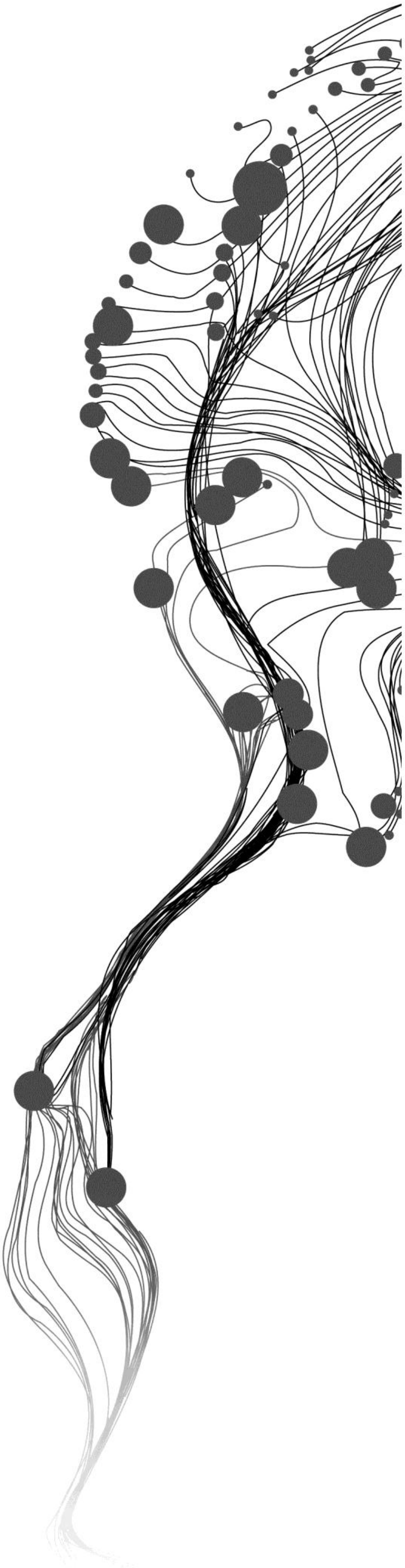
DATA INTEGRATION OF SUBSURFACE UTILITY MAPS AND CADASTRAL MAPS AS A NEW BUSINESS MODEL IN SOUTH – KOREA

BYUNG YONG, KWAK
February, 2012

SUPERVISORS:
Ir. Christiaan Lemmen
Prof. Dr Jaap Zevenbergen



DATA INTEGRATION OF SUBSURFACE UTILITY MAPS AND CADASTRAL MAPS AS A NEW BUSINESS MODEL IN SOUTH – KOREA

BYUNG YONG, KWAK
Enschede, the Netherlands,

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements of the degree of Master of Science in Geo-Information Science and Earth Observation.
Specialization: Land Administration

SUPERVISORS:
Ir. Christiaan Lemmen
Prof. Dr Jaap Zevenbergen

THESIS ASSESSMENT BOARD

Chair: Prof. Ir. P. van der Molen
External examiner: Dr.ing. S. Zlatanova
First supervisor: Ir. C.H.J. Lemmen
Second supervisor: Prof. Dr. J.A. Zevenbergen

ABSTRACT

Cadastres have been developed gradually with technical evolution and social needs; but the traditional cadastre (2D) could not satisfy new requirements from society where the 3D legal and spatial representation of properties is concerned. 3D cadastres have been introduced including surface and subsurface rights. The South-Korean Law defines the ownership 'extending above/under the land within legitimate interest' (Civil Code, article 212).

Population growth, urbanization and industrialization brings a need for more space (Aien *et al.*, 2011). For example utilities are moving to underground space in South-Korea (Lee *et al.*, 2007). In the past, the utility is laid to underground without any recordation at all or with improper recordation of the situation concerned. Incorrect information brought two disasters in Ahyundong and Sangindong with huge property damages (Son *et al.*, 2004). After those accidents the South-Korean government tried to correct inaccurate information of underground utilities and develop a system for managing underground utilities since 1998 (Lee et al., 2007). But the availability of primary data of underground utilities is still depending on the willingness of co-operation of utility companies and organizations.

Two different maps are used for different domains in South-Korea. The cadastre maintains and uses the cadastral map and the utility companies use and maintain the topographic map. Those maps have differences in geo-reference and registration. The cadastral map presents all the information related to ownership and the utility map presents the actual situation including buildings, type of utility, elevation etc. Moreover the cadastral map is maintained by cadastral surveying and utility map is maintained by utility surveying. Different base map bring deferent results in the projection of the same objects

In this research, the problems of South-Korea spatial data and the reasons of different between two maps are discussed based on data integration and data sharing perspectives. The data integration method is addressed by a prototype developed. To assess the quality of data integration, field measurements have been conducted to check the differences between reality and the cadastral map at Seogwipo Dong Moon. Auto-CAD, Arc-GIS and Google Sketch-up have been used for the prototype to integrate the two maps. The prototype shows the possibility of successful data integration of two maps combined with a 3D visualization.

Furthermore to find suitable business model in South-Korea, a comparative study has been performed between the Netherlands and South-Korea. The proposed business model expects to support in the improvement of the South-Korean spatial data infrastructure.

ACKNOWLEDGEMENTS

I read this passage 'The God did not create Netherlands, the Dutch created Netherlands' in the travel book before I came to Netherlands. I could not understand the meaning but I realised after studying in ITC. Studying in ITC was one of the most valuable times in my life and gives a motivation to change my fixed idea, stimulating my life. I would like to express my sincere gratitude to all.

First of all, I would express my gratitude to KCSC. The company allowed me to study in the Netherlands with all kinds of support. Also thank to ITC of University of Twente to attend this course.

I would like to give my utmost thanks and appreciations to my supervisors Ir. C.H.J. Lemmen and Prof. Dr Jaap Zevenbergen and Chairman Prof. Ir. P. van der Molen for their invaluable suggestions and contributions. They always gave me an inspiration and challenges during thesis period.

I would like to thank Course Director Walter de Vries, Ing.L.Bert Raidt and Course Secretary Ms. Jacqueline Mol for their kind support and information during the period at ITC.

I also appreciate to my KCSC Seowipo staff to support valuable information during my field work. Their supports and advice brings positive result of my thesis. Further, I really thank Ir. R. C. J. Witmer (GBKN) and C. J. Groot (KLIC) of The Dutch Kadaster for interviewing.

For last 18 months, I had a great time with my special friends Alvin, Phuong, Tang, Daniel, Nuria, Chao, Susheel, Thumba, Robert, Ngalandji, Eliessa, Georgina, Nneka, Wang, Alamin, Shanti and Olawale. And sincere thanks to all of my ITC colleagues and staff.

Finally, Very special thanks to my wife HyounWook and my first baby 'Happiness' will be born. I am really thank God for having both of you.

Give thanks to God

Byung Yong Kwak
February,

Table of contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CIF	Cadastral Information File
EI	Electromagnetic Induction
GBKN	Grootschalige Basis Kaart Nederland
GPR	Ground Penetration Radar
GRS	Geodetic Reference System
KASM	Korean Association of Surveying and Mapping
KCEI	Korea Cave Exploration Institute
KCSC	Korea Cadastral Survey Corporation
KDHC	Korea District Heating Corporation
KEC	Korea Expressway Corporation
KEPCO	Korea Electronics Power Corporation
KLIC	Kabels en Leidingen Informatie Centrum
KLIS	Korea Land Information System
KOGAS	Korea Gas Corporation
KWRC	Korea Water Resources Corporation
LADM	Land Administration Domain Model
LIDAR	Light Detection and Ranging
LIS	Land Information System
MKE	Ministry of Knowledge Economic
MLTM	Ministry of Land, Transport and Maritime Affairs
NARK	National Assembly of the Republic of Korea
NGII	National Geographic Information Institute
NGIS	National Geographic Information System
RTK	Real Time Kinematic
SDI	Spatial Data Infrastructure
TOSS	Total Survey System
UIS	Underground Information System

1. INTRODUCTION

1.1. Background

The *ownership* of land includes the space above and under the surface of a parcel to a height and depth to which the users are (possibly) interested. Also it is possible to *use* the space above and under the surface in case of the user gets a permission from the owner (Stoter & van Oosterom, 2006). But the range of ownership has difference kinds of limitations by law (Paulsson, 2007). The current land laws in many countries have no specifications (how many meters above/below) about 3D use or ownership of space. In other words, the ownership rights are defined ambiguously. According to Stoter (2004) 'the pressure on land in urban areas and especially their business centres has led to over-lapping and interlocking constructions'. The efficient use of space is a very important aspect in urban planning and development.

