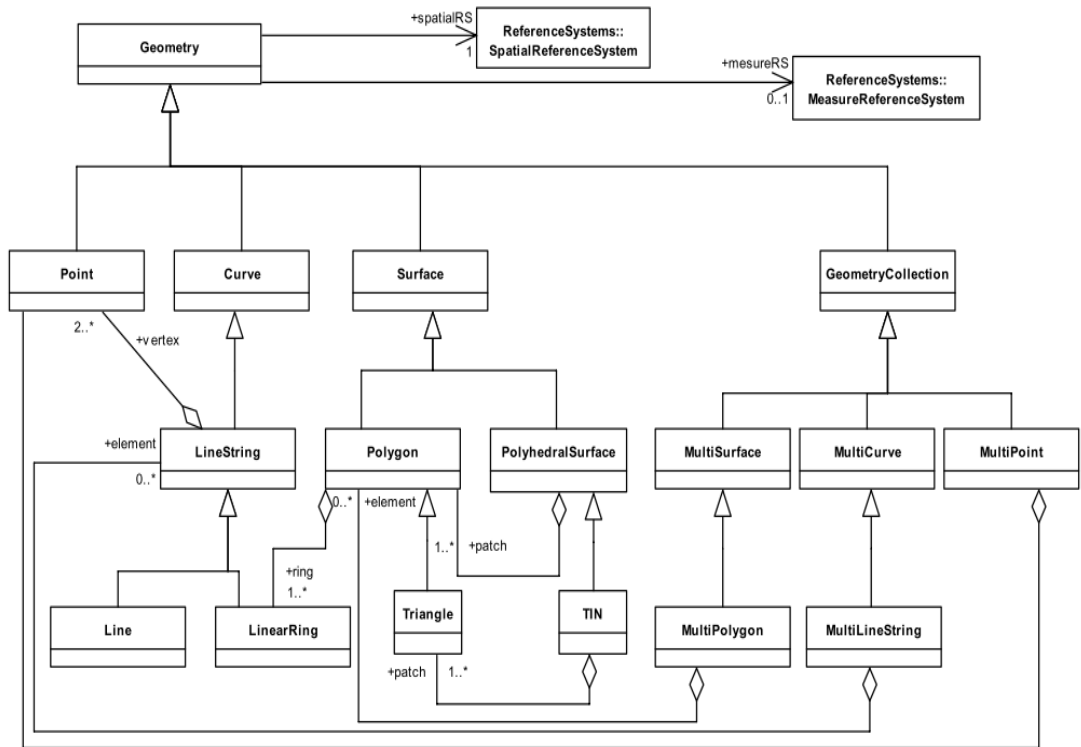
Figure 3.1 OGC Feature Geometry Schema (OGC Geometry)

3.1.2 Raster Layers

The paper maps were scanned and stored on server as raster files. These files were registered before digitization.

3.1.3 Other Non-Spatial Database Systems in Telecom:

There are some other databases, which store non-spatial data and look up tables, exist in TT. The spatial tables also have non-spatial attribute columns. Subscribers, invoices, Telecom Management System (TMS) and some other tables are example of non-spatial data. The connection between spatial and non-spatial tables are made by subscriber address and service box numbers.

3.1.3 Using Oracle SDO with MapInfo

Oracle have spatial database component named Spatial Data Option (SDO), since version 8.5. MapInfo can connect and use SDO tables with a direct connection. The spatial data definitions and parameters are stored in a separate table named as MapInfo_MapCatalog explained in Section 3.1.5.

"Oracle Locator is a feature of Oracle Database Standard and Enterprise Editions that provides core location functionality needed by most customer applications. Oracle Spatial is an option for Oracle Enterprise Edition that provides advanced spatial features to support high-end GIS and LBS solutions" (Oracle Spatial Web Page).

Oracle Locator, a feature of Oracle Database 11g (Express Edition, Standard Edition, Standard Edition One, and Enterprise Edition), provides core location features for many business applications and partner-based geospatial solutions. Locator provides vector data storage and management, indexing, spatial relationship analysis, coordinate systems support, SQL access, and more (Oracle Spatial Web Page). More information could be obtained about Oracle Locator Feature at Oracle web pages. Figure 3.2 depicts the components of this technology. Figure 3.3 shows the elements of the SDO_Geometry type.

Oracle Locator has the following features:

- Store and index vector geometries in the database
- Query nearest neighbor and other spatial relationships between geometries
- Perform location queries on relational information not stored in Oracle Spatial geometry

- Support long transactions

- Enhance application performance
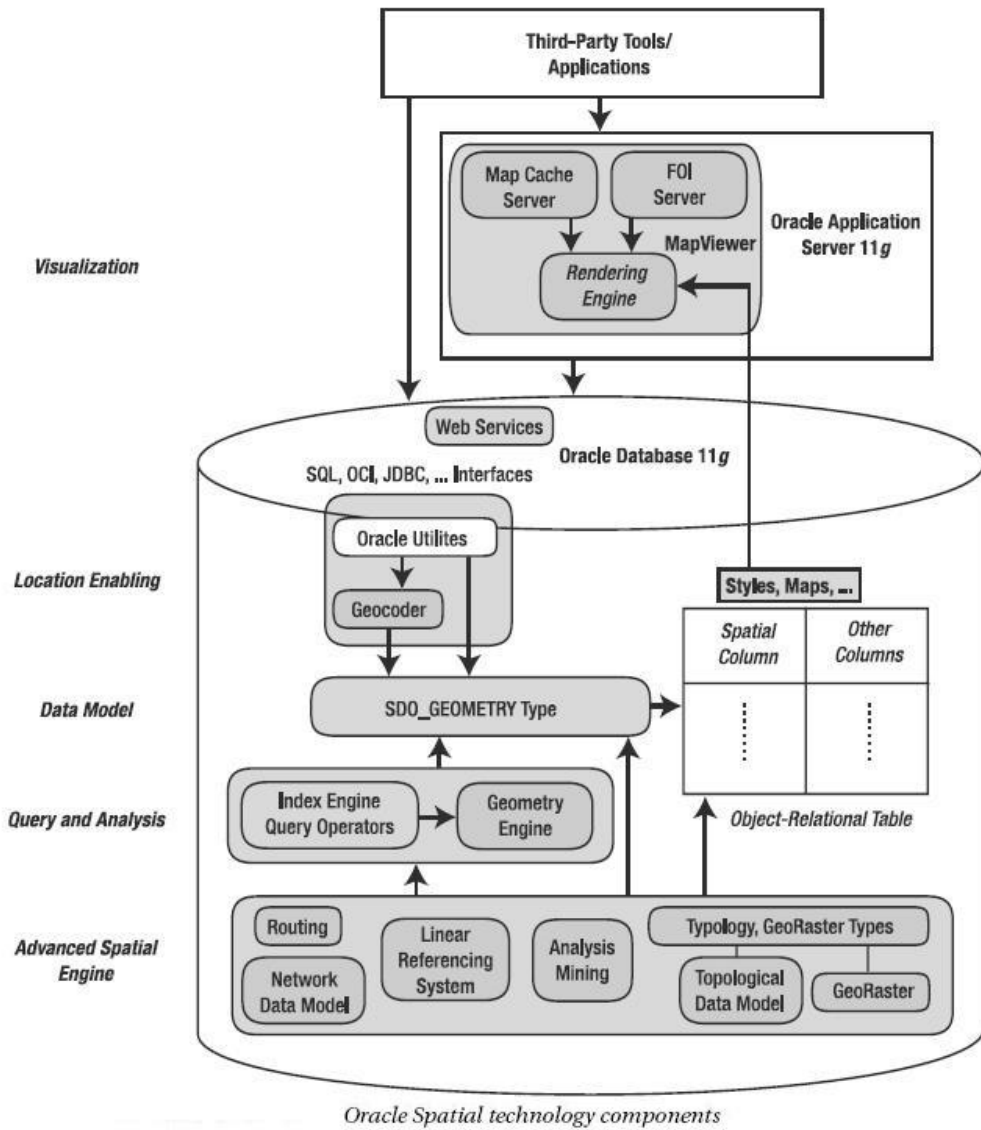
Figure 3.2 Oracle Spatial Data Option technology components (Oracle Spatial Web Page)

Oracle Spatial has the following features:

- Everything that Oracle Locator does, and:
- Perform length and area calculations on geometries
- Generate new geometries such as buffers and unions
- Perform coordinate systems transformations, for individual geometries or entire layers
- Store linear measure information
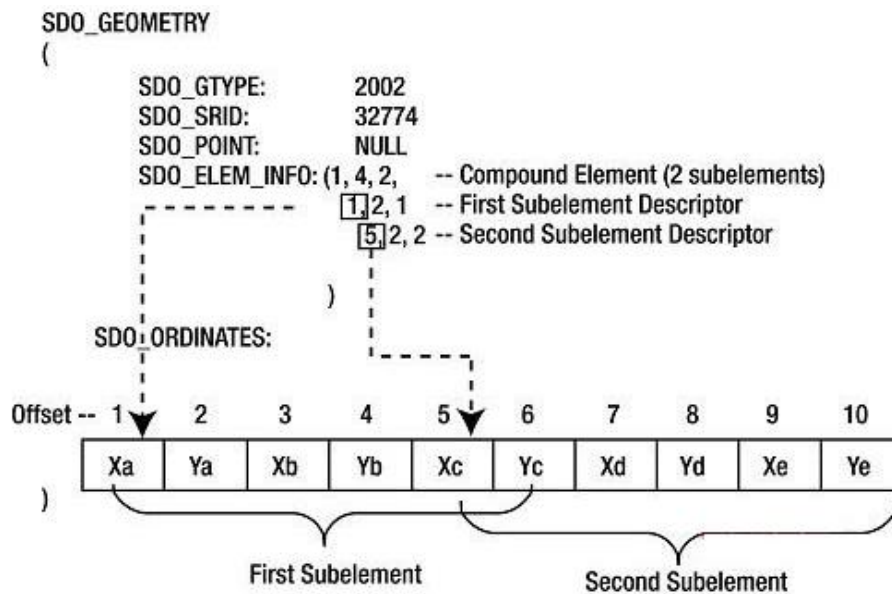
Figure 3.3. Explanation of Oracle SDO Geometry Object Type Elements (Oracle Spatial Web Page)

3.1.5 MapInfo MapCatalog

MapInfo MapCatalog table is used to store spatial table information in Oracle. In this table Spatial type, Layer/Table name, Oracle Owner name, Column name that stores spatial data, minimum and maximum boundary coordinates, Coordinate System, and style information are stored. The catalog information is given in Figure 3.4.

The steps of manual creation of MapInfo MapCatalog are explained as follows.

Step 1: Login to database with a user, which has Database Administrator (DBA) access rights. Create a user named "MAPINFO" with password "MAPINFO" in the database where the mappable tables will be located.

Create User MAPINFO identified by MAPINFO

Step 2: Create the table named MAPINFO_MAPCATALOG in the database. The Create table statement needs to be equivalent to this MapInfo create statement for the specific remote database. It is important to have the structure of the table exactly like the given statement.

Create Table MAPINFO_MAPCATALOG   (

SPATIALTYPE Float,
TABLENAME Char(32),
OWNERNAME Char(32),
SPATIALCOLUMN Char(32),
DB_X_LL Float,
DB_Y_LL Float,
DB_X_UR Float,
DB_Y_UR Float,
COORDINATESYSTEM Char(254),
SYMBOL Char(254),
XCOLUMNNAME Char(32),
YCOLUMNNAME Char(32)   )

Step 3: Create a unique index on the TABLENAME and the OWNERNAME so there is only one table for each owner that can be made spatial.

Step 4: Grant Select, Update, and Insert privilege are kept on the table MAPINFO_MAPCATALOG to user MAPINFO. This allows the tables to be made spatial by the MapInfo users. Deleting privilege should be reserved for DBA. The DBA should be aware of the documentation of the buttons corresponding to the privileges. Another problem could be the SPATIALTYPE column in the MAPINFO_MAPCATALOG. The value specified here can also prevent the user from inserting too complex spatial objects into the table. In using Oracle the spatial data type, one can specify the codes in Table 3.1.

Figure 3.4 List of TTGIS tables and information in MAPINFO_MAPCATALOG.

Table 3.1 List of spatial data types codes and Object types that can be stored

SPATIALTYPE Code	Object Types
13.0	Only Points
13.1	Only Lines
13.2	Only Regions/Polygons
13.3	Mixture of object types is possible

3.1.6 Tables of TTGIS User:

For each provinces of Turkey, a schema is created and named with the name of province, such as "Ankara", "Istanbul", etc. The list of tables for Ankara user is shown in Figure 3.5.
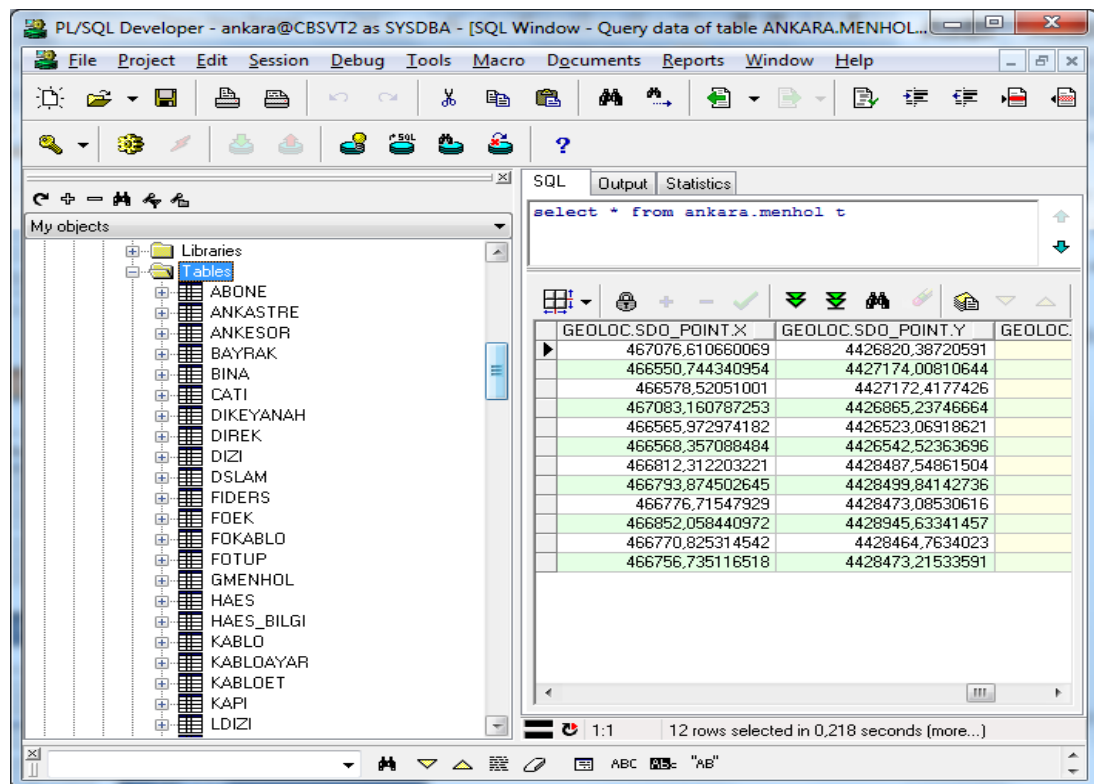
Figure 3.5 The table of the "Ankara" schema and SDO coordinates stored in a table.

The operators have a username and password to connect to the system. The users are granted to select, insert, delete and update tables either by Oracle user management tools or in batch mode.

In Figure 3.6, a sample SQL statement and the result text returned from the Manhole table is presented to show how spatial information is stored in the records by using Oracle SQL Plus application.

SQL>select TIP, OZELLIK, SANTRAL, NO, GMID, MI_STYLE, MI_PRINX, GEOLOC from menhol where rownum=1;

TIP	OZELLIK	SANTRAL	NO	GMID	MI_STYLE	MI_PRINX
A	64	31206009	30149	8095	Symbol(12,35,256)	1

GEOLOC(SDO_GTYPE, SDO_SRID, SDO_POINT(X, Y, Z), SDO_ELEM_INFO, SDO_ORDINATES)

SDO_GEOMETRY(2003, NULL, SDO_POINT_TYPE(467076.611, 4426820.39, NULL), SDO_ELEM_INFO_ARRAY(1, 1003, 1), SDO_ORDINATE_ARRAY(467078.863, 4426823.59, 467075.398, 4426824.11, 467074.359, 4426817.19, 467077.823, 4426816.67, 467078.863, 4426823.59))

Figure 3.6 SQL statement shows the spatial information stored in Oracle.

Uploading the data from MapInfo to Oracle Spatial

MapInfo has an application named EasyLoader.mbx for uploading the MapInfo files into Oracle. After running this application from Tools ➔ EasyLoader, a dialog appears. After connecting to a database by supplying username, and password, required tables can be uploaded to spatial database. This program applies DDL (create table etc) commands in the database and creates the records. See Appendix A for details of uploading MapInfo tables to Oracle.

Opening Oracle Data in MapInfo

Before connecting to Oracle using any application someone will need to:

- Install the Oracle Client, preferably the Oracle Instant Client 10.x.
- Setup the client by building TNSNAMES.ORA file.

Connecting to Oracle Databases to download tables

In order to retrieve a table from a remote database, an Oracle spatial connection needs to be performed. The new DBMS connection is made as follows:

1. **File > Open DBMS Connection** should be chosen. **Open DBMS Connection** dialog box displays.

2. **ODBC** or **Oracle Spatial** option is chosen from the **Connection Type** drop-down list. If only one driver type is available the control is disabled and the **Select Data Source** dialog box can be used directly otherwise:

3. **New** button is pressed. **MapInfo Oracle Connect** dialog box displays.

4. To connect to database the username, password and server name for the spatial database are typed as displayed in Figure 3.7. The Server name must be defined in user's TNSNAMES.ORA file and user should be created in Oracle.
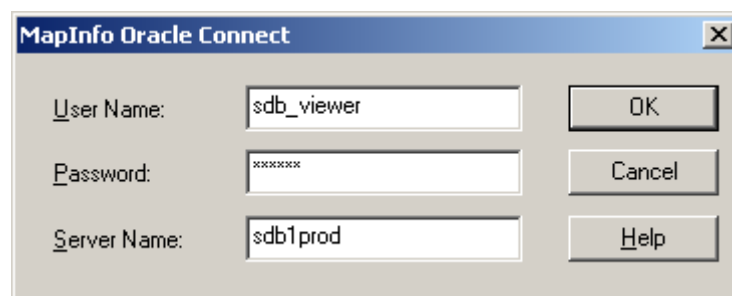
Figure 3.7 MapInfo Oracle Connection dialog

5. To complete the connection press **OK**.

6. After making the connection **File > Open** is chosen**.**

7. The Open dialog box should be displayed. Choose the database you wish to open for the file type.

8. This should bring up all of the available tables in that database. Choose the

connected username as in the **Owner:** select box at the top of the dialogue.

9. The layer that is needed to download is chosen.

10. The Open DBMS table option dialog box will appear. Choose standard mode, download the data (link table) for the options and define a destination location for the TAB file.

11. Click OK to complete.

The structure of the TAB file is shown in Appendix B.

3.2 Database Storage Decision Chart

Turkey is divided into 81 administrative provinces. In TT, Istanbul is split into two regions as Europe and Asia sides. Total 82 schemas were created. There were several database schema models tested in the past. One of them was storing one schema for whole Turkey. The second method was splitting it into 3 degree GK/UTM Projection Zones, and having 7 schemes. The last option was creating different schemes for each province. The main reasons behind these options were having a fast database access, better user management, and working on the suitable coordinate system. The advantages and disadvantages of the different schema structures are shown in the Table 3.2.

All three options were evaluated in a pilot application. The final decision was made as having different schemes for each province, the 3rd Option, because of more flexibility per province, better performance for each scheme, easy maintenance per province and easy programmability. One another reason is having the data and staff available for the provinces are not similar. The disadvantage of the chosen method is difficulty in maintenance, the needs to apply all setting for each schema. The Database server, Application servers, Web Map server and Users of the system are schematized in Figure 3.8.

Table 3.2 Part of the Decision Chart for Database Structure Possibilities

	Opt1 One Schema for Whole Turkey	Opt2 One Schema for Each 3º Zone	Opt3 One Schema for Each Province
No of Occurrence For Each Database Table	1	7	82
Coordinate System possibilities	Lat/Long, Lambert,	Lat/Long, Lambert, GK 3 Degree Zones	Lat/Long, Lambert, GK 3 Degree Zones
User Access Controls for Editors	Cannot be set as per Table, must be set for a province, sub-province or a central region	Cannot be set as per Table, must be set for a province, sub-province or a central region	Can be set as per Table
Summary data for Managerial tasks	From single schema	From a combined view of tables	From a combined view of tables
Changes In Data Structure	Need to apply to one table only	Need to apply to 7 tables	Need to apply to 82 tables
Latency In Processes	Other users in different cities will be affected	Slightly will affect other users in different cities	Will not affect other users in different cities
Distributed Databases in Different Location	Difficult to maintain	Easy to maintain	Easy to maintain
Flexibility in Application Development	No problem, But in each and every query must include many SQL where conditions clause	No problem, But in each and every query must include many SQL where conditions clause	No problem, Some queries must include less SQL where conditions clause
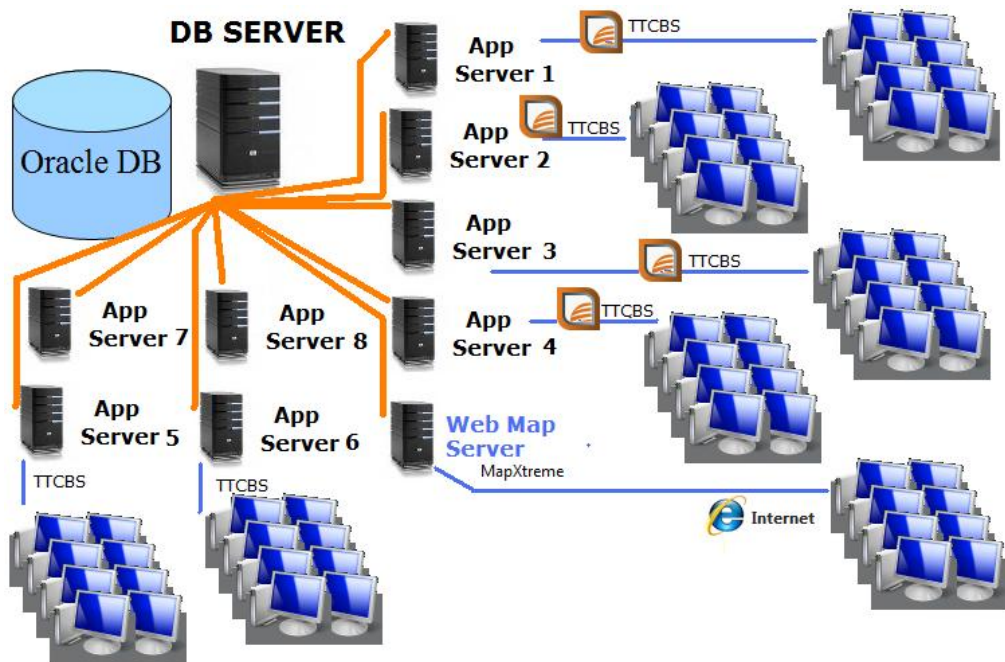
Figure 3.8 TTGIS System Architecture

3.3 Database Structure

In spite of the fact that in many of the GIS projects the main tables are named as Administrative Areas, Streets and Buildings, TTGIS project primarily focused on her network layers due to the fact that, the cable installation was not made by considering the administrative area boundaries. Since the main focus is the cable network and accessories for the TTGIS project, the address layers are used mostly for information or referencing. Table 3.3 and 3.4 shows the TTGIS network layers and base layers respectively. When the data is uploaded from MapInfo to Oracle, MapInfo creates a primary index column named "Miprinx". This column is used as primary key. Appendix A describes how to upload the data to Oracle from MapInfo by using MapInfo Easy Loader application. The content of the downloaded layer metadata information is given in Appendix B. Handling the spatial layers catalog information is described in Appendix C.

Table 3.3 The Cable Network and Accessories tables/layers used in project database:

Name In Turkish	Table Name	Description/ Usage	Primary Key	Object Type
Ankastre	Ankastre	The mechanism of building telecom cable infrastructure	Miprinx	Point
Ankesor	Ankesor	Phones in the Streets/Public Areas	Miprinx	Point
Bayrak	Flag	The holes within the trench	Miprinx	Point
Cati	Roof	Repartitor detail	Miprinx	Point
Direk	Pole	Pole	Miprinx	Point
Dizi	Sequence	Local cable sequence(A,B)		
Fider	Feeders	The feeders from box to building	Miprinx	Line
Gmenhol	Real Manhole	The real manhole location.	Miprinx	Point
Kablo	Cable	The cable path and information	Miprinx	Line
Kabloayar	CableSettings	Cable settings lookup table	Id	-
KabloEt	CableThickness	Cable Thickness lookup	Id	-
Kapi	Building Entries	Door number	Miprinx	Point
Menhol	Manhole	Manhole Layer	Miprinx	
Proje	Projects	Project Layer	Miprinx	Line
ProjeSinir	ProjectBoundary	Project Boundary Layer	Miprinx	Area
Santral	Central Region	Central region layer	Miprinx, Santral_ID	Region
SD	FieldBox	Field Service Box	Miprinx,	Point
SDSinir	Field Box Service Region	Field Box Boundary	Miprinx,	Region
SntBina	Central Building	Central Building layer	Miprinx,	Region
Transe	Trench	Trench that carries cables	Miprinx,	Line

Table 3.4 The Base and Reference tables/layers used in the project database:

Name In Turkish	Table Name	Description/Usage	Primary Key	Spatial Object Type
Ada	Parcel_Block	The outer boundary of parcel lots.	Miprinx, Ada_No	Region
Belediye	Municipality	Municipality Boundary	Miprinx	Region
Bina	Building	Footprint of the buildings, Reference layer from as built maps	Miprinx	Region
Hata	Problems	Problems layer	Miprinx	Point
Ilce	SubProvince	Sub province Boundaries	Miprinx	Region
Mahalle	Quarters	Lowest administrative area	Miprinx	Region
Parsel	Parcel Lot	Boundary of ownership	Miprinx	Area
Site	Subdivision	Reference layer from as built maps	Miprinx	Point
Yolorta	Street Centerlines	Road Centerlines	Miprinx	Line
Yolkenar	Sidewalks	Road boundary layer from as built maps	Miprinx	Line
YolAd	Street Names	Street name archives		-
Onem	Landmarks	Important Locations and Buildings	Miprinx	Point
OnemAlan	Landmarks	Important Locations	Miprinx	Region

The relation diagram defined between the data layers is given in Figure 3.9
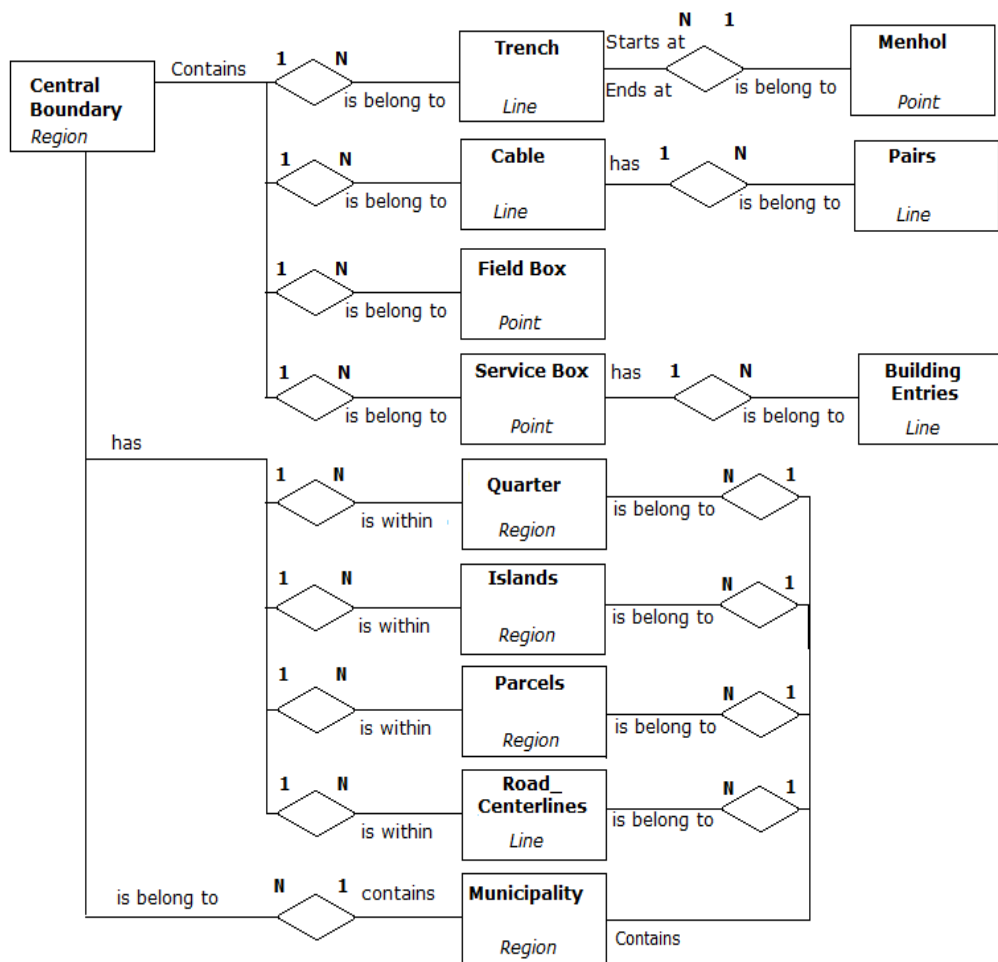
Figure 3.9 Part of TTGIS database relations diagram.

3.4 Software Development Environment

TTGIS applications were developed with Borland Delphi 7 and Microsoft .NET Framework C# Visual Studio 2008. MapInfo v9.5 and MapXtreme .NET 2008 is used for desktop and web applications respectively.

MapInfo is used within the Delphi Application with OLE (Object Linking and Embedding). Some of the applications are developed with MapBasic and these MapBasic applications are called within Delphi I. The OLE integration codes are given in Appendix D.

CHAPTER 4

GIS APPLICATIONS

In this study, several applications depending on the organization of TT departments are developed. There are data entering people in TT. The first group of staff is drawing spot maps, another group was drawing infrastructure elements and cables. A third group was working on drawing Fiber Optical cables. A separate group was working on new projects, and they needed a special application for cost calculations. For managers, web-monitoring application has been developed which is used to view either the whole Turkey infrastructure, or only a city or a part of database, and to make spatial analysis on them. The web monitoring application is also used for spatial decision support system.

After drawing the physical network of the system, it became possible to calculate the ADSL speeds on real network and a calculation tool is developed. This tool is also used for spatial decision support system whether or not to replace the infrastructure with F/O cables.

TT has got many contracts for implementation of security systems called MOBESE (Mobile Information and Electronic System Integration) for security departments. MOBESE systems use security cameras installed in the important locations of the city. The Dial 155 Police hotline department uses these cameras. They need to know the location of the camera. They also need to know the location of the caller. The fix phone subscribers are geo-coded by using their addresses and service box numbers. Subscriber coordinates could be provided to other emergency department hotlines since subscribers are located on the map. This tool needs a hardware installation on the hotline central, to convert dialer number into digital

format, so the application can automatically asks the coordinate of the caller.

The main applications in TTGIS system are listed below.

- As Built Drawing and Data Entry Application (Spot)
- Cable Drawing and Data Entry Applications
    - Infrastructure Drawing
    - Copper Cable
    - Fiber Optic Cable
- Project Preparation Application
- Web Monitoring Application
- ADSL Capacity Application
- Providing Coordinate of Fix Phone Number as a Service

4.1 As Built Drawing and Data Entry Application (Spot)

This application is used to:

- Draw buildings and roads from as-built maps and plans which are scanned or translated from CAD into GIS format
- Enter building type, no of floors, no of flats and no of shops in the building
- Enter street name
- Draw boundaries of municipalities, central service regions

The user case UML diagram for spot application is given in Figure 4.1 and user case data entry diagram is given in Figure 4.2.
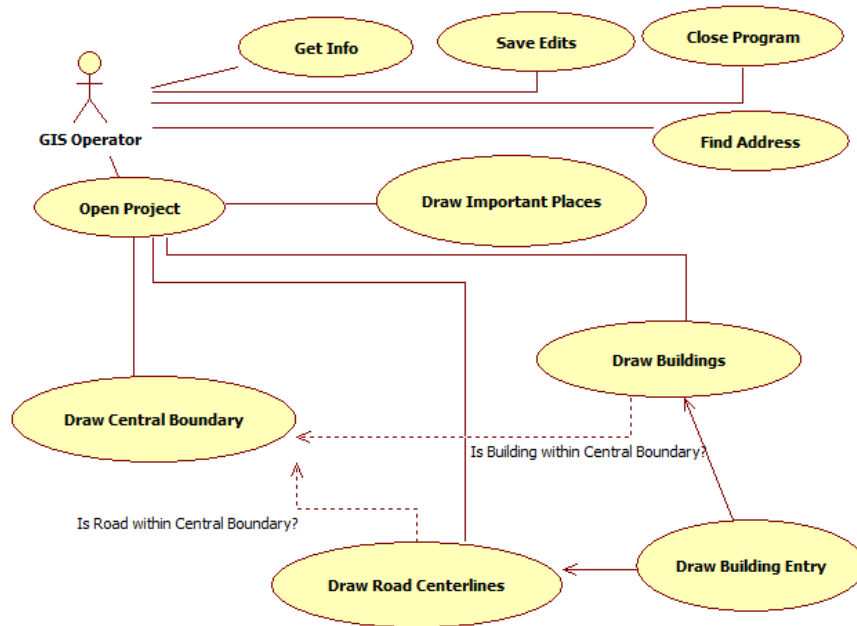
Figure 4.1. Spot Application Use Case Diagram
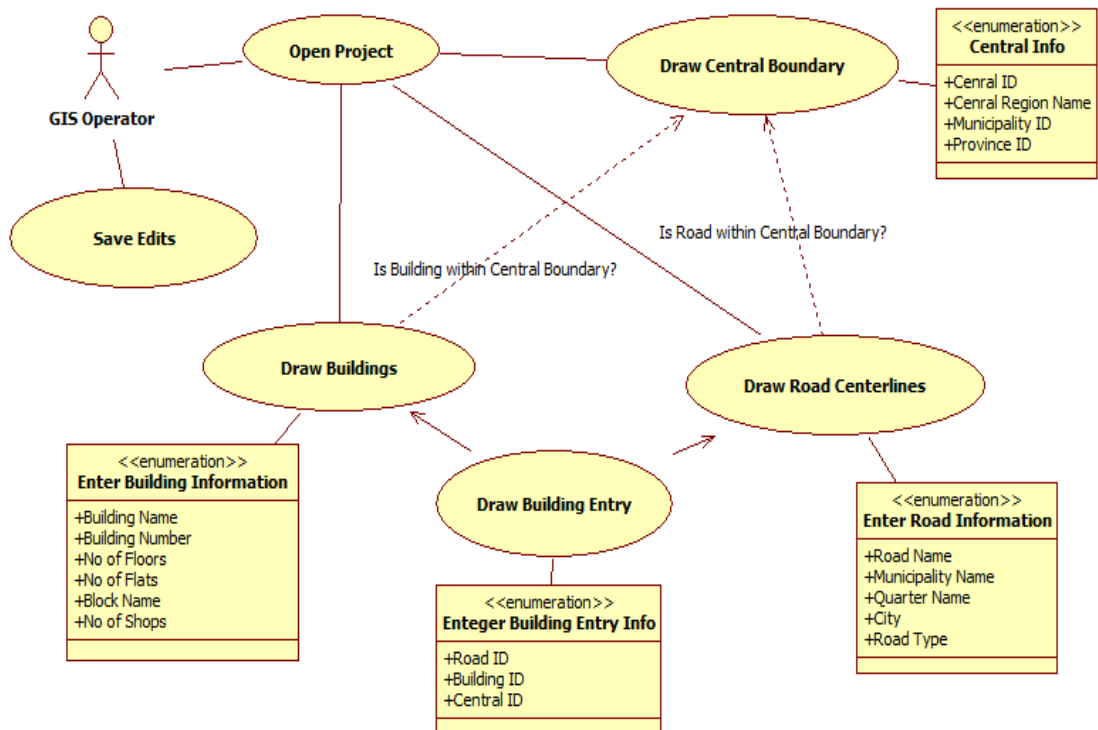
Figure 4.2. Spot Application User Case Diagram with Data Entry

4.2 Cable Drawing and Data Entry Applications

Copper cables are divided into two groups as local and principal cables. Principal cables between the centrals and local cables are from centrals to the field boxes.

4.2.1 Infrastructure and Accessories

Manhole, Trench, Field Box, Service Box, Pole and their detailed drawings are made in the application. Each item is stored in a proper table with its attribute table. The drawing procedure is given in Figure 4.3.

The drawing starts with Central Building Boundary, and it is drawn by a super user or moderator. Central Building is drawn first, then Repartitor is drawn (see Figure 4.4), Manhole and trench are drawn, and then Fuses are drawn (1 to 18 with 1800 pair capacity for each fuse, named from A to U), Field box and Principal cables (between Central building and Field Box) are drawn, then Field box Series are drawn (A, B, C to O). Each Letter conveys 100 pairs, and each 10 pair is represented with a number from A-1 to A-10, then service box and local cable between SB and Field box are drawn. Then ankastre is drawn and it is connected to service box. The telephone, fax, internet, cable TV etc are connected to the ankastre from each flat.

There is another type of cable called Rigid Cable infrastructure drawing, which is explained below:
- Central Building is drawn,
- Repartitor is drawn,
- Manholes and trenches are drawn

- Fuse and principle cables are drawn,
- Rigid cables are drawn to Subscriber Service Box directly.

4.2.2 Copper Cable Drawing Application

The copper cables consist of principal and local cables. The cable could be buried in trenches or hanged between the poles. The cable consists of several "pairs" divided into groups of hundreds and tens. As an example: a cable exit from Central Building, with a capacity of 1800 pairs, it will split into several branches of hundreds and each branch split into tens and end in the building service box. The tens of pairs are connected to the flats as one or more pairs.

This application is used to split and distribute the cables along the trenches and field boxes. Each branch has a naming convention such as A, B,C ...etc. Then it is split into A1, A2, A3, etc. The drawings are made in a topological order so each customer connection could be traced up to the main central. A real object representation of the drawing is depicted in Figure 4.3. The application and sample drawing of a Central is shown in Figure 4.4.