One of the alternative solutions in efficient use of space is in using underground space. This provides new space (to overcome lack of ground space) for functions such as underground utilities and for infrastructures like shopping, parking and other functionalities. The construction costs of underground building are a very important aspect when building a structure in underground. Monnikhof et al (1999) found remarkable result that 'gains in available space up to 50% in specific areas seemed possible and, when costs of working and maintenance were taken into account, underground construction for several facilities was no more expensive than above ground construction, which contradicts a widely held belief in the Netherlands'

Current cadastral surveying and mapping methods and registrations use 2D approaches to register ownership rights. In South-Korea, it is possible to give clear information about the legal status of land rights for each parcel. But in cases of multiple use of land space difficulties can be recognised to register such cases on 2D cadastre/maps. The traditional 2D cadastre is not sufficient to represent complex 3D ownership rights such as skyscrapers and underground utilities. It is difficult to reflect the spatial legal information of those structures (Oosterom *et al.*, 2011). In addition, a cadastral map is usually based on parcel registration; such map should keep up-to-date land information and recording of the interests in land or structures e.g. rights, restrictions, and responsibilities with handling spatial data (FIG, 1995).
The 3D cadastre showed up now to indicate information regarding to the 3D spatial object/rights (Stoter *et al.*, 2002). In many cases a 2D representation is not sufficient to catch up with the development of complex situations in land and related constructions. One of the reasons for the introduction of the LADM is a 3D cadastral representation. LADM attempts to introduce a generic standard for cadastral data and to offer facilities in data sharing. LADM defined a class LA_LegalSpaceNetwork which means legal space for utility networks. It has become a motivation considering the relations between physical and legal representations in real objects (Döner *et al.*, 2010).

Temporal (3D + time) can be either integrated with the spatial dimensions or as separate attributes (Döner et al., 2010). The representation of above/underground space is difficult because a boundary is a spatial boundary e.g. between two parcels and it is a temporal boundary because there can be transfers of rights to others where boundaries are changing (e.g. a parcel subdivision). (Döner et al., 2010).

1.2. Motivation

Land is under pressure from human activities in urban areas. Population growth, urbanization and industrialization brings a need for more space (Aien et al., 2011). Utilities are moving to underground space in Korea (Lee et al., 2007). Two huge gas explosion accidents happened to Ahyundong in Seoul in 1994 and Sangindong in Deagu metropolitan city in 1995. Those accidents occurred by same type of mistake labourers digging hit the gas line. As a result from the Ahyundong accident 12 people died, 101 people were injured and the amount of damaged property was equal to $7.1 million. In the Sangindong accident 101 people died, 202 people were injured and the total value of damaged property was about $50 million. The main reason of the explosions was the fact that the gas line was laid only 0.3 m under the surface - where it should be 1 meter by law (Son et al., 2004).

After those accidents the government has corrected inaccurate information of underground utilities and tried to develop a system for managing underground utilities since 1998 (Lee et al., 2007). But the availability of primary data of underground utilities is still depending on the willingness for cooperation of many utility companies and of organizations providing surveying results.

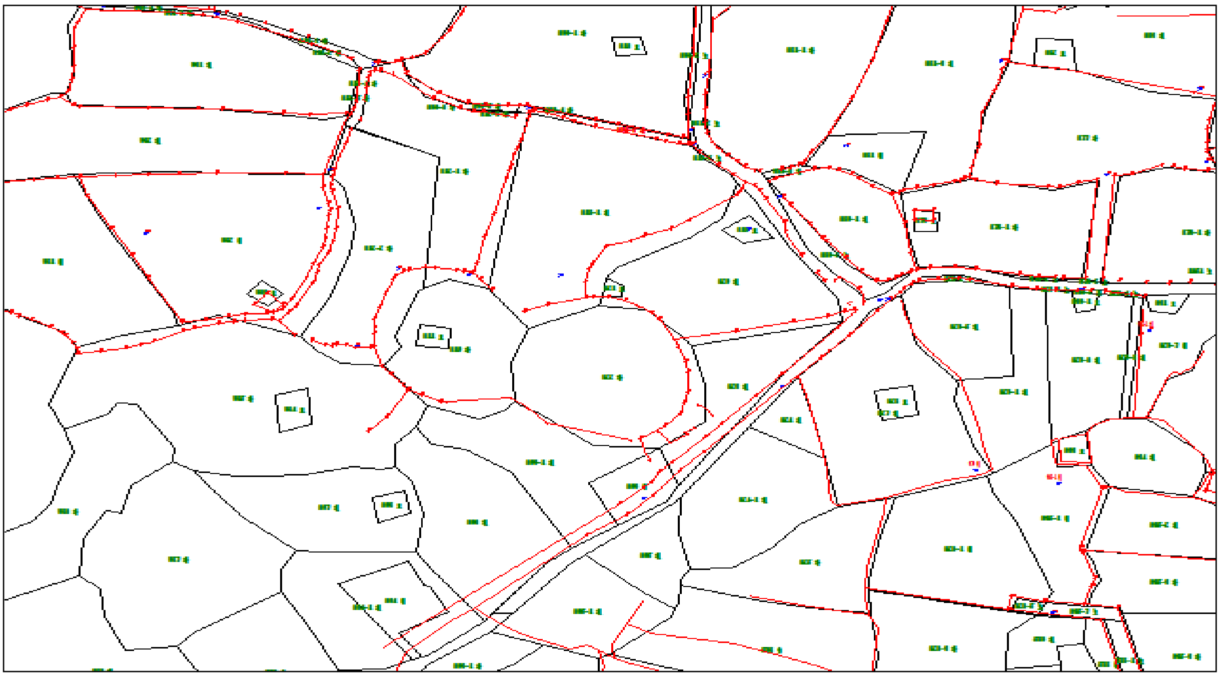


Figure 1-1 Difference of actual boundaries and cadastral map boundaries (Source: KCSC Seogwipo branch)

Here below is an example for the motivation of integration utility map and cadastral map. Figure 1-1 shows a difference of actual boundary (in red[1]) and cadastral map boundary (in black[2]). The black line is the legal parcel boundary on the cadastral map and the red line is the representation of the actual boundary in reality. The legal parcel boundary cannot be changed because of its legal meaning – in South Korea the representation of boundaries on the cadastral map is correct by law. Most of the calculated areas almost match within the allowed tolerance but in the centre area the parcel boundaries and the road do not match. There are many reasons for mismatching such as registration, surveyor's mistake and

1. Those boundaries represent survey work – total stations – which still have to be completed. For this reason the map is not yet topologically correct, not all areas of parcels can be calculated

2. Those boundaries are a result from digitizing old cadastral maps (scale 1:1200) which are based on plane table data acquisition

incorrect control point, and human mistake (expending the parcel boundary by owner), mistakes in mapping at the plane table, mistakes in digitizing etc (propagation of errors).

The utility organizations will install the water/sewage pipe along the road but as one can see, the road is located sometimes in a private parcel *on the map, not in reality*. The reason is the fact that the red lines represent a boundary surveyed with high accuracy, the black boundaries have been measured with very low accuracy – but is legally valid.

This proves that if there is a plan for installing the pipe line in this area using the utility map (which is based on topographic map) all utilities will be laid to private lands. Therefore, the integration of topographic map and cadastral map is really needed to avoid invading private land and to prevent damage of utilities.

1.3. Research Problem

Land information is exchanged and re-used by organizations/ companies all over the world. However, 'some business domains involve different organizations that, although normally in competition, must share information' (Beck *et al.*, 2007). The surveying of underground utilities and structures such as gas, sewage, electricity, telecommunication, water supply and heating lines is usually conducted by utility companies and organizations. Moreover, basements of buildings, tunnels and subways are surveyed by private companies and organizations in South Korea. Normally the data are separately saved within the utility companies or organizations in South Korea (Lee et al., 2007). Although the Road Traffic Act article 20, 21 has been revised since September 2010, the results of survey data should be registered to the government database compulsory but it is still stored without field inspection. It is possible to get permission of installing utilities if formal documentaries are fully ready. This documentary does not need require result of field inspection

As a result of that, the government provides, in many cases, different results of survey to users. Thus insufficient and unclear information on location and depth of underground utilities is quite a big cause of damage in underground space. The effect of this damage is difficult to be estimated (Döner et al., 2010). Still, the number of accidents in underground space is also covered with tacit approval. In other words, the current situation of underground spatial data is not only unreliable but also depends on companies where the data is changed and modified in the field and creates redundancy and has low accuracy. However, reliable land information has to be provided to users and decision makers. Above the situations as mentioned there are the differences in spatial data quality in underground utilities/structures. The reason, size and impact of these differences have not been investigated yet in Korea.

1.4. Research Objective

The main objective of this research is to design an approach for an integrated and more accurate representation of underground utility-information on 3D cadastral maps. Further a new business model will be designed for 3D underground data combined with cadastral data. Hence this research aims at analyzing the processes of managing underground spatial data and integrating those with 3D cadastral maps. Then the bottlenecks of underground spatial data will be identified, making suggestions and proposals for creating a business model and improving the land management system on the basis of integrated spatial and non-spatial data.