To start drawing an infrastructure element, the Region of the Central must be defined first (Figure 4.5). The Use Case and the work flow diagram of the cable drawing application are shown in Figure 4.6 and Figure 4.7 respectively. The user's responsibility area must be defined in User Rights table. The drawing should start from Building of the Central and continue by adding Manholes, Poles, Field Boxes, Service Boxes, Feeders and Trenches between the manholes. The cables between all of the above elements should be drawn from Source to destination (e.g. from Pole/Manhole to Pole/Manhole, from Pole/Manhole to Field Box, From Field Box to Service Box, the Feeders) should be drawn from service box to building.
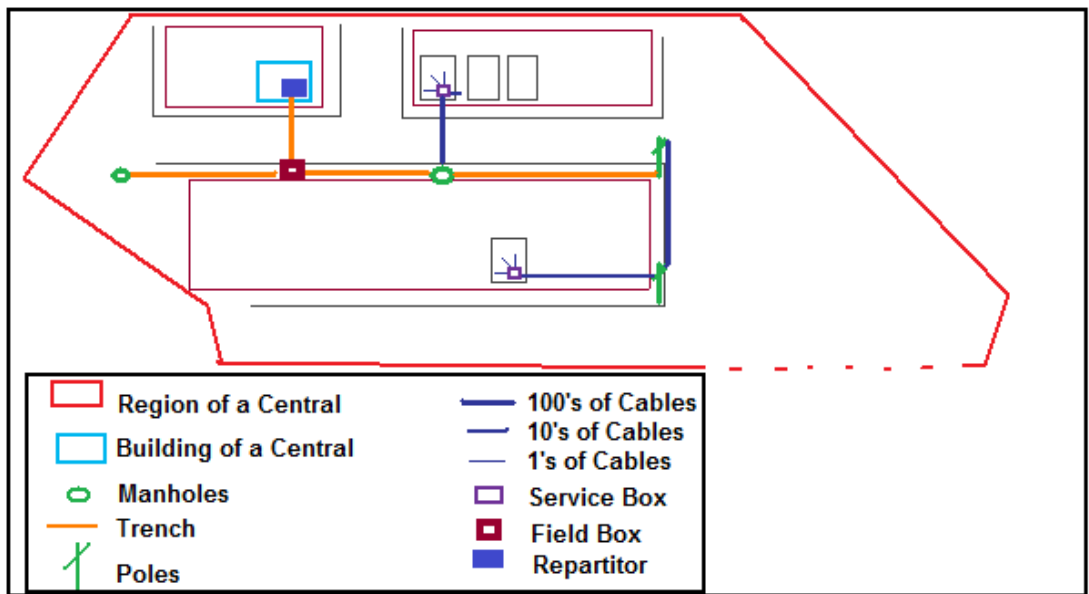
Figure 4.3 A sample drawing of central, manhole/pole, field box, service box etc.
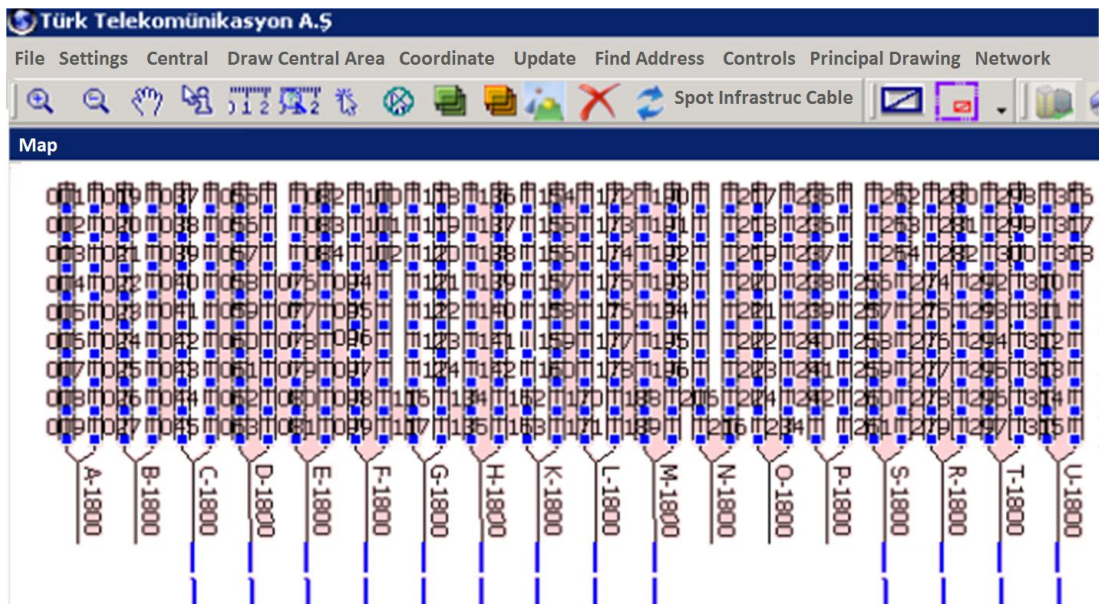
Figure 4.4 Drawing of a sample Repatitor within Central Building
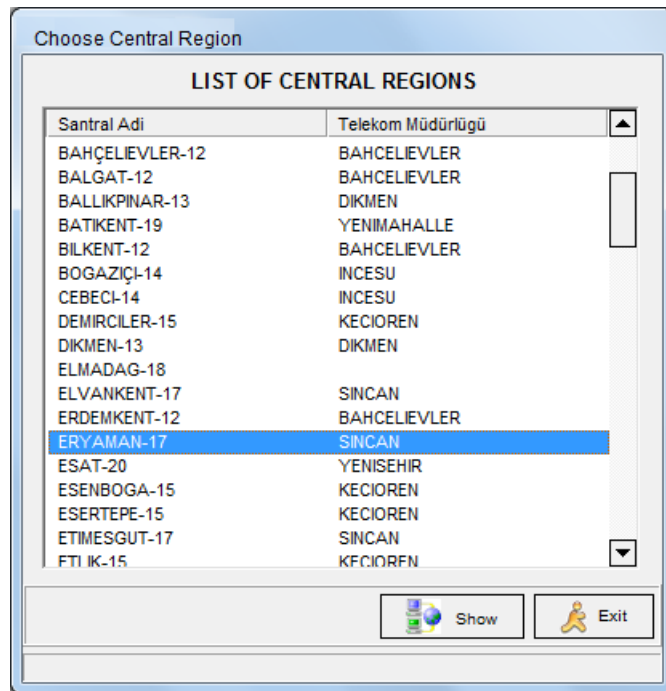
Figure 4.5 Choosing the Central Region to make editing in that region
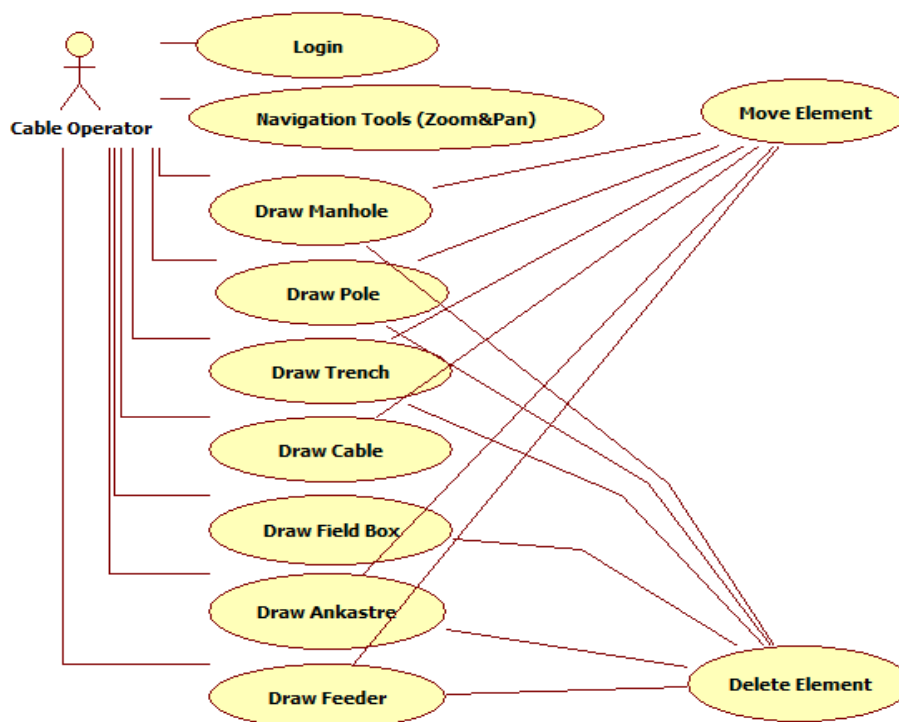
Figure 4.6: The Use Case Scheme of the Copper Cable Infrastructure Drawing
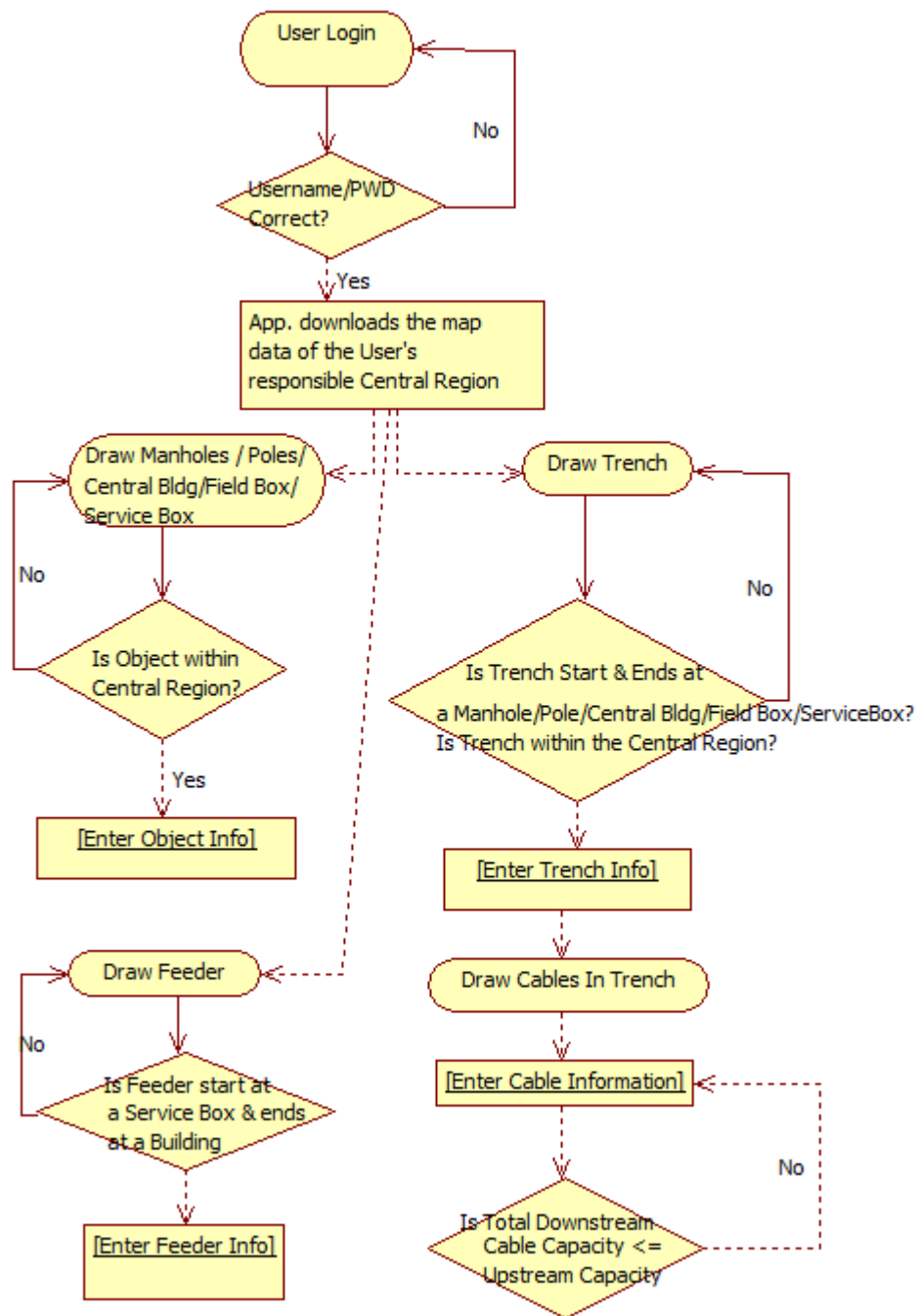
Figure 4.7 The Workflow Diagram of the Cable Drawing Application.

4.2.3 Fiber Optic Cable Drawing Application

Fiber Optic module (Figure 4.8 a and b) is created to digitize F/O cable infrastructure. An optical fiber (or fibre), which is a glass or plastic fiber, that carries light along its length. Fiber optic is the overlap of applied science and engineering concerned with the design and application of optical fibers. Optical fibers (which permits transmission over longer distances and at higher bandwidths or data rates than other forms of communications) are widely used in fiber-optic communications. Fibers are used instead of metal wires because signals travel along them with less loss, and they are also immune to electromagnetic interference. Fibers are also used for illumination, and are wrapped in bundles so they can be used to carry images, thus allowing viewing in tight spaces. Specially designed fibers are used for a variety of other applications, including sensors and fiber lasers.

Fiber optical cables does not have pairs and can be freely connected to another F/O cable, and due to that tracing logic is different than the one for copper cable network. Unlike the Copper Cable, which allows only one connection over a pair of cables, F/O cables can serve many connections over each fiber.

(a)

(b)

Figure 4.8 Fiber Optical Cable Application, a) The main form b) The data entry form
of the F/O cable.

4.3 Project Preparation Application

This module is designed for cost calculations of new network installations. This module is used to digitize planned network elements and related information considering the geographical structure, economical status, level of development and population increase rate of the region of interest. The same drawing tools are used in this application.

After drawing the project boundary, i.e, the area is defined for the planning engineer and operator (Figures 4.9). The project area could be changed afterwards, or Project details can be entered at any time (Figure 4.10).

Project Module uses the base and as built maps of current infrastructure data, (Figure 4.11), which is created by related TTGIS modules. After digitizing and entering the information, the project cost can be calculated.
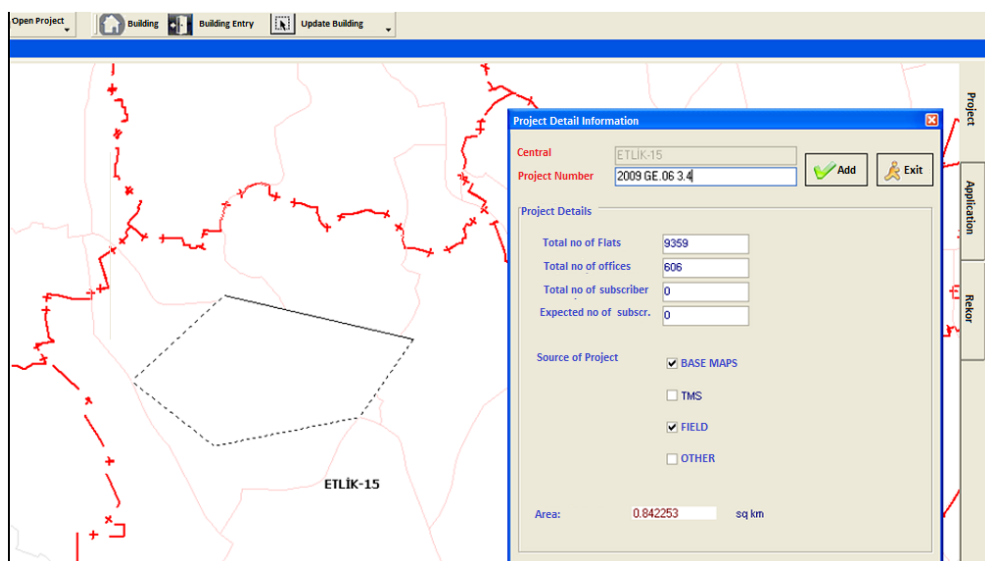
Figure 4.9 Project boundary and settings form for the project area.
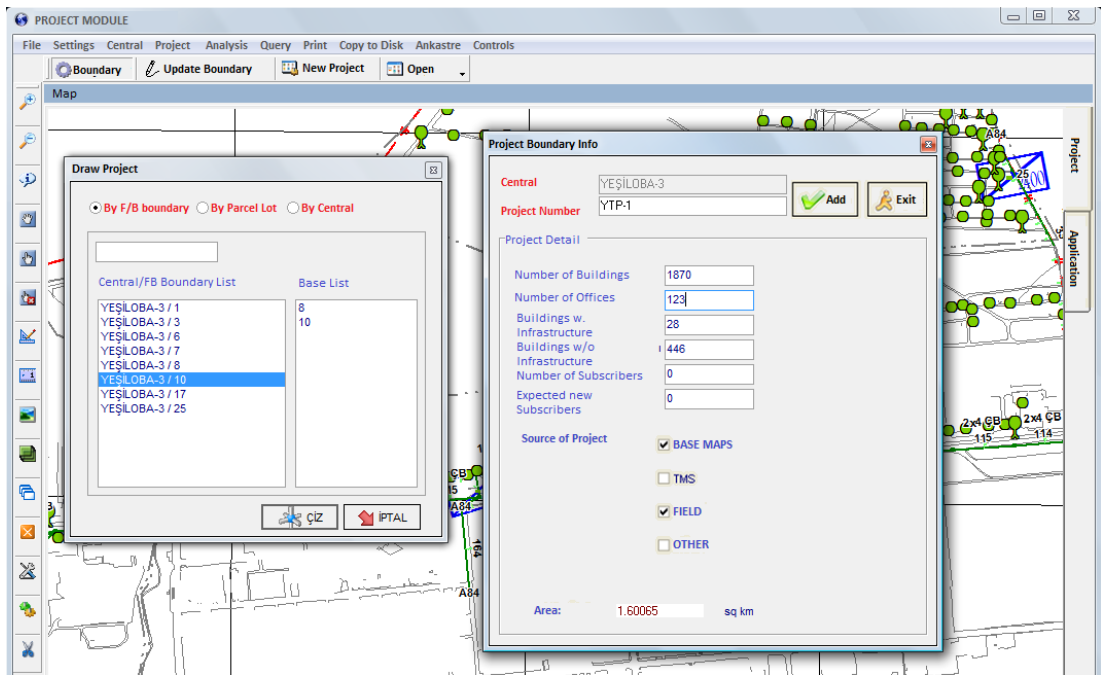
Figure 4.10 Project Area selection by field box numbers and project boundary information entry.
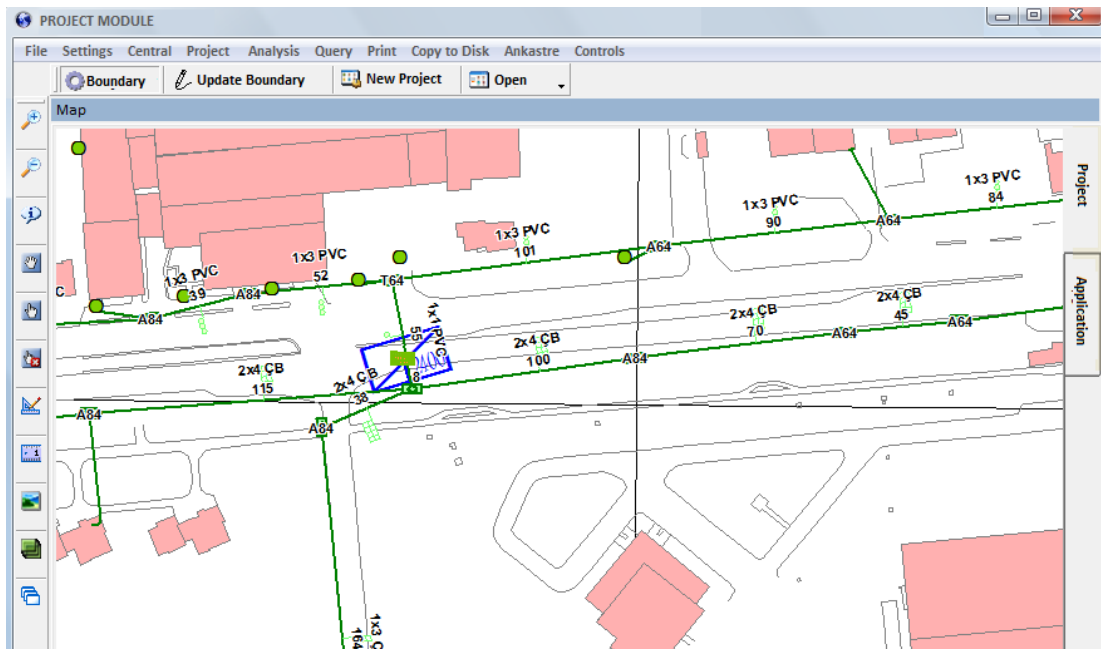
Figure 4.11 Existing network elements in the project area.

It is possible to query, analyze and prepare bill of materials and labor cost.

The project could be exported and stored in a local computer for field investigations and contractors. For each project area, it is possible to create different scenarios, and the alternatives are saved separately. Figure 4.12 shows the existing projects in the same area.
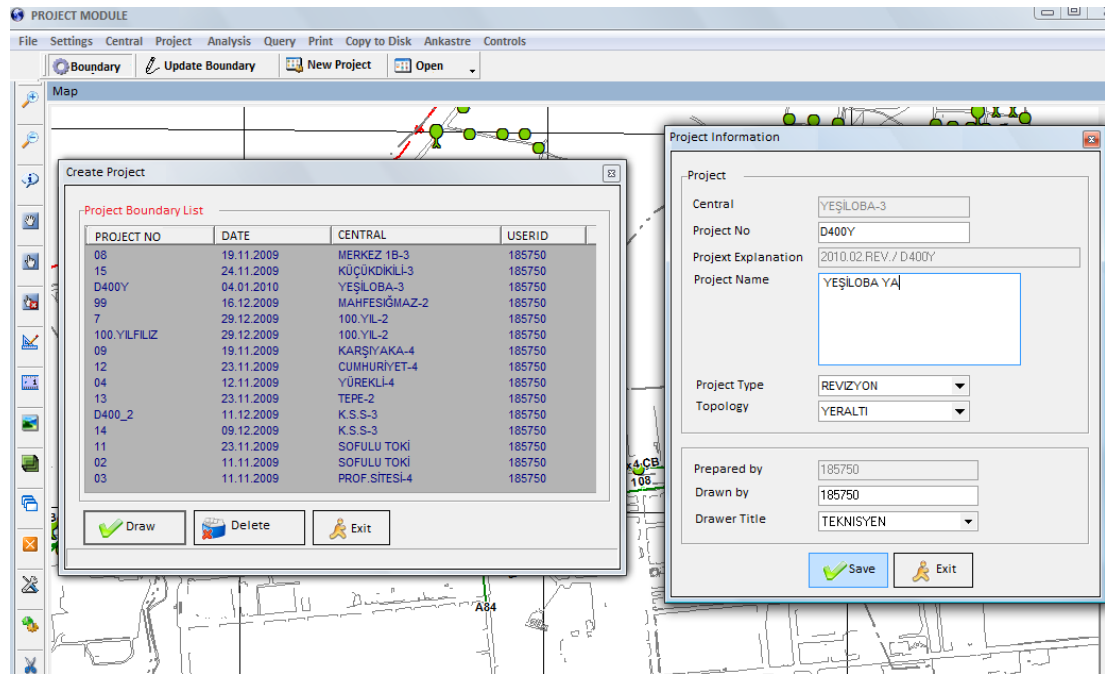
Figure 4.12 The list of exiting boundaries and selected project info entrance

The planned or offered objects are stored in separate layers (Figure 4.13), which could easily be updated to existing network layers. All the projects prepared in different provinces and Central regions are stored in the main server. It is possible to create alternative plans in the same project area.

After preparing a project, updates and changes could be made at any time. The existing elements cannot be deleted but can be marked for cancelling or displacement. Estimated costs can be displayed and printed. Amount and cost of each item to be constructed, used and required labor cost and total cost can be analyzed by

the application. The result could be exported into Excel and Word documents.
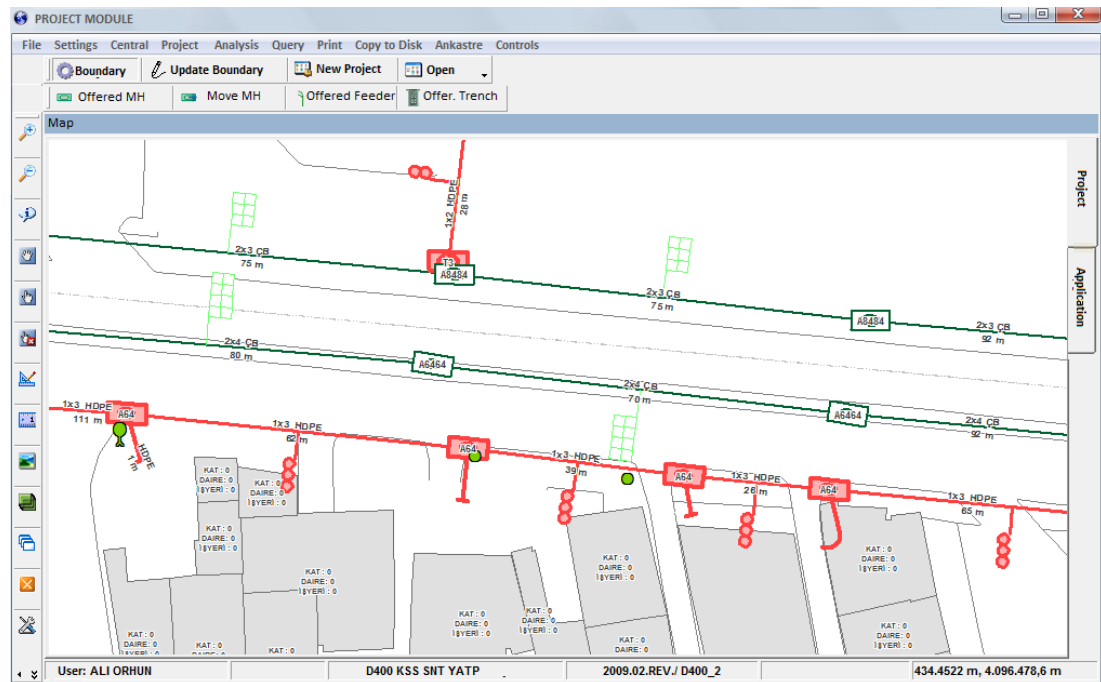
Figure 4.13 Planned objects are drawn in separate layers in red color.

The application can calculate interim and final project costs and can show the plans together or separately (Figure 4.14). The portable or local version of the application and the data of the project area are easily delivered (Figure 4.15) to contractors. The contractor can make the final changes and submit it back to TT. This feedback is very important for updating the existing network.

The application has a scaled printing option with a corporate legend as seen in Figure 4.16.

Figure 4.14. List of element types, amounts listed in project interim report.
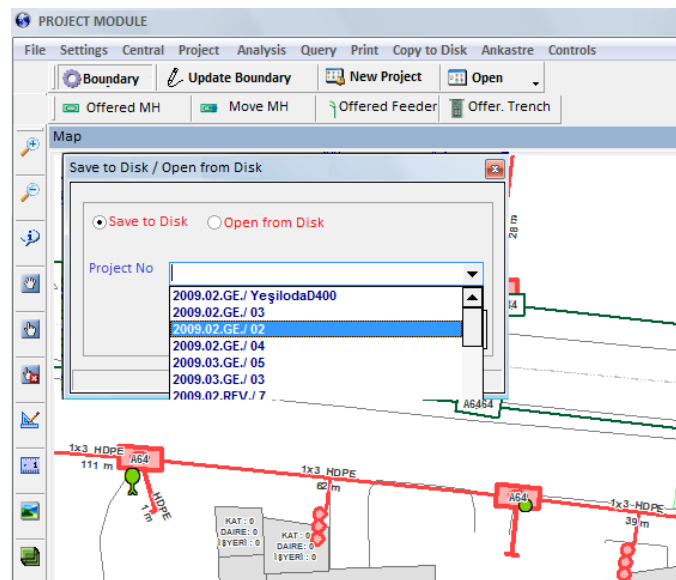
Figure 4.15 Exporting project elements for local usage for contractors.
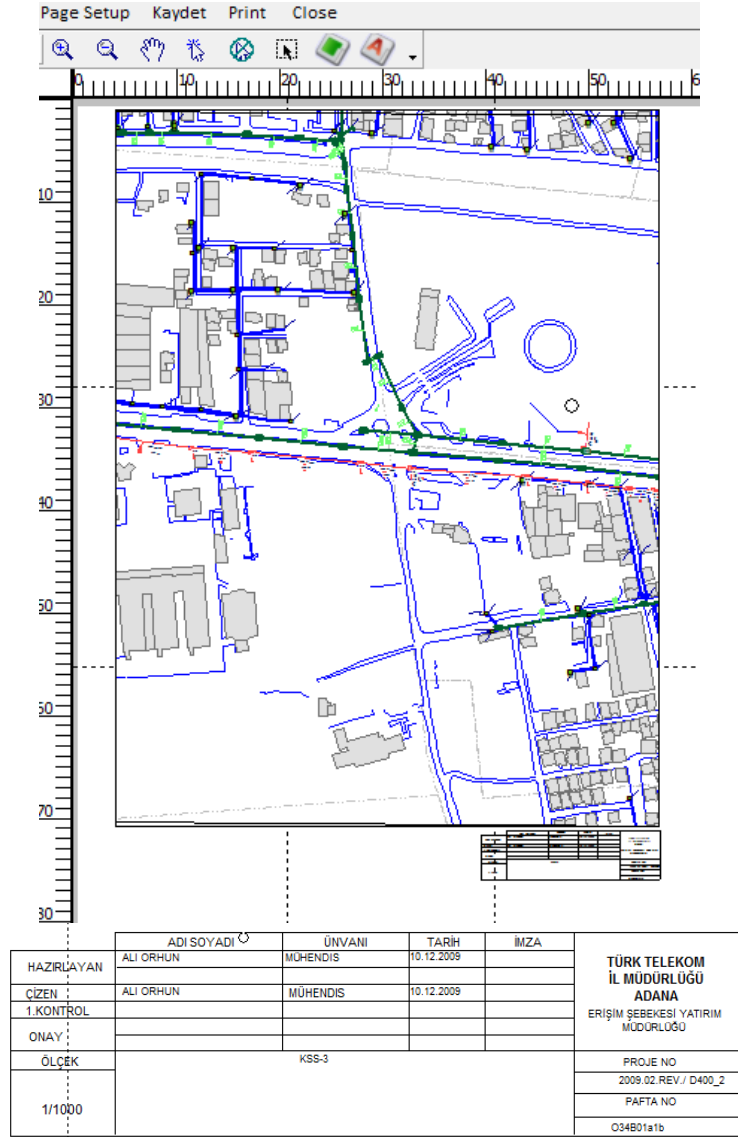
Figure 4.16. Scaled print out preparation with the legend specific to TT

4.4 Web Monitoring and Spatial Decision Support Application

This module is designed for managerial purposes and used for spatial decision support system. The whole network coverage in Turkey can be monitored within this application. The complete TT infrastructure of Turkey, or any region, any province, any municipality, any Central region or any street can be seen and queried by using this application.

Main interface of the application is shown in Figure 4.17. Main functions of the application that were currently developed are as follows:
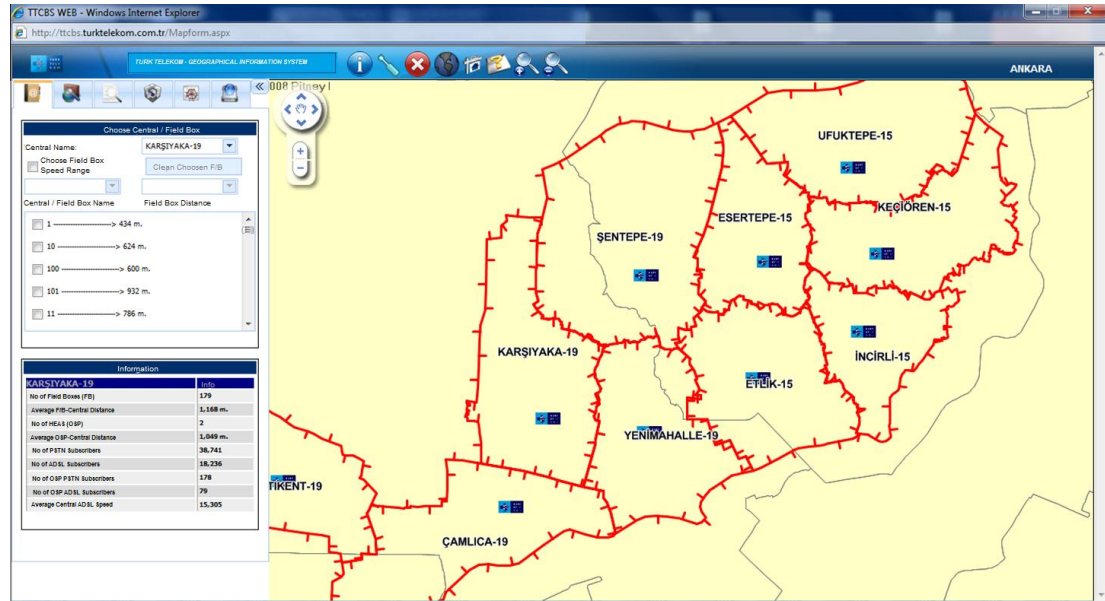
Figure 4.17: The Web Monitoring Application Interface.

- **Query Tab:** This tab is used to query the address and inventory of the infrastructure based on different filters, such as: the whole coverage, in any region, in any province /sub province and region of a central.

- **Network Analysis Tab:** Several network analyses are carried within this tab. By selecting a subscriber, the path from subscriber service box to the central building is traced and total distance to Central is calculated.

- **Thematics Tab:** Several thematic layers are created and displayed by using this tab. Total number of manholes per region, total length of cables (cumulative of each single cable) per region, no of ADSL subscriber per region etc.

- **Reports Tab:** Many different reports are produced and can be printed by using this tab. For example, the number of extension, active, spare and empty lines are reported.

- **Layer Control Tab:** This tab is used to open and close layers at current viewing scale.

There are several functions existing in Web Monitoring Application and there will be enhancements due to the new inquiries received from different TT Departments. Several analyses could be prepared with the web monitoring application. Some of them are shown as listed below.

- Number of PSTN and ADSL Subscribers (Figure 4.18): To see how many fix phone and internet subscriber exists in each field box service region, or in a central region, this analysis can be used.

- Distance from Field Boxed to the Central (Figure 4.19): It is important to see the range and average distance of subscriber from his/her home/office to the field box. This distance affects the quality and speed of internet connection.

- Distance from Field Box Regions to the Central (Figure 4.20): It is also important to see the range and average distance of field box to the central. If the distances are high, then there the areas should be split or F/O cable installation is needed.

- ADSL Speed Analysis of subscribers (Figure 4.21): To see the real status and speed of the internet speed of the customers, this application is used.

- ADSL Speed Analysis of OSP (Figure 4.22): This tool is used to know speed of customers having high-speed external internet connection, this tool is used.

- ADSL Speed Analysis of transmission network (Figure 4.23): This tool is used to see the speed of ADSL transmission network.

- Cost calculations for replacement with OSP (Figure 4.24): One of the most important question can be solved for cost calculation in case of changing the infrastructure to F/O, or not to change it to F/O.

By using this GIS infrastructure also the following analysis can be done:

- Number of Total Field Box SD in each Central Region

- Number of OSP (HAES) per region

- Average SOP to Central distance

- Number of PSTN subscriber serviced with OSP

- Number of ADSL subscriber serviced with OSP
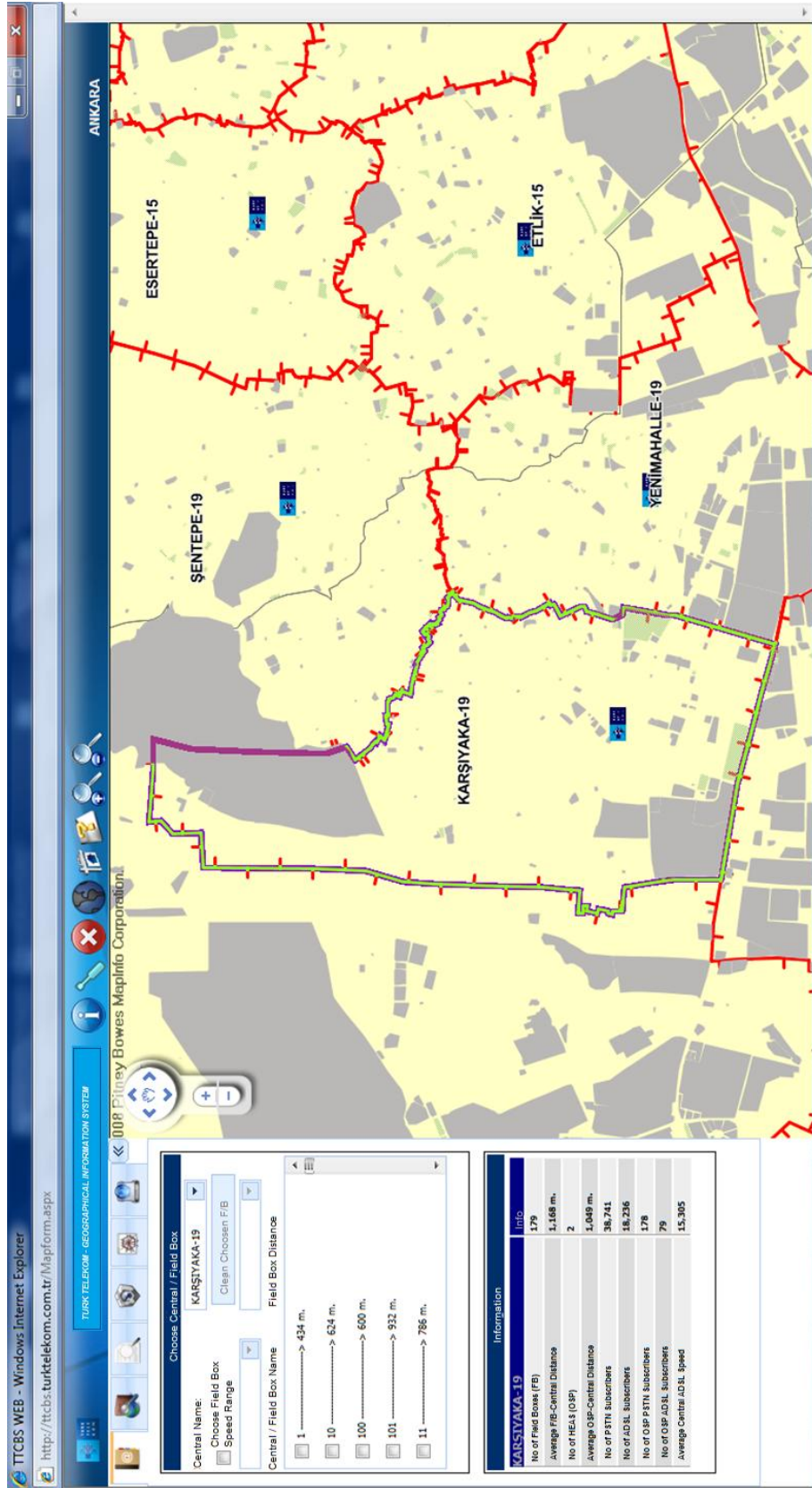
Figure 4.18 Analysis of Number of Fix Line and ADSL Subscriber in each Field Box region
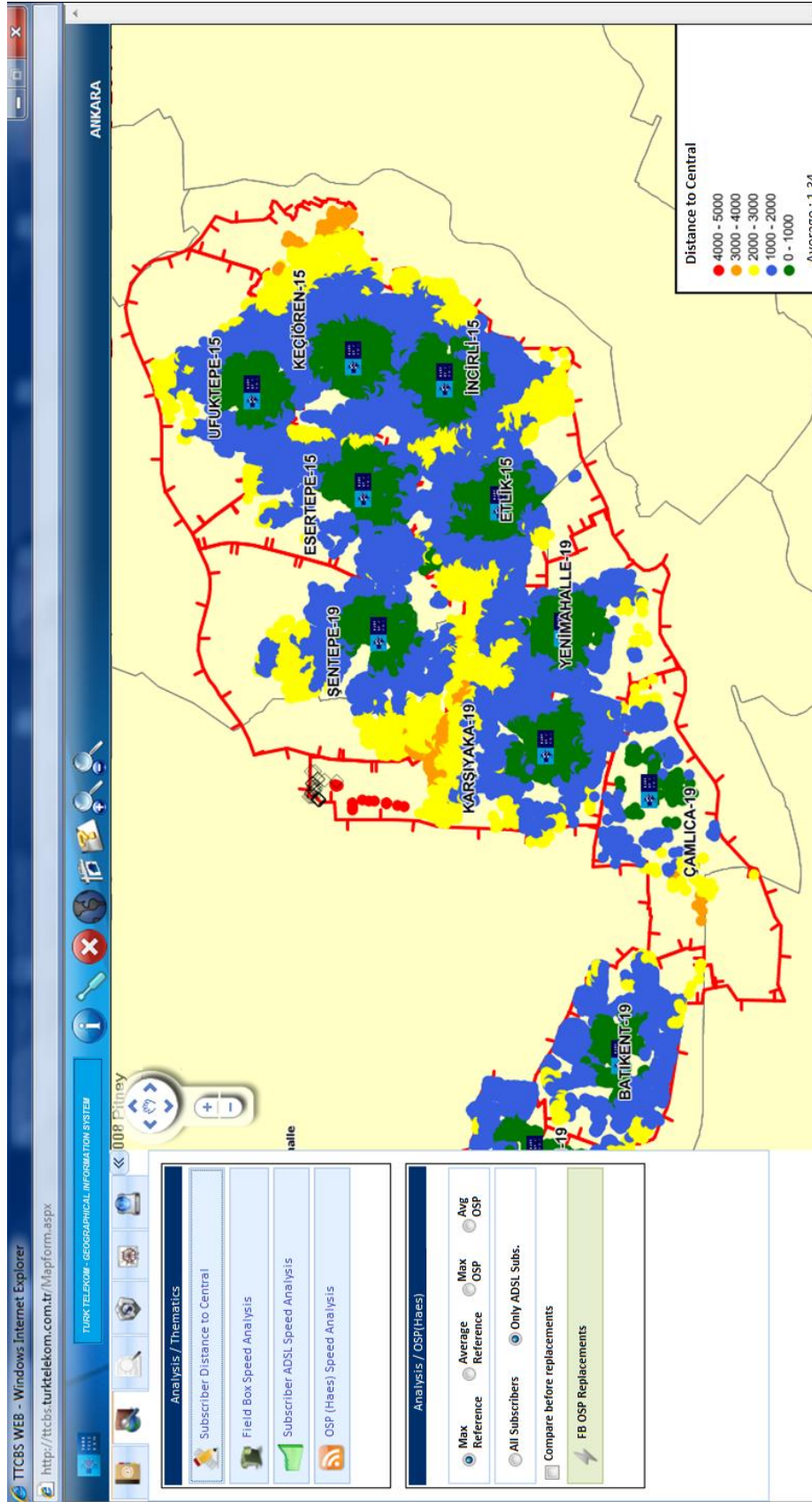
Figure 4.19 Distance Analysis of Field Boxed to the Central
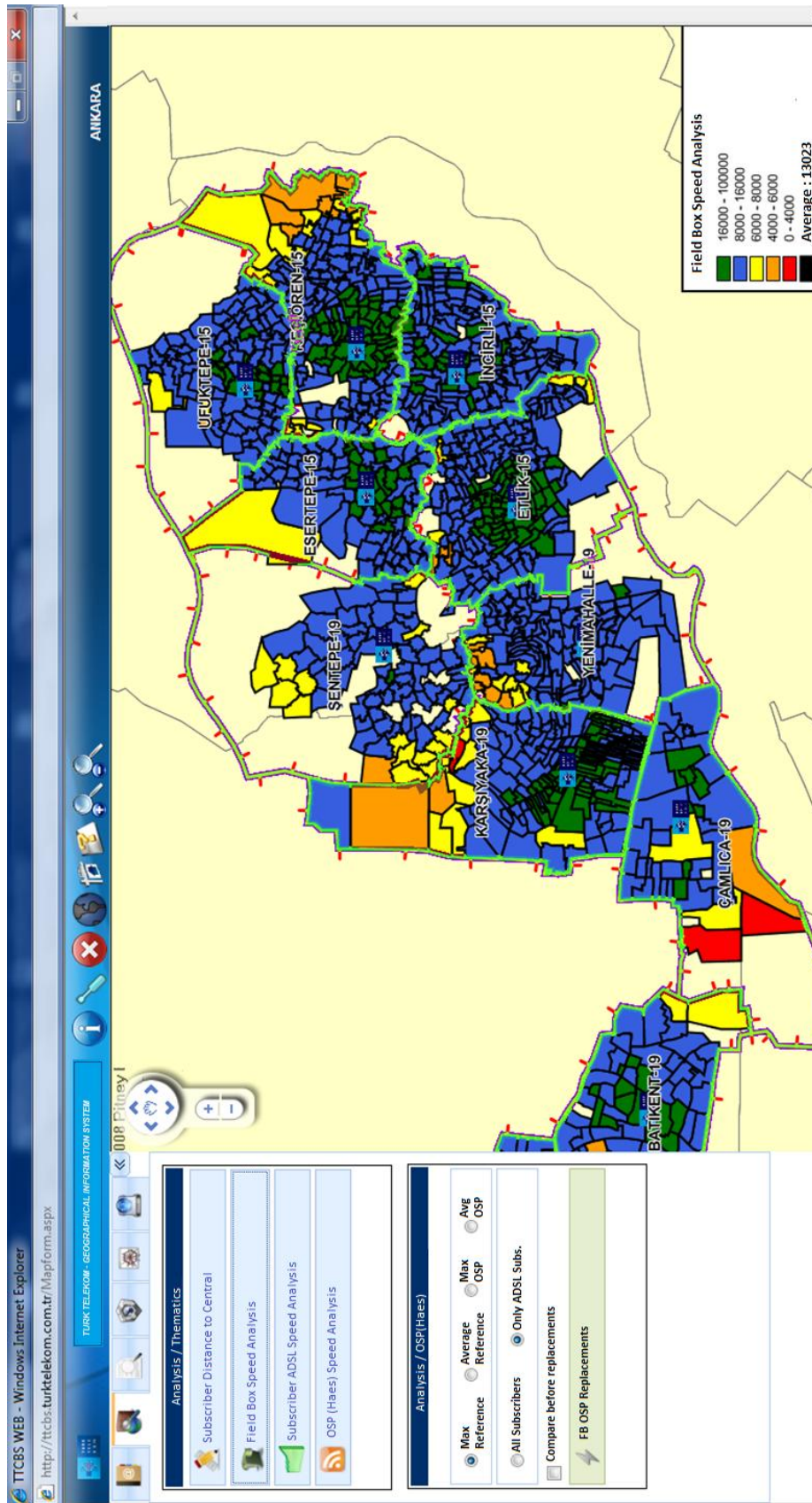
Figure 4.20 Distance Analysis of Field Box Regions to the Central
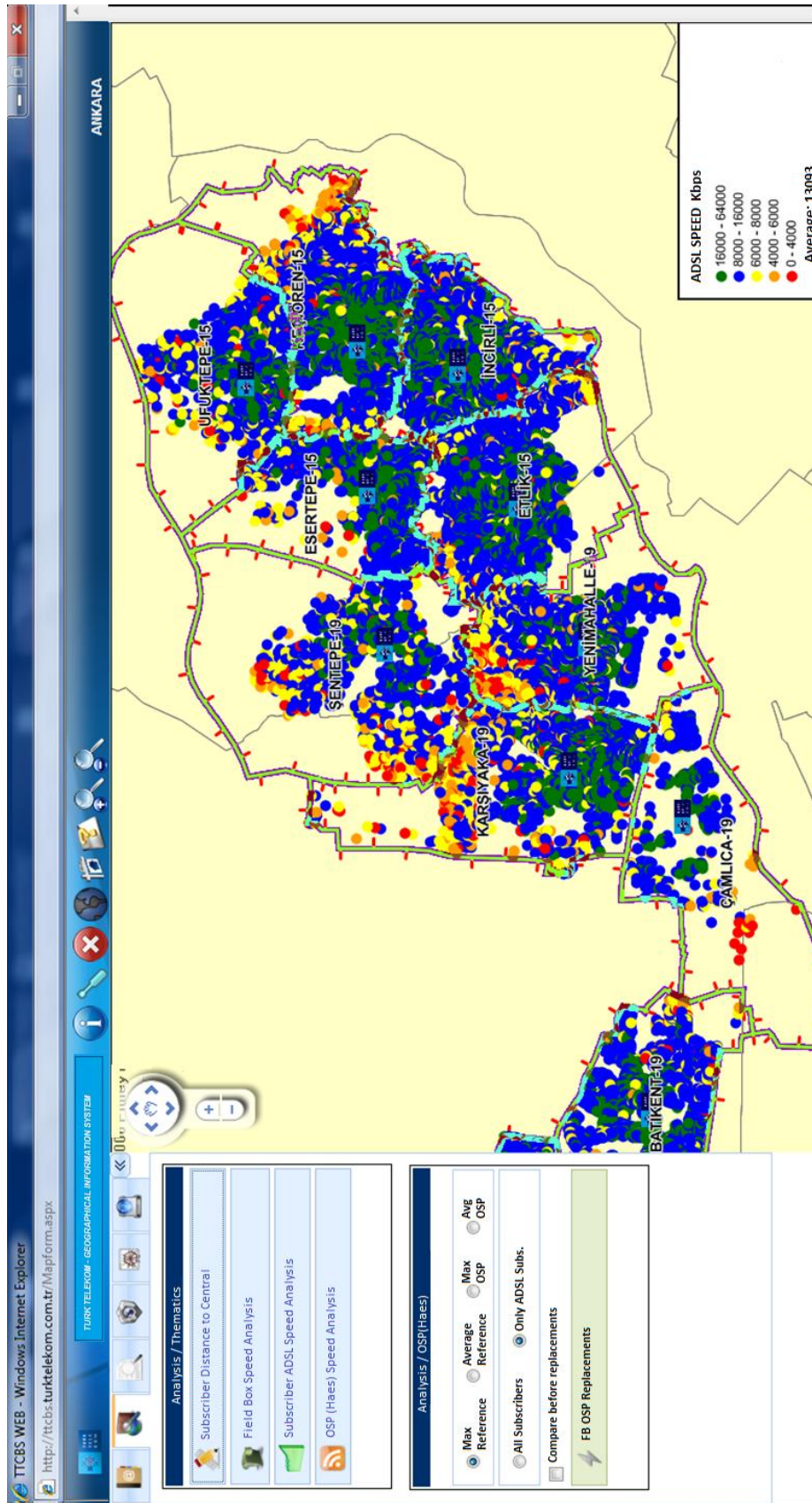
Figure 4.21 ADSL Speed Analysis of subscribers
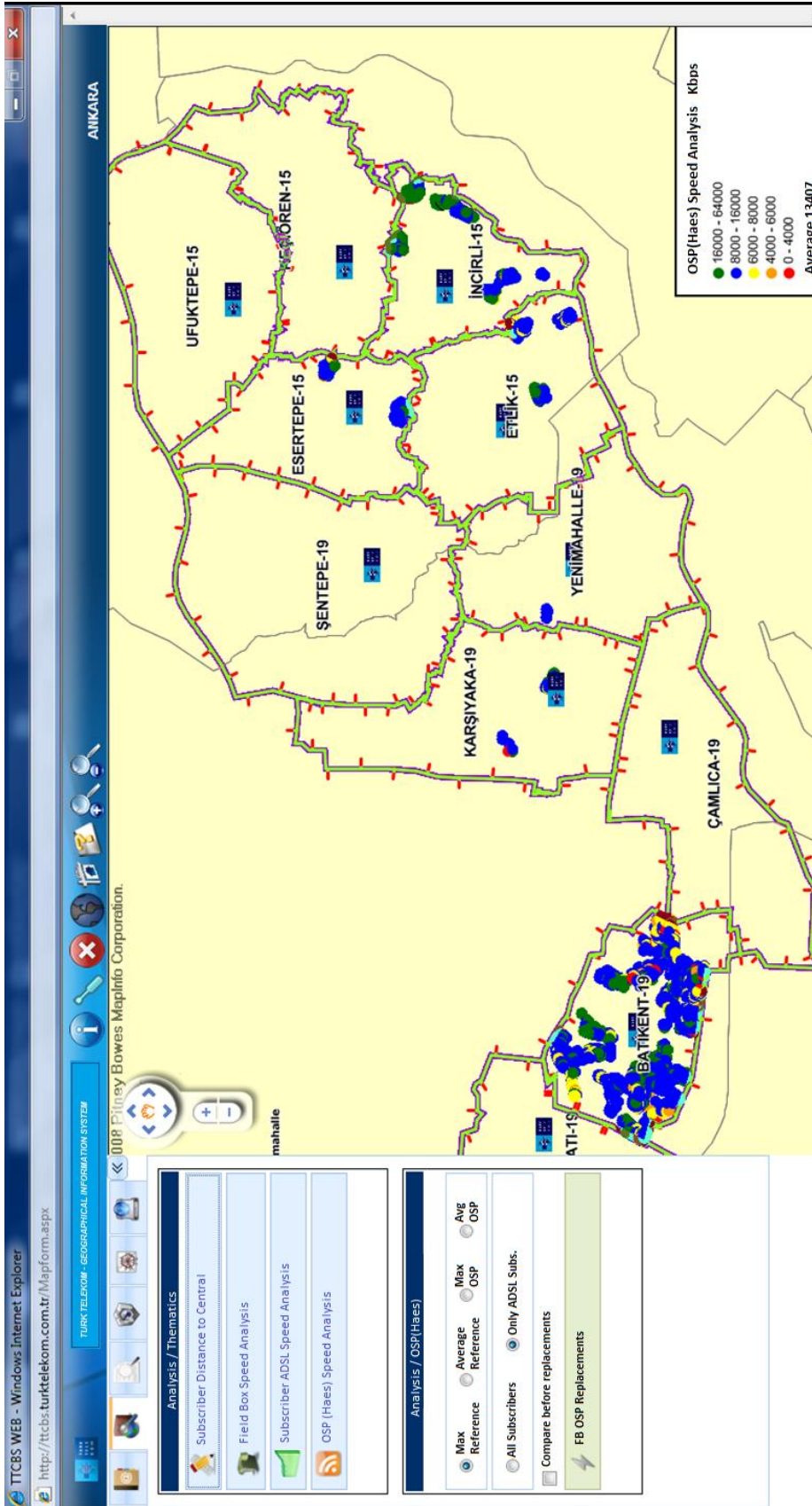
Figure 4.22 ADSL Speed Analysis of Out Site Plant Subscribers