The following sub-objectives arise out of the main objective:

Sub-objective 1

- -To analyze the differences of represented underground utilities and boundaries represented on the cadastral map (comparison of data quality)

Sub-objective 2

- -To analyze the implementation, mapping and surveying and spatial data provision tasks of utility companies and cadastral organizations in the law

Sub-objective 3

- -To analyze business cooperation in case of data sharing with a focus to spatial data

Sub-objective 4

- -To identify bottlenecks in the process of managing underground utility data and self-accountabilities in organizations and companies

Sub-objective 5

- -To design a new business model for co-operation between 3D spatial data providers

1.5. Research Questions

Sub-objective 1- Q1: What is difference between cadastral map and underground utility map in South-Korea?

Sub-objective 2- Q2: What are the main reasons of representations for the same object measured between utility companies and cadastral organizations?

Sub-objective 3- Q3: How to organise a sustainable cooperation between utility companies and organization for data sharing?

Sub-objective 4- Q4: What is the companies and organizations self- accountability?

Q5: Is the 3D cadastral map needed for presenting underground facility and structure?

Sub-objective 5- Q6: How should the business model for proper information supply look like?

Q7: How does integrated (spatial and non spatial) data effect to land information (3D underground data)?

1.6. Conceptual Framework

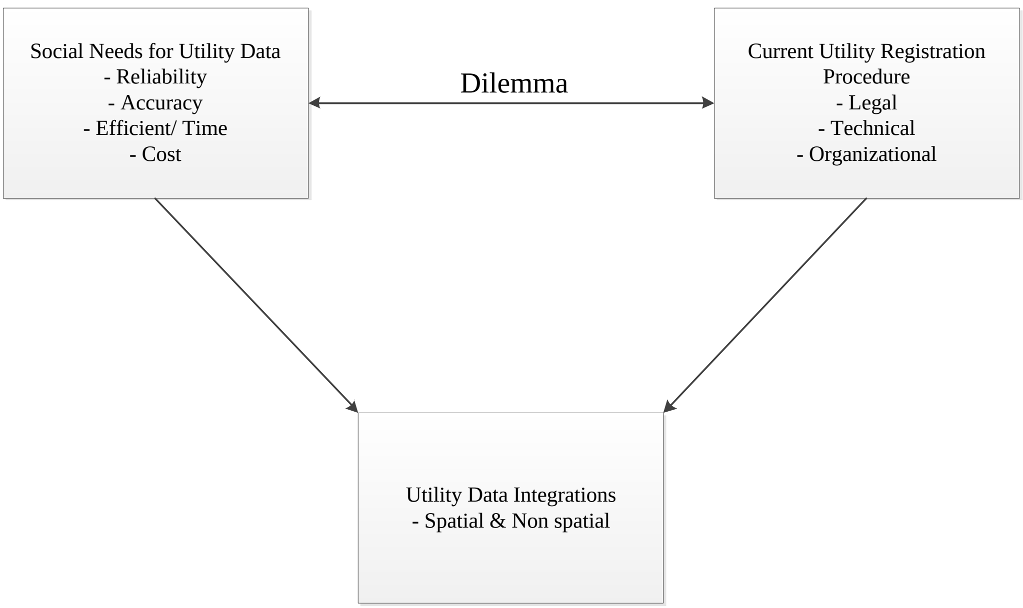


Figure 1-2 Conceptual framework

The conceptual framework consists of three elements which are Social needs for utility data, Current utility registration procedure and Utility data integration.

There is a dilemma between social need for utility data and current registration procedure. People want to know exact location of utility but due to the regulation in the law information is not available to people. To develop high quality utility data, there is a need to integrate those elements for proving utility information. Currently, data providers do not really co-operate to solve this issue.

1.7. Research Approach, Methodology and Design

1.7.1. Research Approach

Figure 1-3 shows the research approach for achieving the research object. It has 6 phases, the processes and steps are explained.

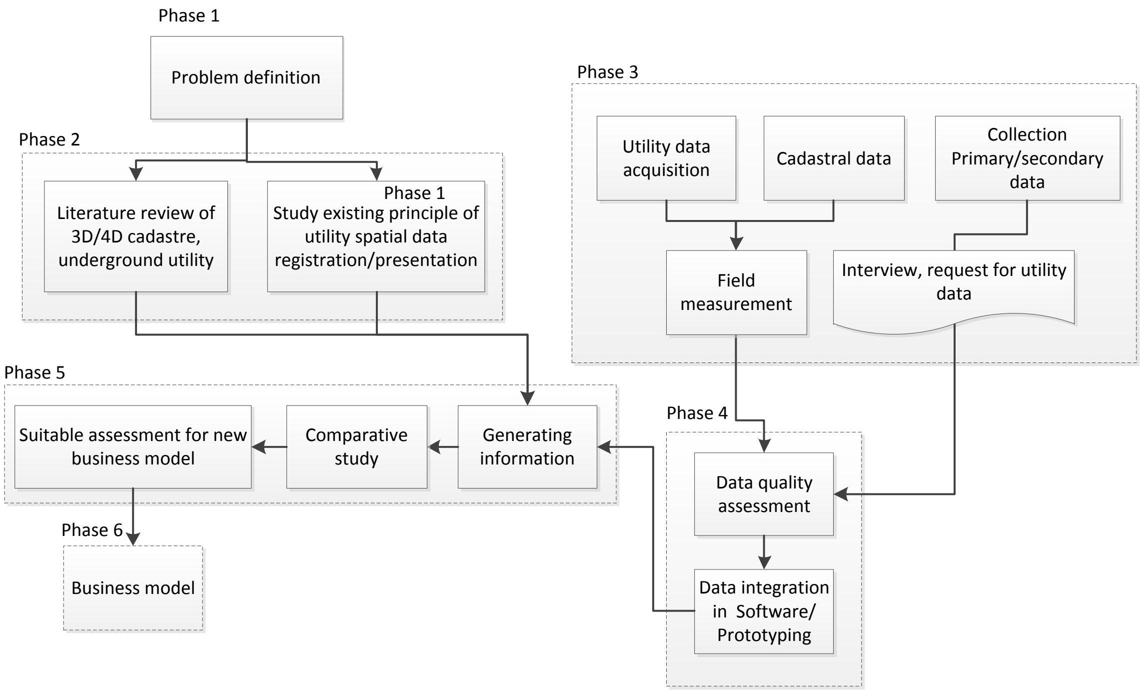


Figure 1-3 Research approach

Phase 1 Research proposal

The research problem, objective, questions, methodology have been addressed for proposal.

Phase 2 Desk research

In this step literatures review and background knowledge of underground utility and 3D cadastre definition are addressed with consideration of the difference aspects (legal, technical and institutional aspects). Those aspects have been used as a basis for a comparative study.

Phase 3 Field works and Data collection

This step consists of three parts. First, the current situation of underground utility/structure data and cadastral data in South-Korea has been analysed. Second, a field work has been performed for collecting data. The utility data and cadastral map are acquired during the visits to utility companies and municipality offices for field measurement during the field work. Third, with those data, the measurement has been performed in field for comparing data. The main objective of this stage is to find out differences between utility data and cadastral data.

Phase 4 Data assessment for integration

After analysing of utility and cadastral field surveying data are integrated in phase 4 for visualizing with software such as Arc-GIS, Auto-CAD and Google Sketch-up. It can interoperate to other software which is quite widely known for spatial data users.

Phase 5 Design new business model

In this phase the empirical outcome is discussed. All kinds of information and data are generated. And comparative study is addressed to compare with the Netherlands in order to find a suitable new business model for South Korea.

Phase 6 Finalizing thesis

This phase presents the newly designed business model for managing underground spatial data. It might contribute to utility spatial data distribution. According to data usability, the integrated data is used for various business domains and it can be one challenge how to extend it to effect land information. It is used for urban planning, design purposes and permission issue for construction or reconstructing purposes (Stoter, 2004).

1.7.2. Research Methodology

a. Desk research

Reviewing literatures is basically desk research. This method is applied to legal, technical and institutional aspects. There are different perspectives from the views of people, legislation, public sector and private sector. To define categories of research is very useful for case studies or comparison analysis.

b. Case study research

In this research pilot projects are performed in South-Korea and those areas are compared with the Netherlands utility system which includes large topographic map, data sharing, and a multi-use business model.

1.7.3. Research Design

Kumar (2000) says that data collection consists of two parts: one concerns primary sources and another concerns secondary sources. The first is created by the researcher and the latter is already created before. In this paper primary data is collected by observation, interview and questionnaire and secondary data is gathered by documents. The table 1-1 shows the research design to achieve the research objectives with questions, data resources and expected output.