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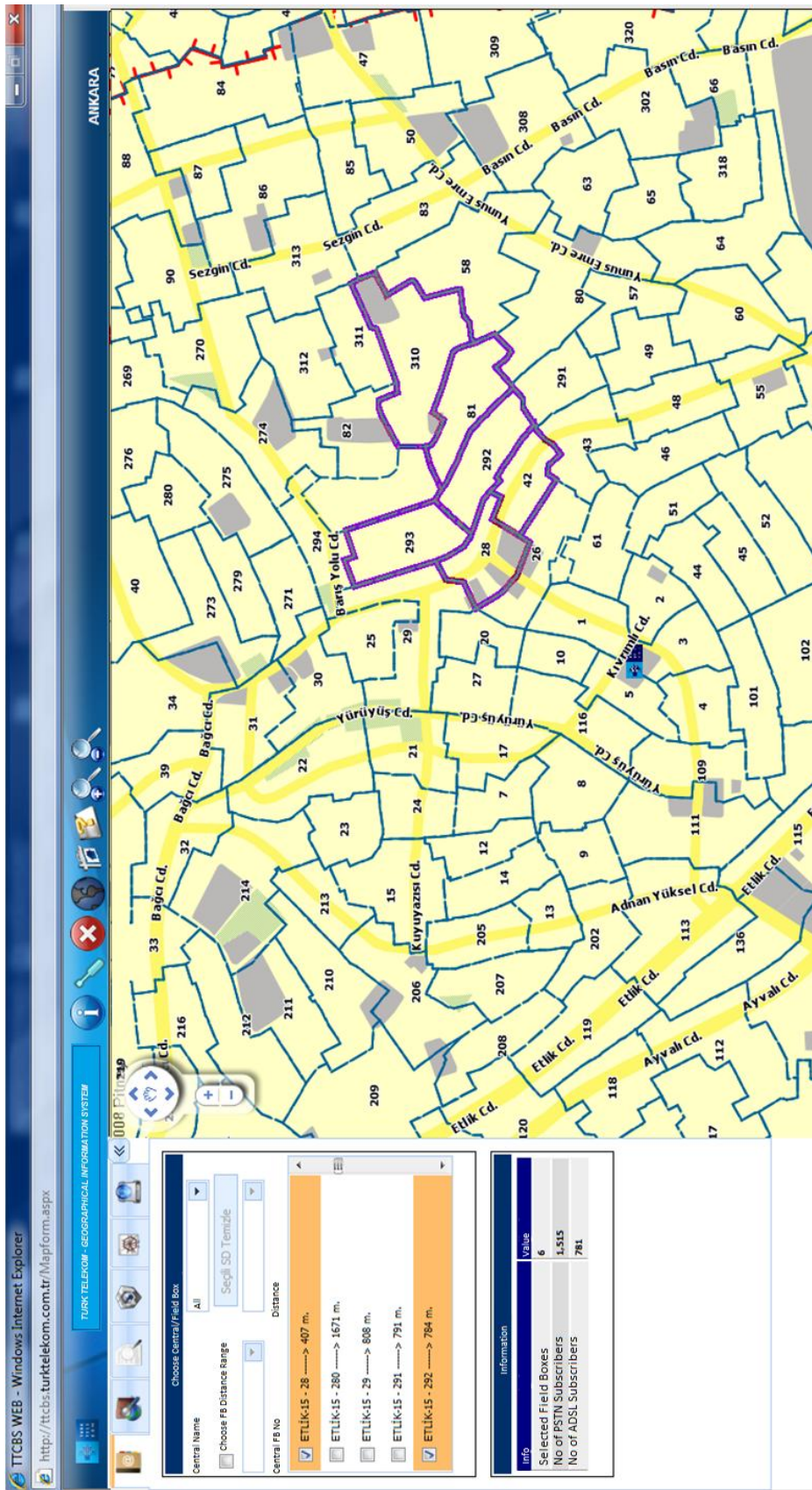
Figure 4.23 ADSL Speed Analysis of transmission network

Range		Range	
0 - 4000	3071	0 - 4000	3071
4000 - 6000	5699	4000 - 6000	5663
6000 - 8000	19406	6000 - 8000	19342
8000 - 16000	135021	8000 - 16000	134267
16000 - 64000	78767	16000 - 64000	79627

Replacement Costs

Central	Field Box	Cabin Cost	ADSL Cost	PSTN Cost	Replacement	F/O Cable Price	Total Price
ETLiK-15	28	20,700 TL.	2,448 TL.	3,744 TL.	1,344 TL.	2,394 TL.	29,286 TL.
ETLiK-15	292	20,700 TL.	4,896 TL.	5,616 TL.	2,016 TL.	4,704 TL.	35,916 TL.
ETLiK-15	293	20,700 TL.	4,896 TL.	5,616 TL.	2,016 TL.	3,666 TL.	34,878 TL.
ETLiK-15	310	20,700 TL.	7,344 TL.	7,488 TL.	2,688 TL.	9,396 TL.	44,928 TL.
ETLiK-15	42	20,700 TL.	4,896 TL.	4,680 TL.	1,680 TL.	3,564 TL.	33,840 TL.
ETLiK-15	81	20,700 TL.	4,896 TL.	4,680 TL.	1,680 TL.	8,538 TL.	38,814 TL.
Toplam	Toplam	124,200 TL.	29,376 TL.	31,824 TL.	11,424 TL.	32,262 TL.	229,086 TL.

Before Replacements   After Replacements

No of Subscribers before replacement

Range	Count
0 - 4000	0
4000 - 6000	36
6000 - 8000	64
8000 - 16000	754
16000 - 64000	645

No of Subscribers after replacement

Range	Count
0 - 4000	0
4000 - 6000	0
6000 - 8000	0
8000 - 16000	0
16000 - 64000	1505

Figure 4.24 Cost calculations for changing a region into OSP system.

4.5 ADSL Capacity Application

This module is used to calculate average/maximum ADSL data upload / download speed limit for any ADSL applicant. The total distance from home to the Service box or Field box is calculated by using real cable network infrastructure real path, not the Cartesian distance between two points.

Algorithm of ADSL Speed Calculation is given below:

- Step 1: Find any address and select a building
- Step 2: Find the Service Box of that building
- Step 3: Trace up to Field Box,
  - Calc. the total length of cables (L = ΣL) between Service Box and Field Box,
  - Calc. the total loss in each connection element ml = Σml
- Step 4: If the Cable connected to OSP (Outdoor Fiber Connected Field Box) then goto step 8 else goto step 5
- Step 5: Trace up to Central Building and calculate the sum of length of cables between FB and CB and add to previous cable length(L = L + ΣL), Calculate each connection element losses and add to previous losses ml = ml + Σml of b/w FB and CB
- Step 6:Goto Step 8
- Step 7: Step 5: Trace up to Central Building, FL = ΣFL of fiber between FB and CB , ml = ml + Σmli of each connection element b/w FB and CB
- Step 8: Total Loss = L * kc + FL*kf+ ml
- Step 9: Subsciriber Speed = Speed At Central – Total Loss

where

    L: is the legth of copper cables in meters

    ml: Minor Losses due to fittings and connections in bps

    kc: copper cable loss multiplies in bps/m

    kf: fiber optic cable loss multiplier in bps/m (very low,   pprox. zero)

    SB: ServiceBox   FB: FieldBox

    CB: CentralBuilding

4.5 Coordinate of Fix Phone Subscriber

TTGIS application can help to emergency departments by serving the coordinate of a subscriber who calls emergency hotline. After digitizing all related information, it is easy to integrate subscriber information into GIS system. The billing information system stores all related information about the subscriber including the address and service box. The subscribers are geo-coded by using their address and service box number from TMS system. This service could easily be entreated or used by Emergency Hotlines such as Ambulance (Dial 112), Fire (Dial 110), Security (Dial 154, 155, 156), Utilities (Dial 185 for electricity, 186 for Water, 187 for gas).

In current system, in case of a call received, the caller should give as much information as possible, including the address (sub province/municipality name, quarter/neighbor name) of the emergency location. In case of such an emergency, it is difficult to give exactly correct information. The caller can give wrong definitions, and also it may take several minutes to define the location. Due to the repeating street names in the neighborhood, many problems may happen in finding the correct address, so the service could be late. For solving this kind of problems, the TTGIS system can help to the Emergency Departments (Figure 4.25). Since the location of each subscriber service box is recorded in the database, and the location of each service box is located in the map, there is no need to ask for an address, except for confirmation of the location.

4.5.1 Offered System

The planned system will get the Caller ID (Figure 4.26) and send the phone number to the service. The service will search the customer database to get the service box id. After getting the service box id, the coordinates of the service box

will be received by the TTGIS system. The map will be centered to the location, the reverse geocoding will be done and the required address information automatically will be filled in the form. The location will be shown in the map, so the map could be printed in a suitable scale. There are zoom in, zoom out, pan, address query, info, button for address refinement.
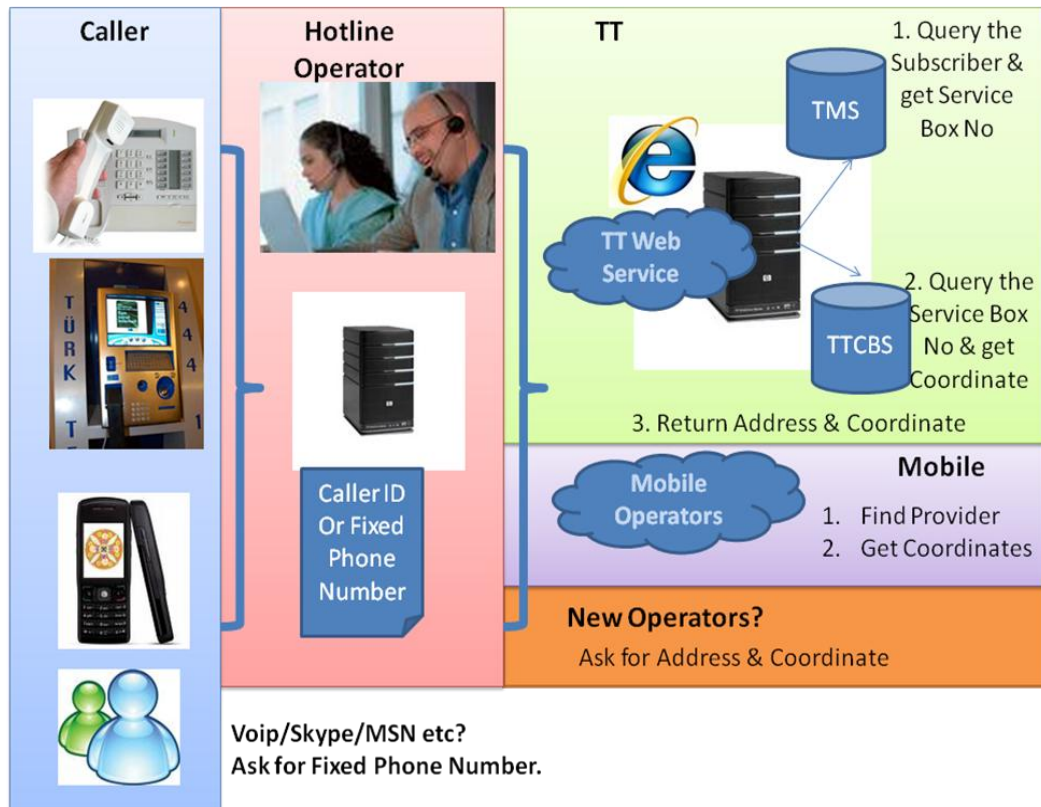
Figure 4.25 Locating a subscriber