Table 1-1 Research design

Research Objective	Main	To design an approach for an integrated and more accurate representation of underground utility-information on 3D cadastral maps					
	Sub	1. To analyze the differences of represented underground utilities/ structure and boundaries represented on the cadastral map (comparison of data quality)	2. analyze the implementation, mapping and surveying and spatial data provision tasks of utility companies and cadastral organizations in the law	3. To analyze business cooperation in case of data sharing with a focus to spatial data	4. To identify bottlenecks in the process of managing underground utility data and self-accountabilities in organizations and companies		5. To design a new business model for co-operation between 3D spatial data providers
Research Question	Q1: What is difference between cadastral map and underground utility map in Korea?		Q2: What are the main reasons of representations for the same object measured between utility companies and cadastral organizations?	Q3: How to organise a sustainable cooperation between utility companies and organization for data sharing?	Q4: What is the companies and organizations self-accountability?	Q5: Is the 3D cadastral map needed for presenting underground facility and structure?	Q6: How should the business model for proper information supply look like?	Q7: How does integrated (spatial and non spatial) data effect to land information (3D underground data)?
Data Source[3]	**Primary data** Observation **Secondary data** Government documents, existing laws and policy		**Primary data** Observation **Secondary data** Existing utility data, cadastral data	**Primary data** Field measurement, Observation, Questionnaire **Secondary data** Existing utility data, cadastral data, existing laws and policy	**Primary data** Observation, Questionnaire **Secondary data** existing laws and policy	**Secondary data** Literature, Existing utility data, cadastral data	**Primary data** Questionnaire **Secondary data** Literature	**Secondary data** Existing utility data, cadastral data

3. See Chapter 4,5 for more details

1.8. Resources Used for the Field Work

Hardware

- Survey observation equipment (total station)
- Computer

Software

- Arc-GIS, Auto-CAD, Google Sketch-up, surveying software (TOSS) developed by KCSC

1.9. Research Structure

Chapter 1: Introduction

In this chapter background, research problem, research object, research question and research methodology are addressed.

Chapter 2: The 3D Cadastre and Utility: a review

In this chapter the theoretical concept is addressed by literature review. In the review, legal, technical and institutional aspects are discussed (especially 3D rights, registration in law).

Chapter 3: Data Collection and Finding

This chapter presents result from data collection. The chapter discuss about the method of primary data and secondary data collection along with the challenges in the field work. It provides information of what are the differences or similarities between utility and cadastre.

Chapter 4: Data Integration

In this chapter the spatial integration is tested with cadastral and utility map. To integrate two different maps three softwares are needed TOSS (representing digital cadastral map), Auto-CAD (representing digital utility map), Arc-GIS (representing spatial adjustment) and Google Sketch-up (testing 3D).

Chapter 5: Comparative Studies

In this chapter analysis is presented to analyze current situation of utility spatial data for business model. How utility spatial data is to be surveyed, formulated, registered, distributed in Netherlands and South-Korea.

Chapter 6: Designing business model

In this chapter the suitable business model is designed for underground spatial data sharing and distributing.

Chapter 7: Conclusion and Recommendation

In this chapter conclusion and recommendations are presented .

1.10. Research Plan

Month / Activity	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Literature review							
Proposal writing and defence							
Field work							
Mid- term defence							
Data analysis							
Report writing							
Final submission and thesis defence							

2. THE 3D CADASTRE AND UTILITY REVIEW

2.1. Introduction

Cadastres have been developed gradually with technical evolution and social needs; but the traditional cadastre (2D) could not satisfy new requirements from society where the 3D legal and spatial representation of properties is concerned. In the present time, many complex situations appear in urban area such as intersecting physical rights and legal rights on or under the land. In order to improve this situation, 3D cadastre has been introduced and one of approaches is to represent rights as volumes above ground and underground on a cadastral map (Stoter, 2004). For this reason the 3D cadastre has been studied in this research for representing complex rights in attributes and geometry.

In general, utility networks cannot be registered by themselves (Döner et al., 2010). The registration of such networks requires a map for positioning. In the case of South-Korea, utility networks are registered on a large scale topographic map. On the other side, all kinds of data which are related to land are registered in cadastre. This means that spatial data sets are registered and stored separately. For this reason the data integration becomes indispensable part in land administration to meet the needs of the government and society.
The framework of this chapter consists of three aspects of 3D cadastre and utility system: Legal (rights), Technical, and Institutional, which is discussed on the basis of a literature review.

2.2. 3D Cadastre

The 3D cadastre has several definitions from all over the world. 3D cadastre is not only used as general term of three-dimensional representation of property rights, but it also concerns the actual cadastre or real property registration system (Paulsson & Paasch, 2011). However the common requirement for implementation of 3D is that it should be based on suitable legislation. One more requirement is to make an interconnection to geo-information infrastructure such as LIS. 3D cadastre is introduced as one of the tools needed in land administration for 3D registration of rights, restriction and responsibilities. In order to define the 3D cadastre, it's the components have to be identified: legal, technical, and institutional (as shown in Figure 2-1). Legal aspects are in support the registration. Technical aspects provide for example visualization tools for the 3D cadastre and lastly institutional aspect are the basis for creation of relationship between parties. To fulfil the 3D regime, these three aspects are considered in 3D cadastre developments for each jurisdiction (Aien et al., 2011).

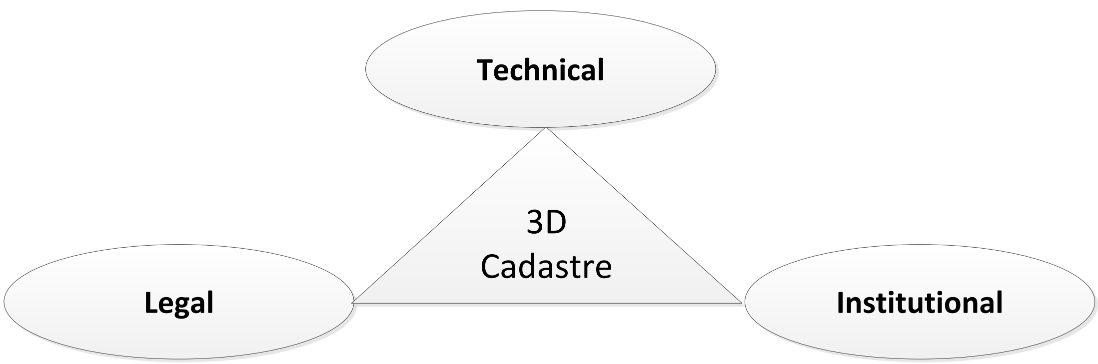


Figure 2-1 Relationship between different aspects of 3D cadastre (Aien et al., 2011)

2.2.1. Legal Aspect

The acquisition of property is achieved when the rights are registered in the title. However, most of the 3D information, such as spatial rights and joint ownership, is not been fully available for registration in 2D cadastre. Moreover, 3D space (vertical and horizontal) contains complex situations such as superficies, long lease and easement etc (Paulsson, 2007). After the registration into the cadastre, it is now possible to obtain the legal rights.

Representation of factual situations ('real' world) in 2D systems cannot state all of legal situations in an efficient manner. Examples are constructions on ground or underground an underground parking place, super- and subterranean infrastructure a tram-line above the surface, tunnels, apartments, (the location and ownership of) cables and pipelines and historical monuments (Stoter & Zevenbergen, 2001).

For 3D registration, the following rights can be concerned: right of ownership, limitation of ownership right (right of superficies, long lease, and easement), apartment/condominium rights and joint ownership (Stoter, 2004). Nevertheless, the 3D registration is not sufficient supported in the current registration systems (geometry, location) because the rules and standardizations are still undefined. However the current cadastral registration can present in 3D property situation without acquiring location (Stoter & van Oosterom, 2006).

In general, the full range of 3D property rights include granted rights and leases. Paulsson (2007) classified 3D property rights in the following categorisation as in table 2-1. Paulsson's research shows two main forms: (1) independent 3D property and (2) condominium, which is the real form of 3D property nowadays.

Table 2-1 Form of 3D property rights (Paulsson, 2007)

1) Independent 3D property	a) Air-space parcel
	b) 3D Construction property
2) Condominium	a) Condominium ownership
	b) Condominium user right
	c) Condominium leasehold
3) Indirect ownership	a) Tenant-ownership
	b) Limited company
	c) Housing cooperative
4) Granted rights	a) Leasehold
	b) Servitudes or easement
	c) Other rights

'*Independent 3D properties'* is an independent form of ownership. An air-space parcel type doesn't have any specific building or construction but it may exist in some legislation as a space volume. On the other hand the 3D construction property has space limitation. If the construction (building) has been destroyed, the property will also disappear (Paulsson, 2007). '*The condominium ownership'* which is also defined as apartment right (Stoter, 2004), has two part systems. If, for example, the apartment is owned by an individual and has been registered, this is regarded as a real property unit but common areas should be shared such as stairs, grounds and parking lots. '*Indirect ownership',* on the other hand, can be described as the relationship between owners and tenants who can either be a private person or a company. '*Grant rights'*, is a type of right for space; it is a form of leasehold and servitude or easement without ownership (Paulsson, 2008).

2.2.2. Technical Aspect

To present/register 3D rights with spatial data, the technical parts have also gradually been developed in accompanied with the 3D legal aspect. The visualization of 3D rights is also one of the challenges in 3D cadastre (Stoter & van Oosterom, 2006).

The 3D technical aspect is used to visualize the 3D situation to the map which can be a topology or cadastral map. Improvement in technology amplify the efficiency of cadastre (Aien et al., 2011). Since the cadastre was based on the paper, it has a limitation for applications (Ting & Williamson, 1999). But the development of software such as Auto-CAD, Arc-GIS, Google Earth that have been introduced in 2000s gave the possibility of drawing, updating, analysing, and visualising in 3D format for registration (Table 2-2).

Table 2-2 3D cadastre development (Aien et al., 2011)

Time	Available Technology	Aims of Cadastre	Possibility of 3D Representation
Before 1980s	Paper	Registration, Fiscal, 2D Visualization	N/A
1980s	CAD	Registration, Fiscal, 2D Visualization	N/A
1990s	CAD, GIS	Registration, Fiscal, 2D Visualization, 2D Vector-based Analysis	N/A
2000s	CAD, GIS, 3D Raster-based Tools	Registration, Fiscal, 3D Raster-based Visualization, 2D Vector-based Analysis	Yes
2010	Augmented reality Virtual reality	Registration, Fiscal, 3D Vector-based Visualization, 2D Vector-based Analysis	Yes
Future	3D (CAD, GIS), 3D DBMS 3D Vector-based	3D Registration, Fiscal, 3D Visualization, 3D Vector-based Analysis	Yes

In addition to the development of surveying equipment there is also an important key role in the 3D data collection (X, Y and Z coordinates) for equipment such as GPS (Global Positioning System), satellite image, photogrammetric based data acquisition and terrestrial LIDAR (Light Detection and Ranging).

Stoter and van Oosterom (2005) mentioned that the technical aspect in 3D cadastre can be divided into four steps: (1) 3D data capturing; (2) 3D data representation; (3) cadastral update, and (4) 3D data modeling. 3D data capturing is done by means of measurements taken using the software and surveying equipment, then visualization takes place in order to create a linkage between 3D data and the LIS (Land Information System). Furthermore, the technical aspect of 3D cadastre requires two components. The first component is the 'surface parcel partition' which is based on elevation models. The second component is the 'volume parcel and representation' Also, many countries in the world already have legislation for the registration of volume parcels, sometimes even including detailed regulations of 3D survey plans. However, until now, these have not yet been integrated in the cadastral information system. The case of Queensland, Australia is an exception, for they designed a prototype of an integrated 3D cadastral information system which contains 'elevation-model-based' surface parcels complemented with volume parcels (Stoter & van Oosterom, 2005).

2.2.3. Institutional Aspect

The 3D cadastre does not operate in itself; it works with others systems (Döner et al., 2010). There is a demand from the public sector, social needs, and private sector for exchanging and sharing information. But all of the components of 3D cadastre have to follow certain regulations. Likewise, it will be meaningless without proper definition of property rights that are law-based, without legal action of executing rights of acquisition, transfer, protection, registration, creation, and registration. To obtain meaningfulness in the 3D cadastre, an institutional context needs to be in place (van der Molen, 2003).

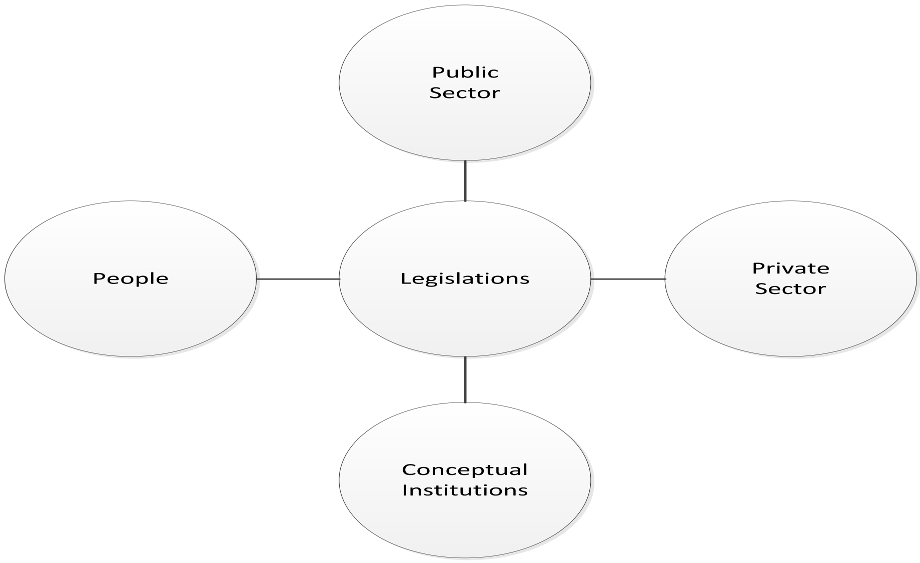


Figure 2-2 Relationship between organizations (Aien et al., 2011)

Aien et al. (2011) mentioned three categories of institutional aspects: (1) the administrative institutions that implement and protect the regulation by legislation, (2) the conceptual institutions that provide standard for 3D concepts such as 3D ownership, 3D property, buildings etc. and (3) the related organizations such as land registry and local government that use one software or system for managing land information data (Figure 2-2).

2.3. Utility System

Due to the lack of space and improvement projects in urban areas, in South-Korea, most of the utilities are laid underground such as gas lines, water supply, sewage, electronic lines, telecommunications etc. As long as these utility networks have been developed, new infrastructure is constantly needed. But utility business domains are involved in different organizations and companies in a competitive situation. Each company has a different way in managing their network dataset, also most of the data are stored digitally using GIS (Beck *et al.*, 2009). Unlike the cadastral boundaries, the utility has been laid beneath the streets, an invisible situation. Recently, the utility dataset has been well mapped with location and attributes but the old utility information remains inaccurate. In order to overcome this situation, South-Korean government has been created utility information system to manage information on underground infrastructure efficiently.

2.3.1. Legal Aspect

The acquisition of rights of utility usage is only obtained when the registration of utility network is legally progressed. Paulsson (2007) stated that '*Grant right*' is an alternative in dividing ownership into 3D units. It is usually applied to underground purpose such as passage rights, transportation, or piping. Rights of lease and easement concern use of the space above and below of a ground parcel.

The important part of registration of utility networks is how to distinguish between legal and physical registration methods. Depending on the methods, the registration needs different requirement such as the right of way to access, encumbrances, and easements. The LADM (LA_LegalSpaceNetwork) has well described why registration of utility network needs distinction between physical and legal representation for land registration purposes. The legal space of utilities concerns mostly a bigger volume then the physical space (Lemmen *et al.*, 2011). However, the utility networks cannot be registered by themselves in many cases the cadastre; the utility is represented mostly by an easement (Döner et al., 2010).

2.3.2. Technical Aspect

The measurement of utility objects also follows similar methods as for 3D cadastre techniques. Normally, the utility networks are represented by lines and points (not by polygons) with mainly X and Y coordinates but rarely Z (depth) coordinates (Rahman *et al.*, 2011). Utilities data have been collected in 2D or 2.5D which has a height data points in particular places (Cypas *et al.*, 2006). It can be visualized by using Arc-GIS, Auto-CAD etc. Most types of utilities maps consist of 2D base maps with Z (depth) in South-Korea but various factors make a confusion and misinterpretation such as in the maintenance of paving blocks, streets, reinstalling, repairing, and replacement.
Nowadays acquirement of Z coordinate can be collect by using GPS, RTK for new networks but it is quite difficult that to collect Z co-ordinates of previously constructed utilities because most of these utilities were laid without Z coordinate data collection in the past. To collect Z coordinate data for past network, many technical methods have been developed such as EI (Electromagnetic Induction), which is the production of an electric current across a conductor moving through a magnetic field. GPR (Ground Penetration Radar) is a geophysical method that uses radar pulses to image the subsurface for getting depth. This non-destructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures (Lee et al., 2007).

2.4. Summary

A main difference between cadastral data and utility-network data is who has a right and how to register and handle spatial data. For example, in the cadastre system all attributes are considered such as transaction of land, apartments, and condominiums. Contrary to this, the utility system is focused on the information of existence in utility maps. If the land owner does not have any information of utility in his/her property, *Grant right (*easement/ superficies) is not enough to insist owner rights to the utility company without utility visualization.