The fixed line has an advantage in the positioning the fix line subscriber over mobile subscriber. The GSM positioning system works by the intersection of the circles drawn from each antenna by using approximate distance of the subscriber. In residential areas, there are many antennas, so the precision is around 50-300 meters, but in rural or seaside areas, it may extend to kilometers (Figure 4.27). But fix line subscriber can be located with a distance range of 5-50 meters.
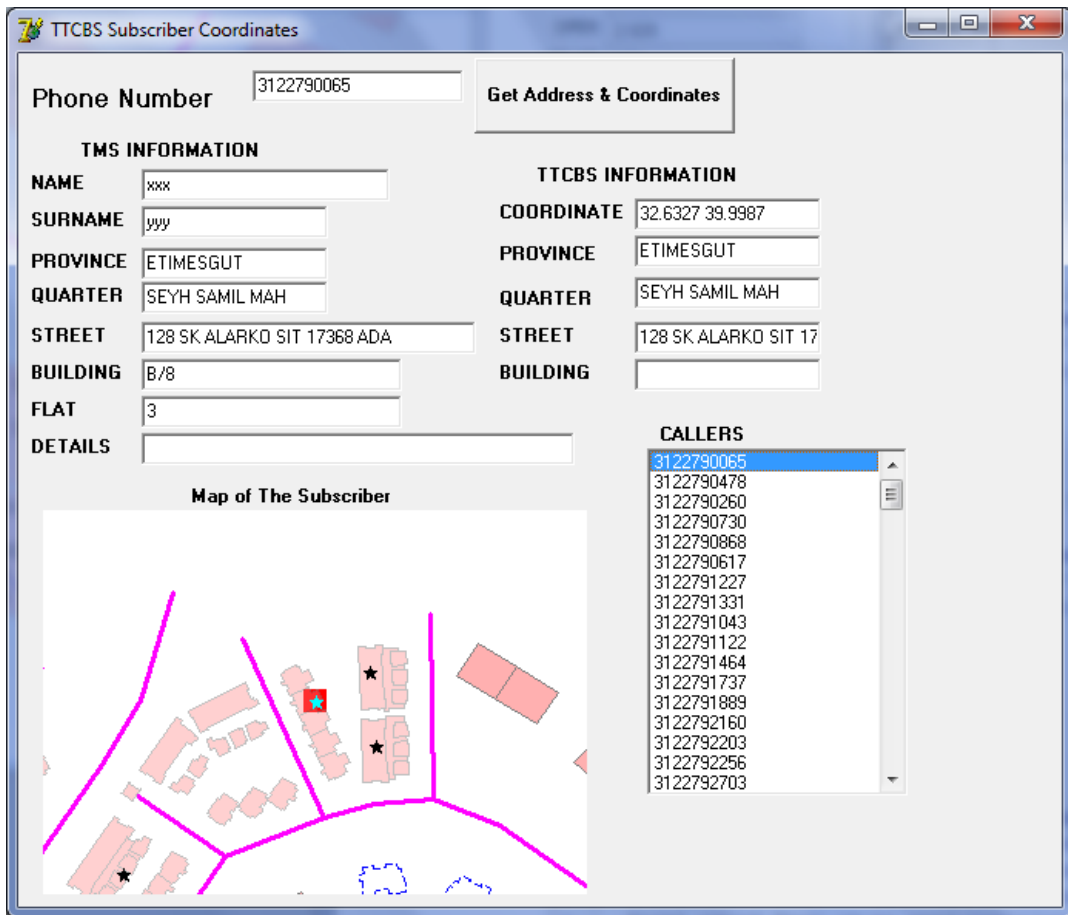
Figure 4.26 Information and Coordinate of a Caller
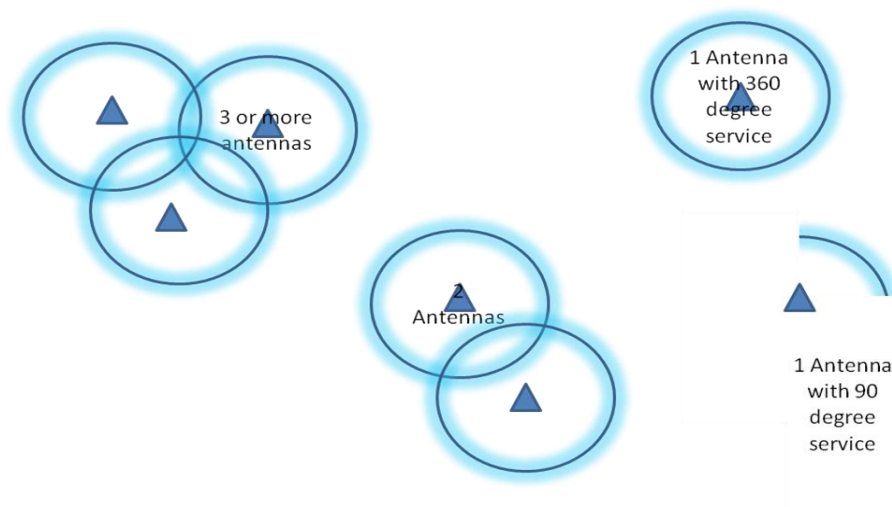
Figure 4.27 Mobile Positioning

4.5.2 Success of the system

Success of the system will depend on the following two criteria: accuracy and up-to-date of the TMS and GIS. Up-to-dateness of the Subscribers phone number and service box id. For example, if a subscriber move to another location and the phone number is not changed, but the service box no is changed, the new service box number must be updated with the new one.

In case the call is made from a mobile phone or somebody else is calling, the operator can ask the fixed phone number of the emergency location to easily access to that address. Also the coordinates of the Mobile subscribers can be get from the GSM Operators by a service and integrated to the system.

4.5.3 Steps Followed in the System

- New Call from Fixed Phone (If not a fixed phone or the emergency is related to another location, get the relevant number)

- Automatically Get Caller ID: *0 312 1234567* (or type the relevant number)

- Press Get Caller Address Button

- The system will connect to TTGIS Web based service: Such as

  www.turktelekom.com.tr/SubscriberLocation?No=03122131413&UserID=X.

- The service will return the **Subscriber Name** and **Address,** an**d Service Box No** from TMS databas**e,**

- Then the service will query the TTGIS system and location of the service box, that has got from TMS database, the Address of the Service box will be returned.

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- The service or application will show the location of the caller in map, and return text information:

  o If the Service box number is not in the TMS database, return the text address only.

  o If the Subscriber number is not in the TMS ask the address.

  o The result address text from the TTGIS system will be displayed.

- The Work order will be prepared and could be sent to the emergency vehicles Navigation device (Figure 4.28).

- So the emergency team will not ask for the address and the route for the destination will be drown automatically by the navigation software.

Figure 4.28 The location of the subscriber is send to connected navigable device.

4.5.4 Returned XML format

The Subscriber Location service returnes XML formatted data. The data include Caller id, name, address and coordinate info. The coordinate couple is

formatted as North and Easth. The structure is as follows.

```
<xml>

<name>

        <Address and Coordinates of Caller ID: 00 90 312 1234567>

</name>

<Address>

        <coordinates>39.91368, 32.975945, 0</coordinates>

        <Province>Ankara</Province>

        <SubProvince>Etimesgut</SubProvince>

        <Neighbour>Eryaman</Neighbour>

        <Street>128 Sk</Street>

        <Building>5/A</Building>

        <Details>5/A</Details>

</Address>

…

Here there may be some more information added.

…

</xml>
```

CHAPTER 5

DISCUSSIONS

In this thesis the following questions have been studied and tried to be solved. What are the benefits of digitizing the paper networks and building a GIS system for telecommunication companies? What kind of new services can be given by using the coordinate information? What is the advantage of having such a system in the competitive telecom sector? How to analyze and improve an existing network? The results of the study and the answers to those questions are as follows.

System Design and Database Creation:

In this study, database creation, system design and developed applications are explained for the Turk Telekom GIS system. The methodology was developed depending on the site expectations. Therefore the applications were developed with the TT engineers. MapInfo Pro 9.5 was used as the GIS software. The applications were developed with Borland Delphi v7 and Visual Studio 2008 .NET Framework software. There are several GIS software that can open or use the TTGIS database, such as ESRI, Autodesk, Intergraph. Since the applications are developed with MapInfo technology, switching to another GIS Software requires recoding. The Oracle Spatial 10g system was chosen for database management system. There are also some other commercial or open source spatial database systems exits such as MS SQL Server 2008 and PostGIS. The Web monitoring system is developed with Mapxtreme .NET technology, and Internet Explorer, Firefox browsers are compatible.

One of the main problems, designing a system and storing the database tables, has been solved. TT operates nationwide infrastructure, and Turkey is a large country with 81 provinces. There are 4 UTM (6 degree) zones and 7 GK zones (3 degree) exist in Turkey. One of the biggest requirements is to store the data in 3 degree UTM/GK projection zones. It is also possible to store whole country in one layer/table in Geographical Latitude/Longitude or Lambert Conformal Conic projections. This problem has been solved with the developed different schemas for each province and proper coordinate system has been chosen for each province. Another problem was maintenance and management of the database. It is preferred to have minimum number of tables for database maintenance. But it is better to have small sized tables for performance issues. It is better to create one schema for each province for security and credentials, so users of one province cannot see and alter the data of another province. Separate schemas for each province were created for combining the projection, database maintenance and security issues. The performance of the separate schemas must be checked in the future when all the data for the whole Turkey are gathered.

Applications:

In Chapter 4, first two applications discussed in this study are for digitization of the as built and cables maps. These applications were already exist within the available system. It is one of the most important applications, because it is used to create all the inventory of the TT. The F/O Cable drawing application is used to digitize the fiber cables installed on the field. With these two applications, TT has a unique, seamless, up to date, controlled nationwide data. This data can be updated, printed with the same applications and it can be queried in monitoring applications. While these applications are developed, the working methodology of different cities are analyzed and unified.

The web monitoring application is important for the managers and planning engineers. By this application any staff with more or less understanding of map or GIS, can easily use and analyze the system, can see good or badness of the infrastructure, which cannot be supplied by list or graphical reports. Also by using analysis exist in the application, the current situation in the field can be seen, and it was not possible in the past.

The Project Preparation Application is needed for planning the future, calculating the costs of installations. This application is also used to track the changes, by showing location of the old cables and planned new cables. By this application the companies making plans for new installation can easily see what exist in the field and what will be installed as new. The final plan data can easily be copied to the GIS system, which will shorten time to update the system.

The ADSL Capacity application is another important applications, which is used to calculate the maximum speed of the internet allowed by the existing infrastructure when a new application is made. By this application, TT engineers or staff can easily reply the inquiries at the application time. This was not possible before and it was needed some days to calculate the speed of the system. This is very important for customer trust also. When customer applies for a higher capacity and if TT declares it is possible, but if it cannot be served actually, the credibility of the company declines. By this application this kind of problems will be reduced.

The last application, which is developed in this study is the serving the coordinate of the customers to emergency or related companies. TT can easily give this service with the current GIS system. Since telecom has the latest and up to date subscriber data, the location of the subscriber is automatically updated. This is an important application providing the safety of people at their home. Also the field

team can use it for faster failure fixing. Also several location-based services can be supplied to the subscribers. One of the major problems in this application is the issues about security of the data and rights of the subscribers. Some subscribers apply to TT for not being listed in the directories. This application can be served the same as the directory service, except for the emergency cases. Currently the telecom subscribers are geocoded for some city security and surveillance systems (which are called KGYS or MOBESE). But this is done only one time in an offline separate database. The change and movement of subscribers are not tracked daily. When TT starts giving the coordinate information of subscribes as online service, the security systems will use directly the latest and up-to-date subscriber location data.

A similar system can be applied to other telecom companies, the system is portable, and can be implemented in another Telecom company here or abroad. There will be some limitations due to the different standards of the countries or working cultures. For other infrastructure systems like gas, water, electricity, it is needed to make changes both in the database and the applications, since the requirements and systems are different. However, several functions on the applications can be used directly.

Turk Telekom, has the biggest infrastructure in Turkey. TT needs to know where the assets are located, otherwise there will be unnecessary investments and installations will be made and unused inventory will be useless. Before starting to digitize her network, all the information was supplied by local staff of the city. As the time past, due to changes in staff, network and city plans, there are many information becoming useless or wrong. GIS implementation provides TT to know the location, amount and quality of her infrastructure.

The system provides less objective and proper decisions making for the new plans, which will be made by using GIS applications. The service quality and number

of applications for new and/or better services will be used for planning.

Many mistakes, which were observed during the application, have been found. These errors were checked by the engineers and corrected either in the office or at the site. Since duplicate copies can exists for some paper maps, different departments can have old or wrong information about the field. With the new system all the information is centrally stored and the latest information could be easily supplied to the TT staff. The amount of installation and number of subscribers and amount of revenues can be analyzed regionally. The amount of installation, such as how many meters or kilometers of cables, trenches, amount of manholes, field boxes can be seen from the map, and can be compared with the amount of money paid to constructor for the installations.

After privatization of TT, many employees quit their work, or went to another government office, and some of them retired. The local knowledge of the TT was mostly on their staff. With this system the local knowledge also will stay in the system.

Limitations:

Building a GIS system does not mean all the necessary steps are done. It is important to build all related updating mechanisms for the system to make it alive and trustable. For updates, project application was developed and with this application all the new installations can be updated. Another managerial rule to apply is to integrate other departments to use the GIS data as input, in reporting and statistics creation.

GIS system cannot answer many questions. Especially this GIS system is the

first and only system in countrywide wire-line telecom infrastructure. For the future requirements system can be expanded and extended, but the current version of the applications and database structure and design may need to be changed or improved.

By the help of the GIS system, the whole inventory in the paper maps are started to be digitized and all the inconsistencies became visible and the missing updates are done before finishing the digitization. The 1/1000 scale maps were combined and became seamless drawing. The smaller scaled maps will be printed directly from the base data. There will be no more different scaled maps with different data. After this system is started to be used, there won't be many versions of the paper maps with different revisions. In the old system, the network in the paper maps, and the inventory in the Telecom Management System (TMS) was not matching. Now two systems are compared and the differences are corrected.

The difficulties of the GIS system are the local solutions generated for some local problems. The paper maps were organized with respect to those problems. When the applications designed with respect to regulations and common know how of the engineers, those non-common tasks became a problem to be solved.

The applications can be analyzed in terms of "Usability" measures, and the user interface of the system can be improved. The mostly used functions can be designed as easily accessible menus or buttons, and also the designs of forms can be unified to have common buttons at the same appearance and positions, such as *OK* and *Cancel* buttons.

The "Subscriber Coordinate Serving Application", can be better used if TT made the digitization of the whole cables and subscriber boxes in whole Turkey. TT is planning to complete this task as soon as possible.

For the Caller ID visibility, almost all of the infrastructures of TT is digital. So all of the caller ids will be visible in the system. If the system is not digital yet, the caller id will not be visible on the screen, so the system will not work. This can be overcome by asking the telephone number of the subscriber.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

While searching an answer to the research question already presented in Chapter 1, we have seen that there are several results and findings associated with this study are given in Chapter 5; apparently, those findings are subject to limitations upto a reasonable level; fortunately, those limitations encouraged us to discover further study avenues. The chapter concludes the thesis by presenting those results, findings, limitations, future works and an answer to the research question.

6.1 Conclusions

The motivation of the study was to explain benefits of building a GIS system for Turk Telekom's wire line infrastructure system. After building a GIS system, it is also important to use and serve this location based data in different managerial and engineering spatial decision support system applications, which was not possible before or not easily done before. It is also important to use the network and geocoded subscriber data in life saving technologies.

As a result of the study, it is founded out that, GIS systems and functionalities supplied by GIS with tailored applications help managing telecom infrastructure, GIS can be used in Telecom wire line infrastructure.

6.2 Recommendations

We can recommend several tasks to be done in the future studies. Some of them are as follows.

TT can serve several Location Based Services (LBS) by using its inventory and information of the subscriber. Such as a map enabled Business Finder (Where is nearest X and what is the phone number) services. These services must protect the privacy policies. The data produced in this project can support investments and these data can be used in finance department of the company.

One of the next step can be the integration with Address Based National Citizenship Records (ADNKS) address codes. The ADNKS has five levels of administrative areas, the streets, buildings and individual units (like flat). These levels are for Province (il), Sub Province(ilçe), City(Bucak), Village(Köy), Neighbour or Quarter(Mahalle). The current address level for the telecom consist of three level namely Province, Sub Province and Quarter. The streets passing more than one quarter, or defines the boundary of the quarter have one unique code for each quarter. In reality it is a single street. The buildings in the left of the street and right of the street will have different street codes if the quarter areas are different. This integration will be essential for future subscriptions. It is important especially for controlling the name and address of the subscriber from the ADNKS.

The field teams may use network maps on the field, and make updates from the field, this will reduce time to find and understand the network,

Another future work can be the digitization of the village infrastructures in the system. This will supply a unique, seamless, countrywide database for the TT.

The historical data later can be used for spatio-temporal analysis. Especially it will be interesting to see the changes in the inventory within last 10 or 20 years. The transition from Cupper to F/O cables can be analyzed by adding the financial parameters.

The current system was designed in 2D. The Oracle Spatial Data structure supports also 3D information. Upgrading the system into 3D (even 4D since time information is stored for changes) is possible. This can be even done by utilizing Google Earth in the future, because of the fact that Google introduced neo-geography to GIS world and changed the way of presentation layers.

In the next phases of the system, there may be more mobile applications developed for field staff, and engineers and managers can have chance to response faster, can make better scenario management in the field visits and faster decision taking in the emergency cases. Currently the information in the GIS system can be reached by using a laptop with an internet connection.

There are several different spatial database systems exits, such as MS SQL Server Spatial and open source PostGIS. The GIS system could be made compatible with these databases.

REFERENCES

Albrecht, J., Key Concepts & techniques in GIS, pp13-18, Los Angeles, Sage Publications, 2007

Bartlett, E. R., Cable television handbook, pp100-123, McGraw-Hill, New York, 2000

Bitdunyasi 1, http://www.bitdunyasi.com/tr/?Sayfa=Detay&Id=1118, Last visited on 07/10/2009.

Bitdunyasi 2, http://www.bitdunyasi.com/tr/?Sayfa=Detay&Id=1979, Last visited on 18/08/2009

Bitdunyasi 3, http://www.bitdunyasi.com/tr/?Sayfa=Detay&Id=785, Last visited on 18/08/2009

BKW FMN, Switzerland, http://www.bkw-fmb.ch, Last visited on 11/01/2010

Bouras, C., Gkamas, A., Papagiannopoulos, J., Theophilopoulos, G., Tsiatsos, T., Broadband municipal optical networks in Greece: A suitable business model, Telematics and Informatics 26, 2009, pp 391–409

British Telecom Global Services, http://www.btglobalservices.com, Last visited on 11/01/2010

Brown, C. M., Hacking Google Maps and Google Earth, Page 4, Indianapolis, IN, Wiley Pub., 2006

Campbell, J. Map use & analysis, Boston, McGraw-Hill, 4th Ed, 2001, p245.

Ciciora, W, Farmer, J. Large, D., Adams, M., Modern Cable Television Technology: video, voice, and data communications, pp162, McGraw-Hill, San Francisco, California, Morgan Kaufmann Pub, 1999

CityCom Graz, Austria, http://www.citycom.co.at, Last visited on 11/01/2010

Cookson, G., The Cable, The Wire that Change the World, p- 31, Tempus Publications, Gloucestershire, 2003

Daosheng, D. "Introduction to Data Quality Standard for Digital Topographic Map Product", 17th Intern. Cartographic Conference and 10th General Assembly of the ICA/ACI, 3-9. September 1995, Barcelona, pp. 2411-2415.

Deshpande, M., Telecom GIS: An Integrated Approach, MapIndia 2003 Mumbai, India, 2003

Djordjevic-Kajan, S., Petkovic, M., Stoimenov, L., Rancic, D., Mitrovic, A., Mladenovic, S., Tosic, M., GIS in Nis PTT, In Proc. GIS/LIS'95-96, Budapest, pp.92-101, 1996.

E-net, Ireland, http://www.e-net.ie, Last visited on 11/01/2010

E.ON Bredband, Sweden,
 http://www.eon.se/templates/StartPageEON.aspx?id=45881, Last visited on 11/01/2010

E.ON Netz ,Germany, http://www.eon-netz.com/EONNETZ_eng.jsp, Last visited on 12/01/2010

EU 14th Monitoring Report, 2009

Globalconnect, Denmark, http://www.globalconnect.dk/, Last visited on 11/01/2010

Mitrovic, D. An extension of RDBMS for application in GIS", Master's thesis, Computer Science Department, University of Nis, 1993.

OECD Broadband Stats, http://www.oecd.org/dataoecd/21/60/39574903.xls, Last visited on 18/08/2009

OGC Simple Feature Access, Open Geospatial Concercium, 06-103r3 Candidate Implementation Specification for Geographic Information − Simple feature access − Part 1 Common Architecture v1.2.0 , Page 15, 2006

Oracle Spatial 11g-Datasheet, page 4

Oracle Spatial Web Page, Spatial and Locator features. http://www.oracle.com/technology/products/spatial/spatial_locator_features.html, Last visited on 24.12.2009

Raghavendran, S., Intelligent Broadband Information System, Alpharetta, GA, U.S.A, GISdevelopment.net, 2003

Shi, W., Kwan, K., Shea, G. And Cao, J. W., A dynamic data model for mobile GIS , Computers & Geosciences 35 ,Hong Kong, 2009, p.2221

Stoimenov, L., Petkovic, M., Stojanovic, D., Djordjevic-Kajan, S., Mitrovic, A., Mitrovic, D. Development of Telecom GIS Application Using an Active, Object-Oriented GIS Environment, Faculty of Electronic Engineering, University of Nis, 1993.