In addition, both systems have different registration system because the cadastre is one of the means of an assertion of rights but most of utility rights go to utility companies/organizations. In the technical aspect, however, the method of spatial data acquisition is almost similar (use of common surveying equipment).

3. DATA COLLECTION AND FINDINGS

3.1. Introduction

This chapter presents collecting primary data, secondary data and finding out the current situation on how to use the utility data in South-Korea. The purpose of the fieldwork is to describe the procedure of data collection methods for achieving objective of the research. The primary and secondary data were provided by related person who works in utility organisations and companies.

3.2. Field Work Area

The field work was performed around 'Seogwi -Dong Dong Moon Intersection' in Seogwipo city, Jeju Special Self-Governing Province, Korea. The Jeju Island is 73km wide and 41km long. With a total area of 1,848km², Jeju is the largest island in South Korea (JSSGP, 2011). Jeju Special Self-Governing province is consisted of Jeju city and Seogwipo city. The area of Seogwipo city is 870.8 km² (47.1% of Jeju province).

The main reason for choice of this area was the possibility of acquiring digital utility maps from Seogwipo city. The field measurements carried out in this area has been performed with total stations and computers. The main object of field measurement was to check the parcel boundary and road boundary because most of the utilities are laid along the road.

Figure 3-1 Field work area: Dong Moon Intersection Seogwipo city in Jeju

3.3. Preparation of Field Data Collection

The case study was initially scheduled in Seoul, but the utility data were not available during field work period. Due to this, the field work area was changed to Seogwipo city in Jeju Special Self-Governing province.

3.4. Data Collection

Almost all of property information is open to public in South-Korea. But during the field work, several days had been spent to get available utility data in digital format in Seoul. Nevertheless the utility data acquisition was denied by utility companies for security reasons under organisation's regulations. For example, as written in the Telecom utility company regulation which is specified by standards of information service under 'The Telecommunications Business Act Article 42', Section 3 (The prohibition of information mis-use).

According to this regulation most of the planned utility data collection during the field work was not allowed. In order to find out the reason of this situation a complaint report has been made by the researcher and this complaint has been sent to each of the utility organisations, companies, and MKE (Ministry of Knowledge Economic). Table 3-2 shows the response from the utility companies and the government. According to the responses of the government of Seoul and MLTM (Ministry of Land, Transport and Maritime Affairs), the utility information has to abide nation security –related regulations, and for this reason the provision of utility data to the public is not allowed

Fortunately the digital utility map which contains water supply and sewage could be collected from Seogwipo city by the researcher. After that the field measurement was performed in the Seogwi-Dong Dong Moon Intersection area with digital cadastral map and total station in order to compare with actual boundaries and cadastral maps.

3.4.1. Primary Data

The Email responses (Table3-2) and field measurement data are the main data from field work. The following are the questions to utility organizations and companies in Korea.

1. Does your organization or company have any record about amount of damage from other companies?
2. Has your company ever destroyed/damaged the utilities of other company?
3. If there are some accidents in field, how to handle this situation?
4. Are there regulations regarding depth of laying for each utility?
5. How to integrate all the utilities companies data?
6. Can you provide the utility data in digital or paper form?

3.4.2. Secondary Data

The secondary data as provided by Seogwipo city are as follows;

- The digital utility map (DXF) which includes (water supply, sewer, pipe-lines etc)
- The digital cadastral map (CIF) includes (owner's name, history of land etc)

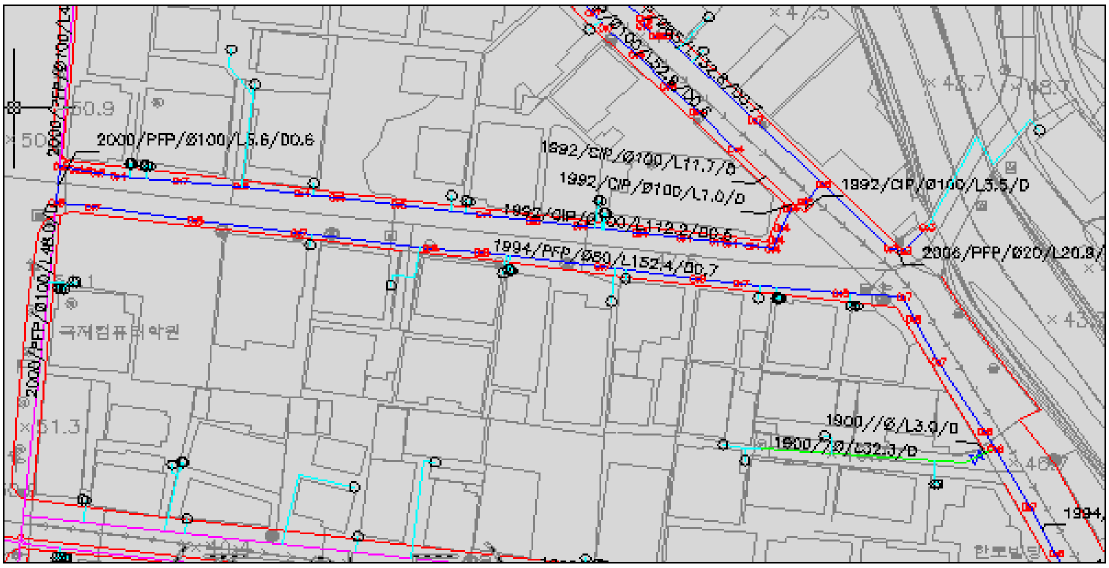


Figure 3-2 Digital utility map (Source: Seogwipo city)

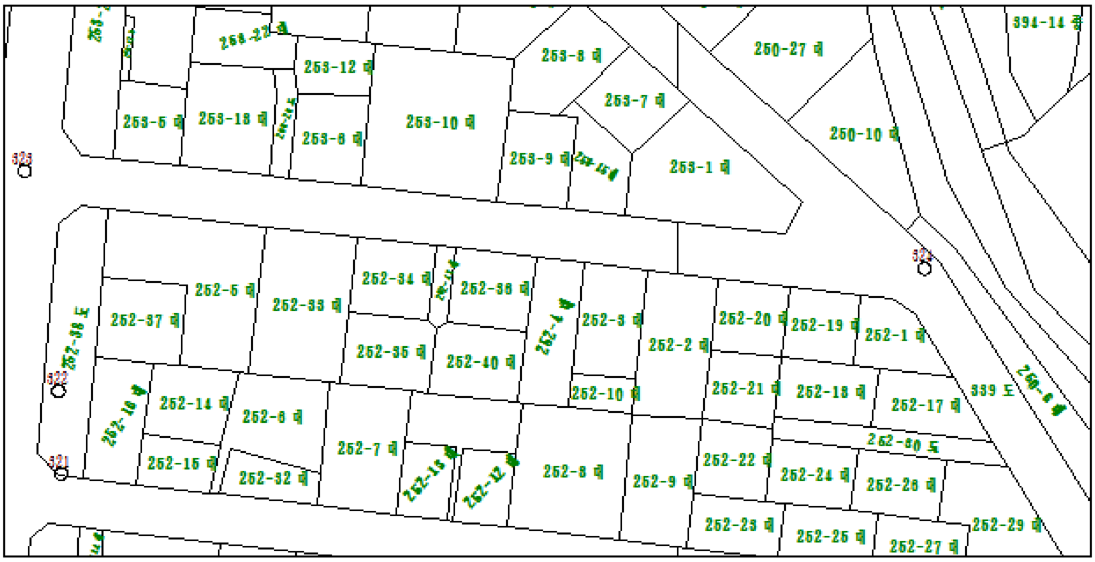


Figure 3-3 Digital cadastral map (Source: Seogwipo city)

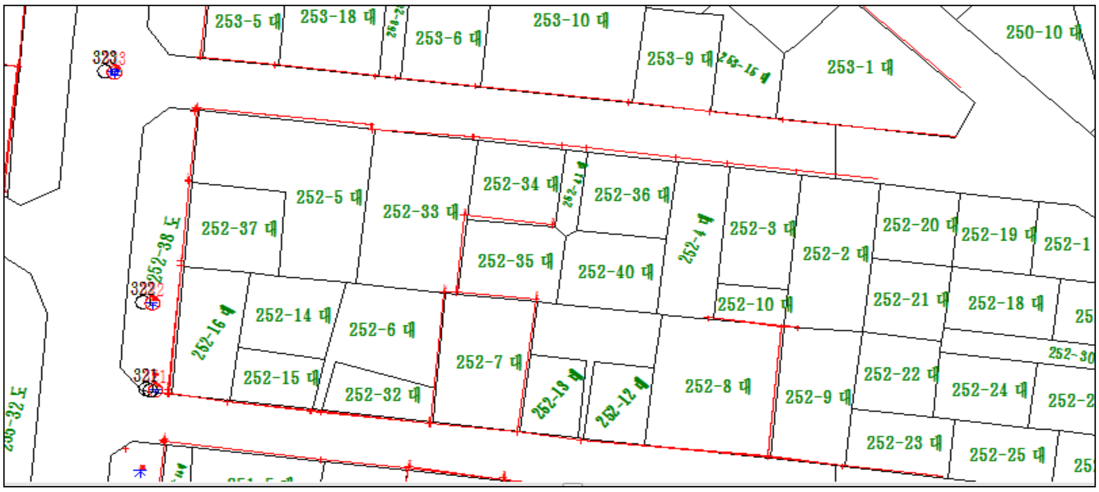


Figure 3-4 Result of field surveying by the researcher

The base map of the digital utility map is topographic map which is produced by the NGII (National Geographic Information Institute). Figure 3-2 is the digital utility map that contains X, Y coordinates, water pipelines, type of pipe, buildings, road lines, (incomplete) parcel boundaries, elevation etc. The data is presented as lines, polygons, and texts and are stored by layer in Auto-CAD file. The utility information is indicated in line with text i.e. '1994/PFP/080/L152.4.9/D0.7' is to describe the year of construction (1994), type of pipe (C.I.P: Cast Iron Pipe, PFP: Pre Fabricating pipe for sewage/water supply), bore of pipe, length/ depth.

Figure 3-3 is a cadastral map that contains parcel number (ID), boundary, coordinate, ground control point, owner, areas, municipality number, registration number, tolerance etc. The government produces those maps and only KCSC has the authority to main those maps by cadastral surveying.

Figure3-4 is the result of field measurement made during field work. To perform the field measurement at first the digital cadastral map of Seogwipo city was collected. Second, assistants for field measurements were requested from KCSC Seogwipo branch office. Then control points were checked in order to set up the total station and computer. Lastly the parcel boundaries (fences) and main road boundaries (edge of sidewalk) were observed in selected study area. The field surveying had been done to check the quality of the cadastral map for integration purposes with the utility map. From the field measurement the cadastral map and the co-ordinates calculated from observations in reality can be harmonized (the red line is road) in the field work area. It can be assumed that the cadastral map and topographic map can be harmonized in case of this accuracy of utility and cadastral map.

3.5. Findings from Field Work

The responsibility of managing utility data is up to each organization, only water supply and sewage are managed by the government. There is no cooperation between organizations and companies for data sharing due to security reasons. Since 2009 the South-Korea government has been collecting utility data (based on topographic maps) provided by utility companies for utility data integration. But only the related organizations and companies are able to get utility information through municipality with official request. On the other hand the public cannot access the utility information.

The topographic map just represents the actual situation without ownership rights. The utilities belong to utility organizations/companies or owners. The differences between reality and cadastral map are not considered. For example, the parcel boundaries in cadastral map and actual boundary can be different due to many reasons such as owner moved the boundary or the cadastral map has initial errors. For this reason, when installing utilities, the utility companies should consider that the possibility to occupy private land and invading ownership should be avoided. Because of this, the data integration of cadastral map and utility map is needed to make a high quality map for utility supplier and for the public.

Table 3-1 shows the comparisons of two systems. The cadastre system uses the cadastral map (cadastral surveying) and the utility system uses the topographic map (topographic surveying). Technically the two systems are using different geo-references with different scale maps cadastral map (urban and rural area; 1:500, 1:600, 1:1000, 1:1200, mountain area; 1:3000, 1:6000) and topographic map scales (1:1,000 to 1:500,000). But the 1:500 scale maps are used for utilities. It is rescaled to 1:1000 scale maps for readability

The government is responsible for cadastral data quality and issues the cadastral map with nationwide coverage for purpose as taxation, planning etc. It is also possible to access the cadastral map through the web by the public and the map is updated daily. The utility system uses the topographic map, which is issued by NGII. This map is updated every two years or more and it has nationwide coverage. The contractor who constructs utilities is responsible for surveying results and each utility company stores its own data based on the topographic map.

Table 3-1 Comparisons between cadastral system and utility system

	Cadastre system	Utility system
Responsibility	Government	Utility companies / organizations
Based map for measurement	Cadastral map	Topographic map
Scales	1:500, 1:600, 1:1000, 1:1200, 1:3000, 1:6000	rescale the topographic map; 1:1000 to 1:500
Geo-references	Bessel 1841	GRS80
(Map) Issued by	Government	NGII
Storage field measurement data	Government/ KCSC	Utility companies / organizations
Guarantee of quality data	Government	Utility companies / organizations
Who is charge of Surveying result?	KCSC	Contractor or Geodetic surveying companies
Accessibility for information	Open	Closed
Using	Cadastral surveying/ governing	Utility surveying/ construction site
Coverage	Nationwide	Nationwide
(Map) Up to datedness	Daily	Biennially or more
Data sharing / Cooperation	-	-

3.6. Summary

As already mentioned above, the utility data is secret due to security reasons in South-Korea even though the right of parcel belongs to the owner who is not able to access the utility data. Moreover the data sharing is not practiced by each organization. The integration of underground utility data is progressing under government supervision but it is just gathering the utility data for integration not for data sharing. With these findings it is possible to assume that integration cadastral and utility map is needed not only to make a high quality map but also for data sharing.

In addition in the field work the differences are also found between cadastral map and topographic map which is used by utility system (Table 3-1). One main difference is who produces the base map and who has a responsibility (guarantee). The cadastral map is issued by government but topographic map is issued by NGII. Technically, the surveying methods are almost similar. But the different geo-reference, base map and scale etc result in differences in surveying results from reality. Another difference is the accessibility of data. The utility data cannot be looked at but the cadastral map is open to access by the citizen who has rights to know what happens within one's parcel boundary. And to conclude data sharing and cooperation are not performed in either system.

Table 3-2 Reply of utility company

	MLTM	SEOUL City	KOGAS	KOWATER	Electronic companies
Q1 Q2 Q3	There are no records about damaged in underground utility.	No records of damage but if you want to get information ask to utility company.	- NO records of damage to other organization. - No damage from other organization	The main business of KOWATER is managing and constructing sewage. When our organization constructs sewage we collect all information which is related project area. So there is no record to give damage to other organization. But sometimes other organization/company makes damage to our utility but most of these damages from field laborer fault. In case of this KOWATER doesn't get any compensation from them. But trouble makers repair their mistake. In conclusion, we don't have any records of damage.	Denied
Q4	Depend on area But normally More than 1.2m	Depend on area But normally More than 1.2m	Depend on area But normally More than 1.2m distance between other utilities 0.3m(article 3-32)	Depend on area But normally More than 1.2m	Depend on area Normally, Road area: 1.2m, and sidewalk: 0.6m.
Q5	MLTS supports making underground digital mapping to municipalities (financial parts).	The utility information system has established in 2003. Basically it has made of utilities organization's data and using for road construction site/ installing utility. Since 10 Sep 2010 the new law has established utility should be surveyed by each organization, be examined quality assessment by KASM then submits GIS file to Government.			By Act of law, drawing map of power cable (based on topographic map) then submit to municipality.
Q6	We don't have authentic right of researching damaged from digging.	keep information secret for security reasons	-KOGAS has a gas line data as a GIS file but it is cannot open for public in our regulations.	keep information secret for security reasons	If other organization wants to check ours you can check electronic cable information through our system also you should submit an official document to our organization.
EXTRA		Most of previous utility data is not accuracy because they did not survey. To make a high quality data (location and depth), should be surveyed and got the examined for new utility installation. Musicality is charge of only water and sewage. Others are charge of themselves in management.			

4. DATA INTEGRATION IN PILOT TEST

4.1. Introduction

As already mentioned in chapter 3, cadastral data is handled under government and cadastral surveying is conducted by KCSC as a government affiliated organization. Utility data is handled by each utility company and presented on topographic map which is distributed by NGII and surveyed by the private sector. However, both datasets might be maintained in same spatial work space (van Oosterom & Lemmen 2001). In this chapter spatial data integration is tested based on collected data from the field work with three softwares.

4.2. Procedure of Spatial Data Integration

Three softwares (TOSS, Auto-CAD, and Arc-GIS) are used to integrate the cadastral map and the utility map for visualization. TOSS (Total Survey System) software is developed by KCSC for field measurement TOSS can present the digital cadastral map issued by government. It contains X, Y coordinate, control points, ownership data, price of parcel, parcel history, land use etc. Those data is presented by line, polygon, and text (see Figure4-1). Auto-CAD is used for analysing of utility map which contains road lines, buildings, water supply and sewage lines in a DXF file format. Arc-GIS is used for spatial adjustment because the geo-reference of cadastral map is the Tokyo datum while the utility map uses GRS80.