Stojanovic, D., Djordjevic-Kajan, S., Petkovic, M., Stoimenov, L., Development and Quality Control of the Spatial Database for Telecom Network Management GIS, Computer Science Department, University of Nis, Yugoslavia, 1996

TeleOS, Germany, http://www.teleos.de, Last visited on 12/01/2010

Telstra, Australia, http://www.webmap.o2.co.uk, Last visited on 11/01/2010

Vanikar Y.V., Patel M.N., Kharod K. P., Matieda I.C., Telephone exchange information and planning system – A case study of Vastrapur telephone exchange, Ahmedabad, India, 1996

APPENDIX A

UPLOADING MAPINFO LAYERS TO ORACLE BY USING EASY LOADER APPLICATION

In MapInfo, run Easy Loader application from Tools ➔ Easy Loader Menu. Click to Oracle Spatial button as shown in Figure A.1.
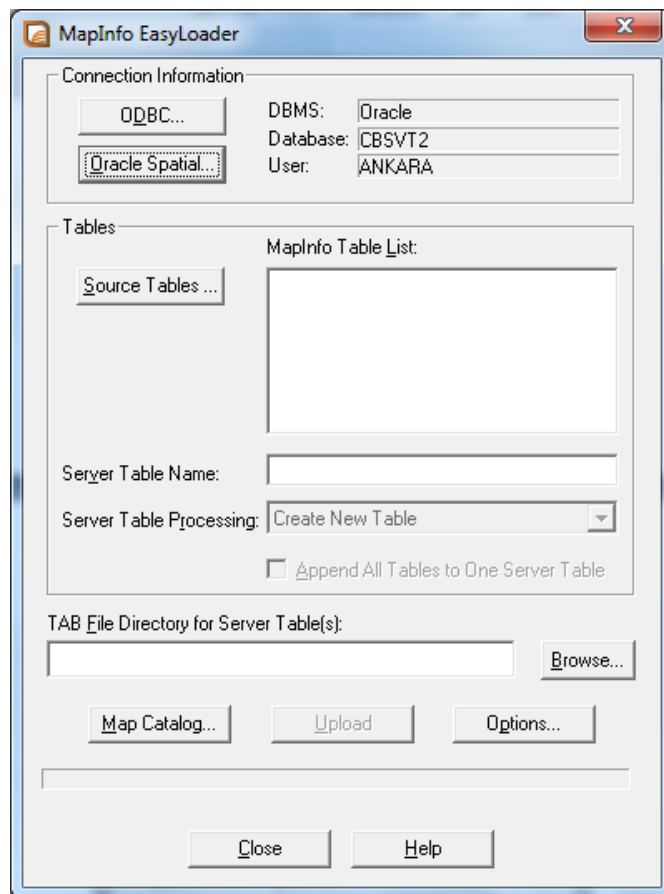
Figure A.1 MapInfo Easy Loader Dialog used to upload map data to Oracle

Type the User ID, password and server name to connect in the Oracle Spatial

Connection dialog in Figure A.2.
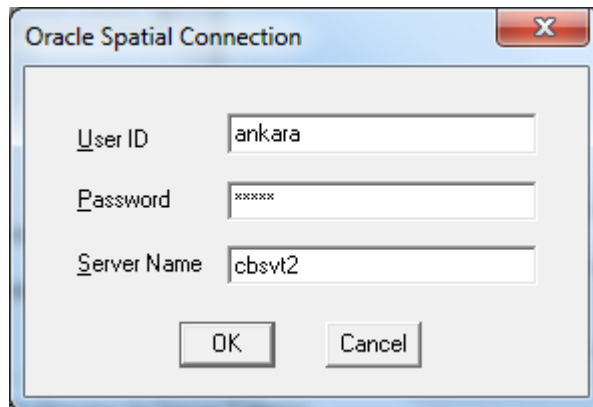
Figure A.2 Oracle Spatial Login Dialog

Press the Source Tables button and choose all tables to be uploaded as shown in Figure A.3.
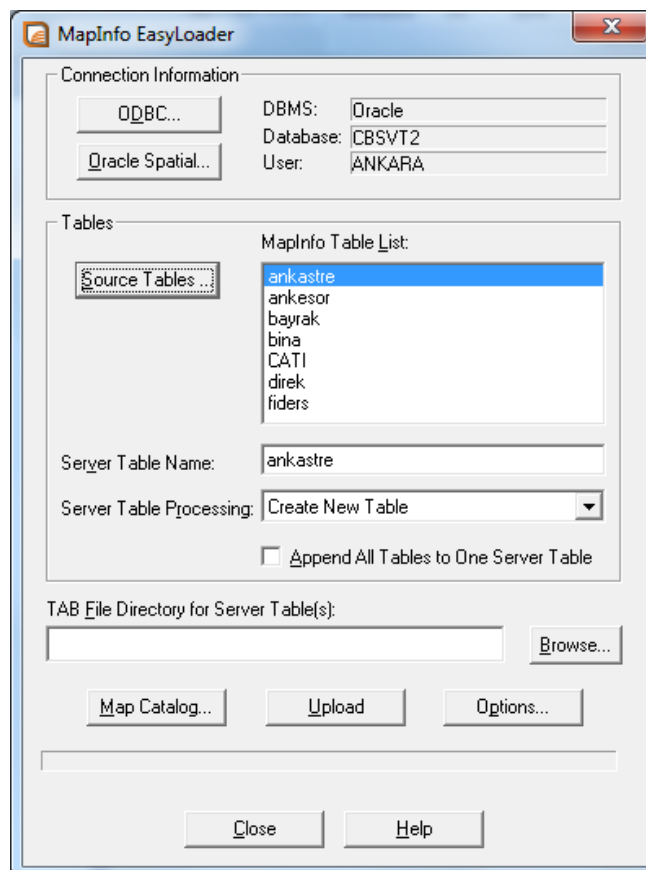
Figure A.3 The tables in MapInfo Table List will be created in Oracle.

The object will be stored with original color if style column is chosen in Options dialog (Figure A.4). Create Primary Key option creates a not repeating and not null integer column and MapInfo uses this column to update or delete transactions.
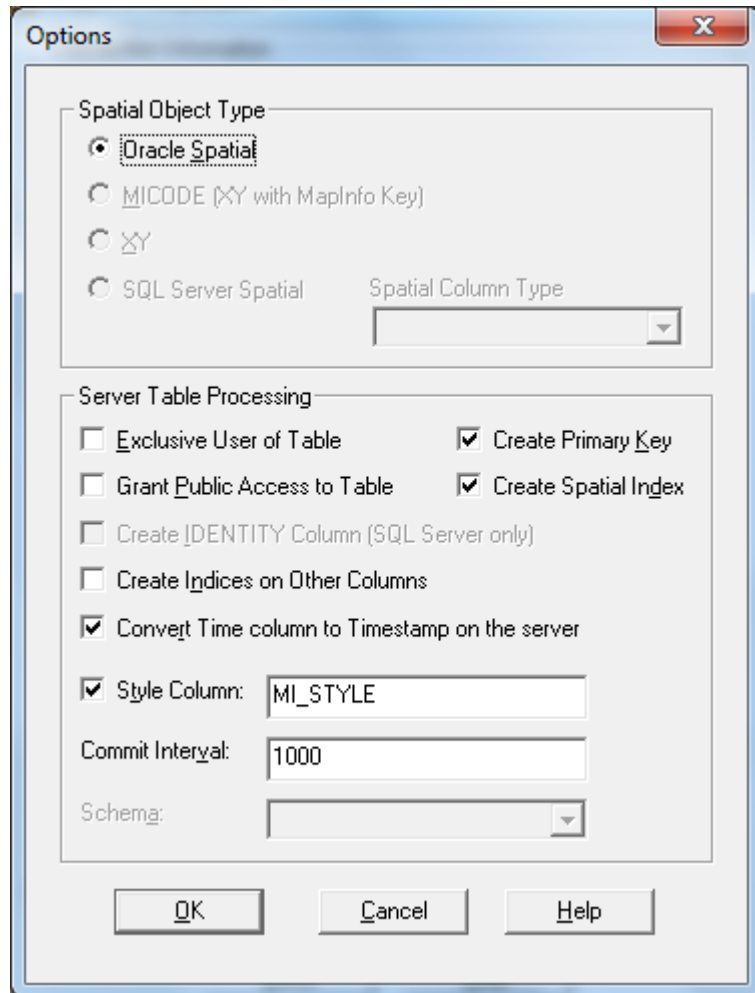
Figure A.4 Options for uploading to Oracle Spatial.

Create Spatial Index options creates and spatial R+ index to fast search and find object from given coordinates or screen extends.

APPENDIX B

CONTENT OF MAPINFO TAB FILE DOWNLOADED FROM ORACLE

A sample MapInfo TAB file that contains Oracle Spatial metadata information is given below.

!table

!version 550

!charset WindowsTurkish ⬅ Charecter set of file defined here

Definition Table

Type LINKED Charset "WindowsTurkish" ⬅ This table is linked

Fields 21

RAK Float ;

PABUC Float ;

CEKMEHALKA Float ;

KAPAKTIPI Char (12) ;

KAPAKYERI Char (12) ;

BOGAZDERIN Char (12) ;

KUBBEYUK Char (12) ;

TIP Char (10) ;

OZELLIK Char (10) ;

SANTRAL Float ;

OPER Float ;

ACI Float ;

TARIH Date ;

NO Char (10) ;

GMID Float ;

SIL Decimal (18, 0) ;

ID Decimal (12, 0) ;

IYIL Decimal (13, 0) ;

IEDEN Char (15) ;

IEPROJE Char (15) ;

MI_PRINX Decimal (12, 0) ;

begin_metadata   ← Metadata section

"\DATALINK" = ""   ← The Oracle connection information is given here

"\DATALINK\ConnectionString" = "SRVR=CBSSERVER;UID=ANKARA1"

"\DATALINK\ToolKit" = "ORAINET"

"\DATALINK\Autokey" = "OFF"

"\DATALINK\Query" =

"select RAK, PABUC, CEKMEHALKA, KAPAKTIPI, KAPAKYERI, BOGAZDERIN, KUBBEYUK, TIP, OZELLIK, SANTRAL, OPER, ACI, TARIH, NO, GMID, SIL, ID, IYIL, IEDEN, IEPROJE, MI_PRINX, OBJ from ANKARA2.menhol where (santral='31206009') "

"\OracleWorkspace" = ""

"\OracleWorkspace\Versioned" = "OFF"

"\OracleWorkspace\Name" = ""

"\OracleWorkspace\ParentName" = ""

end_metadata

APPENDIX C

SETTING UP MAPINFO CATALOG INFORMATION IN ORACLE

To store maps in Oracle Spatial/Locator it is required to catalog the mappable tables and store projection information of the tables. In MapInfo it is easy to upload the data to Oracle. The user needs to run Tools − Tool Manager, and load the DBMS Catalog to enable this extension. After loading the application it is required to choose Tools ➔ DBMS Catalog ➔ DBMS Catalog menu as shown in Figure C.1.
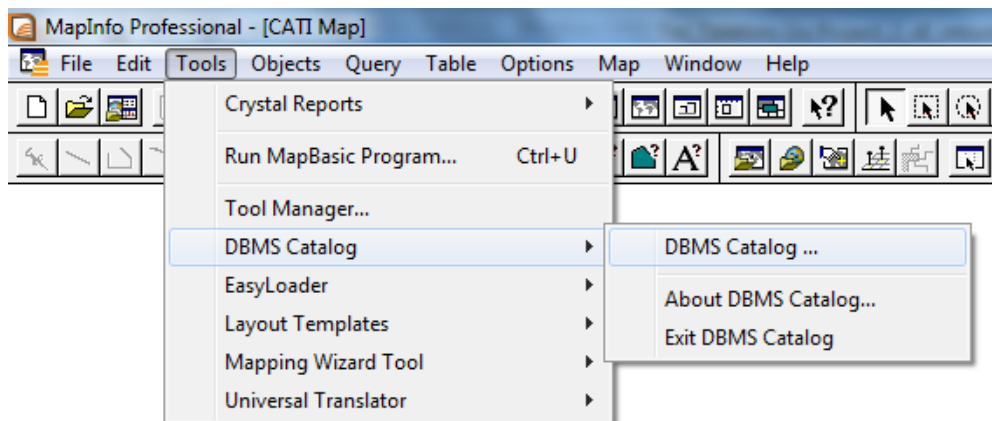
Figure C.1. The DBMS Catalog Menu in MapInfo Professional

After choosing the menu DBMS DBA Functions Dialog appears. First it is needed to connect to Oracle by pressing (Figure C.2.a) the "New Connection" button if there is no connection established yet.
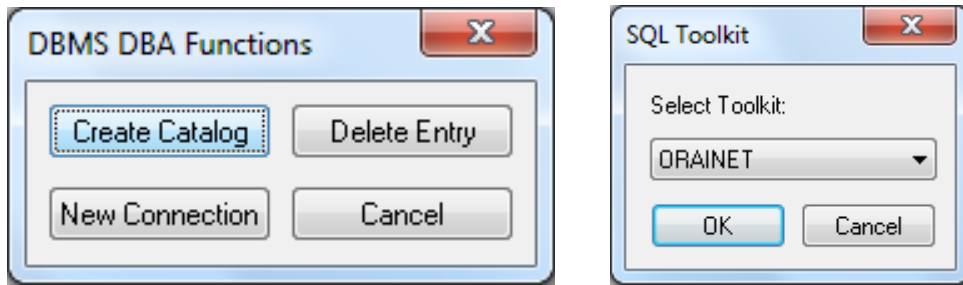
Figure C.2. a) DBMS DBA Functions dialog,   b) New connection dialog

It is needed to select ORAINET from the Select Toolkit list (Figure C.3.b), for Oracle, and ODBC for other databases. After typing a user name, password and Oracle server name the connection will be provided. The last step to create a catalog is to press the "Create Catalog" button in DBMS DBA Functions dialog (Figure C.2.a). The user must have necessary privileges to create a user and table. There will be a new user created as MAPINFO with password MAPINFO in Oracle. To store the catalog data a table named MAPINFO_MAPCATALOG is created automatically by the program.
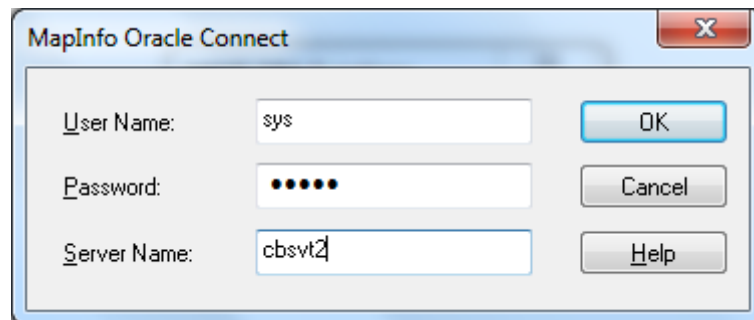
Figure C.3. Oracle Native connection dialog within MapInfo

If it is needed to drop the Catalog information press the "Delete Catalog" button.

APPENDIX D

DEVELOPING INTEGRATED MAPINFO APPLICATION

MapInfo program can be embedded in many popular software development environment by using Object Linking and Embedding (OLE) technology of Microsoft Windows.

D.1 MapInfo OLE Integration with C#:

Application Name: MapInfoApp

```csharp
using System;
using System.Collections;
using System.Windows.Forms;
using MapInfo.Domain;

namespace MapInfo {

    public class MapInfoApp {

        public const int MAPINFO_IN_SELECTION_LIMIT = 98;

        private static readonly string _mapPath;
        private static readonly string _tempMapPath;
        private static readonly string _mbxPath;

        private readonly Type _miType;
        private readonly object _mi;
        private int _mapWindowId;

        static MapInfoApp() {
            _mapPath = Application.StartupPath + @"\map\";
            _tempMapPath = Application.StartupPath + @"\map\temp\";
            _mbxPath = Application.StartupPath + @"\mbx\";
        }

        public MapInfoApp() {
            if (_mi == null) {
                try {
                    _miType = Type.GetTypeFromProgID("MapInfo.Application");
                    _mi = Activator.CreateInstance(_miType);
                    //Process process = new Process();

                }
                catch (Exception ex) {
                    MessageBox.Show(
                        "There is an error in preparing MapInfo Application.\n\nPlease check the license.",
```

```csharp
                "Error", MessageBoxButtons.OK, MessageBoxIcon.Error);
            Logger.logException(ex);
            return;
        }
    }
}

public static string MapPath {
    get {
        return _mapPath;
    }
}

public static string TempMapPath {
    get { return _tempMapPath; }
}

public static string MbxPath {
    get { return _mbxPath; }
}

public int MapWindowId {
    get {
        return _mapWindowId;
    }
    set {
        _mapWindowId = value;
    }
}

public MapperInfoClass MapperInfo {
    get {
        return new MapperInfoClass(this, _mapWindowId);
    }
}

public SelectionClass Selection {
    get {
        return new SelectionClass(this);
    }
}

public TableClass Table {
    get {
        return new TableClass(this);
    }
}

public LayerClass Layer {
    get {
        return new LayerClass(this);
    }
}

public ZoomExtent MapZoomExtent {
    get {
        return new ZoomExtent(this, _mapWindowId).getZoomExtent();
    }
    set {
        new ZoomExtent(this, _mapWindowId).setZoomExtent(value);
    }
}

public WindowInfoClass WindowInfo {
    get {
        return new WindowInfoClass(this, _mapWindowId);
    }
}
```

```csharp
public MbxClass Mbx {
    get {
        return new MbxClass(this);
    }
}

public bool Do(string command) {
    return Reflector.invokeMethod(_mi, "Do", command);
}

public string Eval(string command) {
    return Reflector.invokeAndEvalMethod(_mi, "Eval", command);
}

public bool RunCommand(string command) {
    return Reflector.invokeMethod(_mi, "RunCommand", command);
}

public bool RunMenuCommand(int menuCommand) {
    return Reflector.invokeMethod(_mi, "RunMenuCommand", menuCommand.ToString());
}

public void SetCallback(MapInfoCallBack callback) {
    if (callback != null) {
        string methodName;
        if (Version >= 950) {
            methodName = "RegisterCallback";
        }
        else {
            methodName = "SetCallback";
        }
        Reflector.invokeMethod(_mi, methodName, callback);
    }
}

public int Version {
    get {
        return Convert.ToInt32(this.Eval("SystemInfo(3)"));
    }
}

private object MBApplications {
    get {
        return Reflector.getPropertyAsObject(_mi, "MBApplications");
    }
}

private object GetMbxByName(string mbxName) {
    if (this.MBApplications != null) {
        IEnumerable mbApplications = (IEnumerable) this.MBApplications;
        if (mbApplications != null) {
            foreach (object mbApplication in mbApplications) {
                if (Reflector.getPropertyAsString(mbApplication, "Name").ToUpper() == mbxName.ToUpper()) {
                    return mbApplication;
                }
            }
        }
    }
    return null;
}

public bool MbxDo(string mbxName, string command) {
    object mbApp = GetMbxByName(mbxName);
    if (mbApp != null) {
        if (Reflector.invokeMethod(mbApp, "Do", command)) {
            return true;
        }
        return false;
    }
```

```csharp
            return false;
        }

        public string MbxEval(string mbxName, string command) {
            object mbApp = GetMbxByName(mbxName);
            if (mbApp != null) {
                Reflector.invokeAndEvalMethod(mbApp, "Eval", command);
            }
            return null;
        }

        private object GetMBGlobals(string mbxName) {
            object mbx = GetMbxByName(mbxName);
            if (mbx != null) {
                return Reflector.getPropertyAsObject(mbx, "MBGlobals");
            }
            return null;
        }

        public string GetMBGlobalVariable(string mbxName, string globalName) {
            IEnumerable mbGlobals = (IEnumerable) GetMBGlobals(mbxName);
            if (mbGlobals != null) {
                foreach (object mbGlobal in mbGlobals) {
                    if (Reflector.getPropertyAsString(mbGlobal, "Name").ToUpper() == globalName.ToUpper()) {
                        return Reflector.getPropertyAsString(mbGlobal, "Value");
                    }
                }
            }
            return null;
        }

        public void SetMBGlobalVariable(string mbxName, string globalName, string globalValue) {
            IEnumerable mbGlobals = (IEnumerable) GetMBGlobals(mbxName);
            if (mbGlobals != null) {
                foreach (object mbGlobal in mbGlobals) {
                    if (Reflector.getPropertyAsString(mbGlobal, "Name").ToUpper() == globalName.ToUpper()) {
                        Reflector.setProperty(mbGlobal, "Value", globalValue);
                    }
                }
            }
        }

    }
}
```

Application: FrmMAP.cs

```csharp
using System;
using System.Runtime.InteropServices;
using System.Windows.Forms;
using MapInfo.Domain;
using MapInfo.Enums;

namespace MapInfo.Gui {

    public partial class FrmMap : Form, ICallbackNotify, IMapInfoDocumentWindow {

        [DllImport("user32.dll")]
        private static extern bool MoveWindow(IntPtr hwnd, int X, int Y, int nWidth, int nHeight, bool bRepaint);

        private const string QT = "\"";
        private const string WORKSPACE = "TELEKOM.WOR";
        private const string EMPTY_WORKSPACE = "TELEKOM_BOS.WOR";
        private const string TEMP_TABLE = "TBLTEMP";
```

```csharp
private MapInfoApp _map;
private int _windowId;
private IntPtr _hwnd;
private IMdiParent _frmMDI;
private MapInfoCallBack _callback;
private bool _isActiveMdiChild = false;
private readonly WorkSpaceType _workSpaceType;

public FrmMap(WorkSpaceType workSpaceType) {
    InitializeComponent();
    pnlMap.Dock = DockStyle.Fill;
    _workSpaceType = workSpaceType;
}

public MapInfoApp Map {
    get {
        return _map;
    }
    set {
        _map = value;
    }
}

public IMdiParent MapMdiParent {
    get {
        return _frmMDI;
    }
}

public bool IsActiveMdiChild {
    get {
        return _isActiveMdiChild;
    }
    set {
        _isActiveMdiChild = value;
    }
}

public int WindowId {
    get {
        return _windowId;
    }
}

private void initMapInfo() {
    Application.DoEvents();
    _frmMDI = (IMdiParent)this.MdiParent;

    _map = new MapInfoApp();
    if (Common.MapperMapInfo == null) {
        Common.MapperMapInfo = _map;
    }

    _map.Do("Set Application Window " + pnlMap.Handle);
    _map.Do("Set Next Document Parent " + pnlMap.Handle + " Style 1");
    if (_workSpaceType == WorkSpaceType.Normal) {
        _map.Do("Run Application " + QT + Application.StartupPath + @"\map\" + WORKSPACE + QT);
    }
    else if (_workSpaceType == WorkSpaceType.Empty) {
        _map.Do("Run Application " + QT + Application.StartupPath + @"\map\" + EMPTY_WORKSPACE + QT);
    }
    _windowId = int.Parse(_map.Eval("WindowID(0)"));
    _hwnd = (IntPtr)long.Parse(_map.Eval("WindowInfo(FrontWindow(),12)"));

    _map.Do("Set Window Info Parent " + pnlMap.Handle);
    _map.Do("Set Window Ruler Parent " + pnlMap.Handle);
    //_map.Do("Set Window Legend Parent " + pnlMap.Handle);
    _map.Do("Set Window Info ReadOnly");
```

```csharp
        _map.Do("Set Coordsys Window FrontWindow()");
        _map.Do("Set Map Coordsys Window FrontWindow()");
        //TODO:
        _map.Do("Set Map Distance Units " + QT + DistanceUnit.METER + QT);
        _map.Do("Set Map Area Units " + QT + AreaUnit.SQUARE_METER + QT);
        _map.Do("Set Map Display Position");
        _map.Do("Set Format Date " + QT + "US" + QT);
        _map.Do("Set ProgressBars Off");

        _map.MapWindowId = _windowId;
        _map.RunMenuCommand(ToolManager.ActiveMapTool);
        _callback = new MapInfoCallBack(this);
        _map.SetCallback(_callback);
    }

    public void Form_Load(object sender, EventArgs e) {
        initMapInfo();
    }

    public void Form_Activated(object sender, EventArgs e) {
        _isActiveMdiChild = true;
        WindowManager.ActiveChildForm = this;
        _frmMDI.setStatusPanelsForMap();
        _frmMDI.resetStatusBar();
        //TODO: Tamamla
        //_frmMDI.setMapRelatedButtons(true);
    }

    public void Form_Deactivate(object sender, EventArgs e) {
        _isActiveMdiChild = false;
        //_frmMDI.setMapRelatedButtons(false);
        //_frmMDI.setGraphRelatedButtons(false);
        _frmMDI.resetStatusBar();
    }

    private void FrmMap_FormClosing(object sender, FormClosingEventArgs e) {
        _map.Table.pack(TEMP_TABLE);
    }

    public void Form_Resize(object sender, EventArgs e) {
        MoveWindow(_hwnd, 0, 0, pnlMap.Width, pnlMap.Height, false);
    }

    public void Form_FormClosed(object sender, FormClosedEventArgs e) {
        _map.SetCallback(null);
        _callback = null;
        // TODO:
        _map = null;
        GC.Collect();
        GC.WaitForPendingFinalizers();
    }

    public void OnStatusBarTextChanged(string text) {
        if (_isActiveMdiChild) {
            int indexOfEditingLayer = text.IndexOf("Editing:");
            if (indexOfEditingLayer != -1) {
                string s = text.Replace("\t", " ");
                int indexOfSelectingLayer = s.IndexOf("Selecting:");
                string coords = s.Substring(0, indexOfEditingLayer - 1);
                coords = coords.Replace(",", ".");
                coords = coords.Replace("m.", "m,");
                string editingLayer = s.Substring(indexOfEditingLayer, indexOfSelectingLayer - indexOfEditingLayer - 1);
                editingLayer = editingLayer.Replace("Editing", "Düzenlenen");
                editingLayer = editingLayer.Replace("None", "Yok");
                editingLayer = editingLayer.Replace("No", "Yok");
                string selectingLayer = s.Substring(indexOfSelectingLayer, s.Length - indexOfSelectingLayer - 1);
                selectingLayer = selectingLayer.Replace("Selecting", "Seçilen");
                selectingLayer = selectingLayer.Replace("None", "Yok");
                selectingLayer = selectingLayer.Replace("No", "Yok");
```

```
                    _frmMDI.setPanel1Text(coords);
                    _frmMDI.setPanel2Text(editingLayer);
                    _frmMDI.setPanel3Text(selectingLayer);
                }
            }
        }

        public void OnWindowContentsChanged(uint windowId) {
            if (_map != null) {
                if (_isActiveMdiChild) {
                    _frmMDI.setPanel4Text(_map.MapperInfo.getZoomLevel());
                    _frmMDI.setPanel5Text(_map.MapperInfo.getScale());
                }
                if (WindowManager.SyncMapWindows) {
                    WindowManager.SyncZoomExtent = _map.MapZoomExtent;
                    foreach (Form childForm in this.MdiParent.MdiChildren) {
                        if (childForm is FrmMap) {
                            if (!((FrmMap) childForm).IsActiveMdiChild) {
                                ((FrmMap) childForm).Map.MapZoomExtent.setZoomExtent(WindowManager.SyncZoomExtent);
                            }
                        }
                    }
                    Application.DoEvents();
                }
            }
        }

    }
}
```

Applicaiton: MapToolBar.cs

```
using System.Windows.Forms;
using MapInfo;
using MapInfo.Enums;
using MapInfo.Gui;

namespace MapToolbar {

    public partial class CtlMapToolbar : UserControl {
        private const string TEMP_TABLE = "TBLTEMP";
        private Form _mdiParent;

        public CtlMapToolbar() {
            InitializeComponent();
        }

        public Form MdiParent {
            get {
                return _mdiParent;
            }
            set {
                _mdiParent = value;
            }
        }

        public ToolStripButton getMapToolbarButtonByName(string buttonName) {
            foreach(Control ctl in this.Controls) {
                if (ctl is ToolStrip) {
                }
            }
            return null;
        }
```

```csharp
private void btnNewEmptyMap_Click(object sender, System.EventArgs e) {
    FrmMap frmMap = new FrmMap(WorkSpaceType.Empty);
    frmMap.MdiParent = this._mdiParent;
    frmMap.Show();
}

private void btnNewMap_Click(object sender, System.EventArgs e) {
    FrmMap frmMap = new FrmMap(WorkSpaceType.Normal);
    frmMap.MdiParent = this._mdiParent;
    frmMap.Show();
}

private void btnOpenLayer_Click(object sender, System.EventArgs e) {
    MapInfoTableOpener.openMapInfoTable();
}

private void btnNewBrowser_Click(object sender, System.EventArgs e) {
    FrmTableList frmTableList = new FrmTableList(this._mdiParent);
    frmTableList.ShowDialog();
}

private void btnPrintMap_Click(object sender, System.EventArgs e) {
    MapUtils.printMap();
}

private void runMenuCommand(int toolId) {
    foreach (Form form in this._mdiParent.MdiChildren) {
        if (form is FrmMap) {
            ((FrmMap) form).Map.RunMenuCommand(toolId);
        }
    }
}

private void setActiveTool(ToolStripButton tsb, int toolId) {
    runMenuCommand(toolId);
    ToolManager.ActiveMapTool = toolId;
    uncheckMapButtons();
    tsb.Checked = true;
}

private void btnSelect_Click(object sender, System.EventArgs e) {
    setActiveTool((ToolStripButton)sender, (int)MapToolbarButtons.SELECT);
}

private void btnInvertSelection_Click(object sender, System.EventArgs e) {
    runMenuCommand((int)MapToolbarButtons.INVERT_SELECTION);
}

private void btnSelectRect_Click(object sender, System.EventArgs e) {
    setActiveTool((ToolStripButton)sender, (int)MapToolbarButtons.RECTANGULAR_SELECT);
}

private void btnSelectRadius_Click(object sender, System.EventArgs e) {
    setActiveTool((ToolStripButton)sender, (int)MapToolbarButtons.RADIUS_SELECT);
}

private void btnUnselect_Click(object sender, System.EventArgs e) {
    runMenuCommand((int)MapToolbarButtons.UNSELECT);
}

private void btnZoomin_Click(object sender, System.EventArgs e) {
    setActiveTool((ToolStripButton)sender, (int)MapToolbarButtons.ZOOMIN);
}

private void btnZoomout_Click(object sender, System.EventArgs e) {
    setActiveTool((ToolStripButton)sender, (int)MapToolbarButtons.ZOOMOUT);
}

private void btnFullExtent_Click(object sender, System.EventArgs e) {
```

```
        MapUtils.zoomLayerExtent("CEVREYOLU");
    }

    private void btnPan_Click(object sender, System.EventArgs e) {
        setActiveTool((ToolStripButton)sender, (int)MapToolbarButtons.PAN);
    }

    private void btnPreviousView_Click(object sender, System.EventArgs e) {
        WindowManager.ActiveChildForm.Map.RunMenuCommand((int) MapToolbarButtons.PREVIOUS_VIEW);
    }

    private void btnInfo_Click(object sender, System.EventArgs e) {
        setActiveTool((ToolStripButton)sender, (int)MapToolbarButtons.INFO);
    }

    private void btnRuler_Click(object sender, System.EventArgs e) {
        setActiveTool((ToolStripButton)sender, (int)MapToolbarButtons.RULER);
    }

    private void btnRedrawMap_Click(object sender, System.EventArgs e) {
        runMenuCommand((int)MapToolbarButtons.REDRAW_MAP);
    }

    private void btnClearCosmeticLayer_Click(object sender, System.EventArgs e) {
        ((FrmMap)WindowManager.ActiveChildForm).Map.Layer.clearCosmeticLayer();
        ((FrmMap)WindowManager.ActiveChildForm).Map.Table.deleteAllRows(TEMP_TABLE);
    }

    private void btnExportWindow_Click(object sender, System.EventArgs e) {
        FrmMapExportOptions frmMapExportOptions = new FrmMapExportOptions();
        frmMapExportOptions.ShowDialog();
    }

    private void btnLaunchMapInfo_Click(object sender, System.EventArgs e) {
        Utils.launchMapInfo();
    }

    private void uncheckMapButtons() {
        btnSelect.Checked = false;
        btnSelectRect.Checked = false;
        btnSelectRadius.Checked = false;
        btnZoomin.Checked = false;
        btnZoomout.Checked = false;
        btnPan.Checked = false;
        btnInfo.Checked = false;
        btnRuler.Checked = false;
    }

    public void setMapRelatedButtons(bool enabled) {
        btnOpenLayer.Enabled = enabled;
        btnPrintMap.Enabled = enabled;
        btnSelect.Enabled = enabled;
        btnSelectRect.Enabled = enabled;
        btnUnselect.Enabled = enabled;
        btnZoomin.Enabled = enabled;
        btnZoomout.Enabled = enabled;
        btnFullExtent.Enabled = enabled;
        btnPan.Enabled = enabled;
        btnInfo.Enabled = enabled;
        btnRuler.Enabled = enabled;
        btnClearCosmeticLayer.Enabled = enabled;
        btnExportWindow.Enabled = enabled;
        setGraphRelatedButtons(!enabled);
    }

    public void setGraphRelatedButtons(bool enabled) {
    }

    private void btnCopyZoomExtent_Click(object sender, System.EventArgs e) {
```

```
        WindowManager.SavedZoomExtent = ((FrmMap) WindowManager.ActiveChildForm).Map.MapZoomExtent;
    }

    private void btnApplyZoomExtent_Click(object sender, System.EventArgs e) {
        ((FrmMap) WindowManager.ActiveChildForm).Map.MapZoomExtent = WindowManager.SavedZoomExtent;
    }

    private void btnApplyZoomExtentAll_Click(object sender, System.EventArgs e) {
        foreach (Form childForm in this._mdiParent.MdiChildren) {
            if (childForm is FrmMap) {
                ((FrmMap) childForm).Map.MapZoomExtent.setZoomExtent(WindowManager.SavedZoomExtent);
            }
        }
    }

    private void btnSyncMapWindows_Click(object sender, System.EventArgs e) {
        ((ToolStripButton) sender).Checked = !((ToolStripButton) sender).Checked;
        if (((ToolStripButton)sender).Checked) {
            WindowManager.SyncMapWindows = true;
        }
        else {
            WindowManager.SyncMapWindows = false;
        }
    }
  }
}
```

D.2 MapInfo OLE Integration with Delphi:

Important codes and explanations for developing an MapInfo OLE application within Delphi 7 are given briefly.

D.2.1 Initializing and communicating with MapInfo

MainForm.pas

```
Procedure TFormMain.FormCreate(Sender: TObject);
Begin
 SplashForm.StatusBar1.Panels.Items[0].Text := 'Loading MapInfo Componenrs...';
 panelKontrol := false;
 SplashForm.StatusBar1.Refresh;
```

MapInfo is created as an OLE object by the following command:

```
 mi := createoleobject('Mapinfo.Application');
```

MapInfo Callback is created by the following command. Callback is used to communicate with MapInfo (such as sending mouse coordinates, applying custom button events and repoting the results of the action)

```
MIclb := TMICallBack.Create;
MI.SetCallBack(IDispatch(MIclb));
clickSantralMenu := true;
```

Custom MapInfo buttons are created by the following commands and each button

calls a function in the Callback codes.

```
mi. Do ('create buttonpad "TTGIS" as toolbutton id 2001 calling ole "getinfo"');
mi. Do ('create buttonpad "findlayer" as toolbutton drawmode(35) id 8888 calling ole "findlayer"');
mi. Do ('create buttonpad "findlayerdxf" as toolbutton drawmode(35) id 8887 calling ole "findlayerdxf"');
```

Opening MapInfo Tables within the Application, and closing all of them

```
mi. Do ('Open Table "' + LoginForm.ilKullaniciSantralPath + 'kablo.TAB" Interactive');
mi. Do ('Open Table "' + LoginForm.ilKullaniciSantralPath + 'cati.TAB" Interactive');
mi. Do ('Open Table "' + LoginForm.ilKullaniciSantralPath + 'SntBina.TAB" Interactive');

mi. Do ('Close All');
```

Refreshing MapInfo Tables within the Application

```
mi. Do ('Server Refresh site');
mi. Do ('Server Refresh transe');
```

Opening an Oracle table as a MapInfo layer within the application

```
mi. Do ('Server int(' + miConnectionString + ') link Table "select
MODNO,ID,KABLOSAHIB,TIPI,LIBRAJ,IYILI,IEDEN,IEPROJE,KAPASITE,KAMACI,KSEKLI,KSISIM,PKADI,UZUNL
UK,CUZUNLUK,KONUM,GKDURUM,MYILI,MYAPAN,SANTRAL,HAES_ID,SDNO,YEDEK,OLUDEVRE,PRENSIBA
L,TARIH,OPER,SIL,ETIKET,ETIKETPER,MI_PRINX,OBJ from ' + LoginForm.ilAdi + '.PKablo where (santral="' +
EditSantralId.Text + '" or santral="' + EditSantralId2.Text + '") AND sil<>1 " toolkit "ORAINET" Into "pkablo" file "' +
LoginForm.ilKullaniciSantralPath + 'pkablo.tab"');
```

Setting application window, opening maps and getting information about front

Window Id.

```
mi. Do ('Set Application Window ' + h);
mi. Do ('Set Next Document Parent ' + h + ' Style 1');
mi. Do ('run application "' + LoginForm.mbPath + 'katmanduzenle.mbx"');
lejantid := mi.eval('windowinfo(1,13)');
mi. Do ('dim winid as Integer');
mi. Do ('winid=FrontWindow()');
winid := mi.eval('str$(winid)');
layoutid := winid;
mi. Do ('undim winid');
mi. Do ('select * from santral where  santralid=' + EditSantralId.Text + ' into secsant noselect');
mi. Do ('add map layer secsant');
mi. Do ('Set Map Window frontwindow() Zoom Entire Layer secsant');
mi. Do ('close table secsant');
mi. Do ('set coordsys table santral');
mi. Do ('Set Map Distance Units "m" Area Units "sq m" ');
mi. Do ('set window frontwindow() snap mode on');
mi. Do ('Set Application Window ' + h);
mi. Do ('set window ruler parent ' + h);
mi. Do ('set window info parent ' + h);
```

Setting layers to not to be editable by the users

```
 mi. Do ('Set Table mahalle UserEdit Off');
 mi. Do ('Set Table santral UserEdit Off');
```

Running a MapInfo button or menu within the application by "Run menu command"

```
Procedure TFormMain.dxBarButton6Click(Sender: TObject);
Begin
 mi. Do ('run menu command 1705');
End;
```

Running a Custom Button or menu within the application by "Run menu command id" method.

```
Procedure TFormMain.BlgeSeDiskeKaydet1Click(Sender: TObject);
Begin
 mi. Do ('run menu command id 8888');
End;
```

Getting information from MapInfo by ".eval" method

```
 If mi.eval('numtables()') <> '0' Then
 Begin
  layerCount := strtoint(mi.eval('MapperInfo(' + winid + ',9)'));


 If mi.eval('SelectionInfo(1)') <> '' Then

  mi. Do ('Set Table ' + tableName + ' Undo Off');
```

Selecting all object that intersect to a specific object

```
  mi. Do ('select * from transe_route where obj intersects routeob into selkont');
 End;
 If mi.eval('tableinfo(selkont,8)') > 0 Then
 Begin
  startnode := mi.eval('selkont.fnode');
```

Selecting objects and adding them into the layer control as a new layer and differentiating the style to highlight.

```
  mi. Do ('select * from transe_route where lineselected=1 into selroute');
 If mi.eval('tableinfo(selroute,8)') > 0 Then
 Begin
  mi. Do ('Add Map Layer selroute');
  mi. Do ('set Map Window ' + lejantid + ' Zoom Entire Layer  selroute');
  mi. Do ('Set Map Layer selroute Display Global Global Line (2,64,16711680)');
 End;
```

D.2.2 Login Form and Logging of User Events

Unit Login;

```
Procedure TLoginForm.DatabaseLoginUser(sicil: String; kullaniciAdi: String);
Var
  maxCount: String;
Begin
 DatabaseConnection;
 With DataModule3.ADOQueryUserOnUse Do Begin
   Connection := DataModule3.ADOConnection1;
   SQL.Text := 'UPDATE KULLANICI SET KULLANILIYOR = 1 WHERE SICIL = ' + '''' + sicil + '''' + ' AND
KULLANICI_ADI = ' + '''' + kullaniciAdi + '''';
   ExecSQL;
   SQL.Text := 'SELECT MAX(SESID) FROM LOGIN';
   Active := True;
   If RecordCount > 0 Then
   Begin
    maxCount := Fields[0].AsString;
    If maxCount = '' Then
    Begin
     maxCount := '1';
    End
    Else
    Begin
     maxCount := IntToStr(StrToInt(maxCount) + 1);
    End
   End
   Else
   Begin
    maxCount := '1';
   End;
   SQL.Text := 'INSERT INTO LOGIN (SICIL,GIRISTARIH,GIRISSAAT,SESID) VALUES';
   SQL.Add(' (' + QuotedStr(sicil) + ',' + QuotedStr(FormatDateTime('dd.mm.yyyy', Now)) + ',' +
QuotedStr(FormatDateTime('hh:nn:ss', Now)) + ',' + QuotedStr(maxCount) + ')');
   ExecSQL;
   EditSesId.Text := maxCount;
 End;
End;

Procedure TLoginForm.DatabaseLogoutUser(sicil: String; kullaniciAdi: String);
Begin
 DatabaseConnection;
 With DataModule3.ADOQueryUserOnUse Do Begin
   Connection := DataModule3.ADOConnection1;
   SQL.Text := 'UPDATE KULLANICI SET KULLANILIYOR = 0 WHERE SICIL = ' + '''' + sicil + '''' + ' AND
KULLANICI_ADI = ' + '''' + kullaniciAdi + '''';
   ExecSQL;
   SQL.Text := 'UPDATE LOGIN SET CIKISSAAT = ' + QuotedStr(FormatDateTime('hh:nn:ss', Now)) + ' , CIKISTARIH = ' +
QuotedStr(FormatDateTime('dd.mm.yyyy', Now)) + ' where SESID = ' + EditSesId.Text + '';
   ExecSQL;
 End;
End;

   miConnectionString := mi.eval('Server_Connect ("ORAINET","SRVR=' + ilVt + ';UID=' + ilAdi + ';PWD=' + ilSifre + '")');
     SplashForm.StatusBar1.Panels[0].Text := 'Mapinfo-Oracle connection is OK...';

     If Not DirectoryExists(ilDataPath) Then
     Begin
      Application.MessageBox('There is no folder for this user, Please apply to Admin ', 'CBS TELEKOM', MB_OK +
MB_ICONWARNING);
     End
```