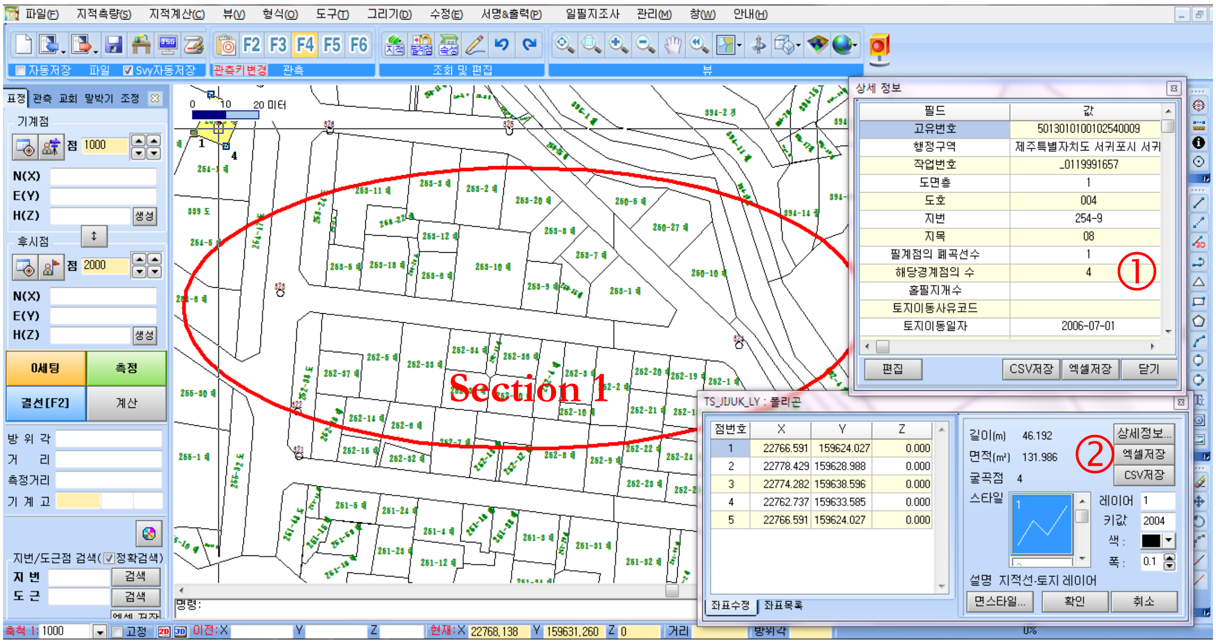


Figure 4-1 Representation of Digital cadastral map (Source: Seogwipo city)

Figure 4-1 is the information of parcel ID '254-9'① this parcel ID is showed with, name of owner, tolerance, land use, price, history of parcel (registered day) etc. ②shows the coordinate, type of polygon, and area. Section 1 is the pilot area for spatial integration. This digital cadastral map can only be opened with KCSC software (TOSS) because the digital cadastral map has been encrypted by the government software KLIS (Korea Land Information System) in order to prevent information spill. It is possible to export to DXF files but the attribute tables are not exported to DXF files. The field measurement was performed on the basis of this map.

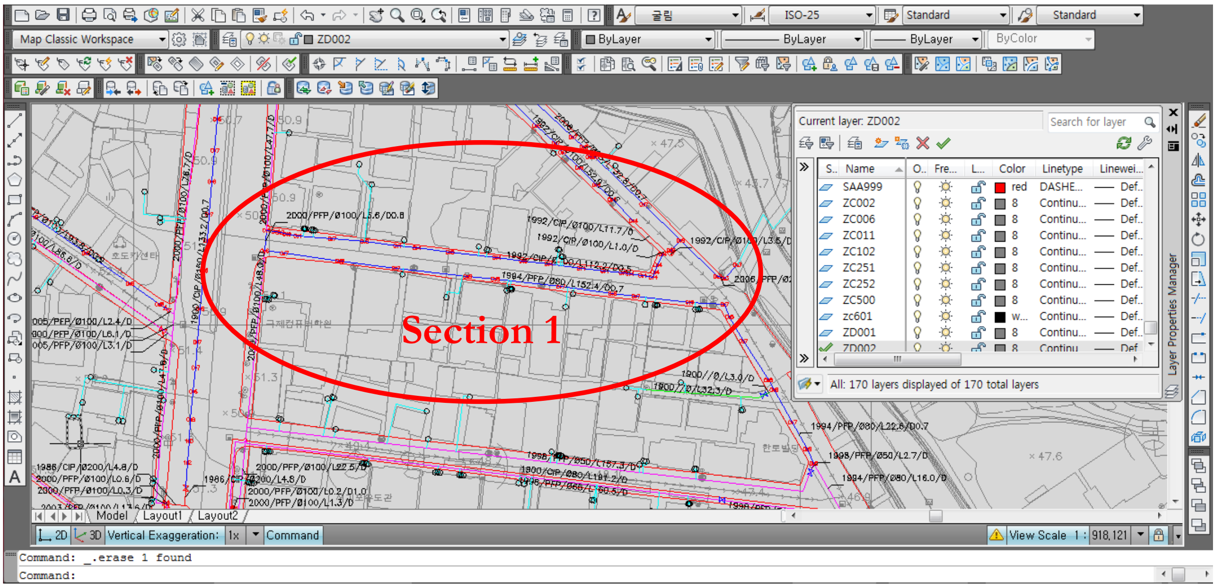


Figure 4-2 Representation Utility map (Source: Seogwipo city)

Figure 4-2 shows the utility information in Layers. The Layer defines the type of utility, buildings, and objects are presented in poly lines, polygons, texts, and numbers. The line and polygon have coordinates without 'Z' but the depth of utility is indicated by text .These layers were designed by the NGII. In this utility map, we only focus on water supply line for this integration pilot.

The utility map and cadastral map were issued in the same period during field work. But the utility map has not been updated yet. The evidence of this, the main road was extended (12 m to 24 m) and the buildings that also have been disappeared last year still exist in the utility map (see Annex C).

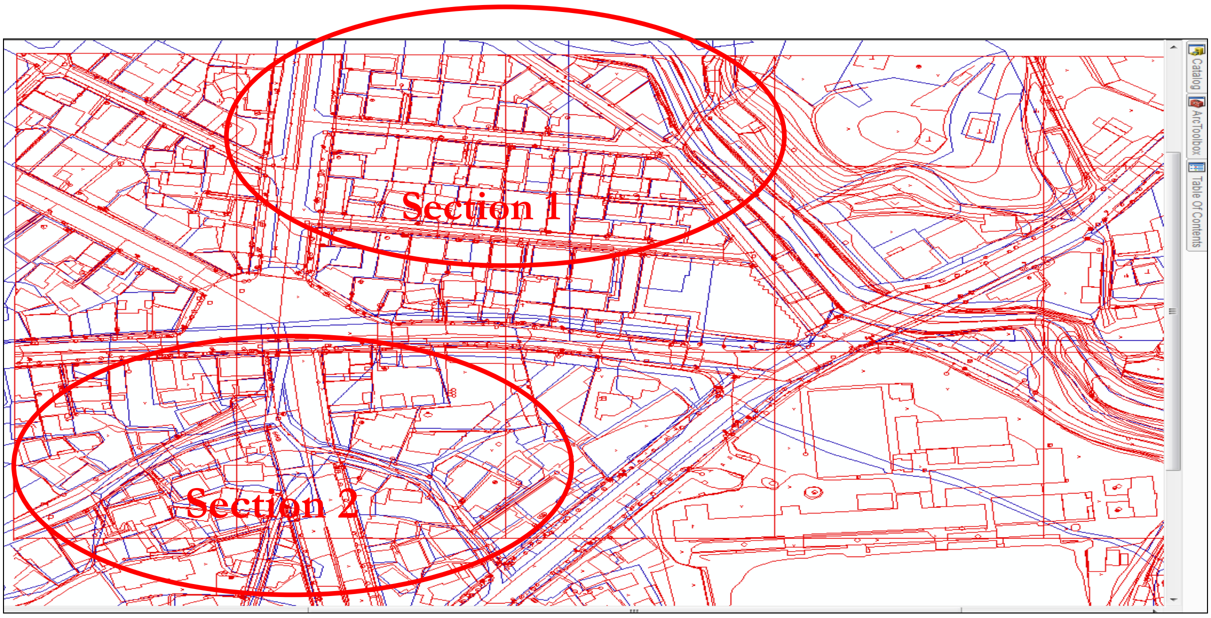


Figure 4-3 Spatial adjustment of cadastral and utility map in Arc-Gis

Figure 4-3 shows the data after spatial adjustment to WGS 84 in Arc-GIS (blue: cadastral map, red: utility map). The result is Section 1 area well is corresponded between the two maps (Figure 4-1 section 1 area and Figure 4-2 section 1 area) but Section 2 is in discord (see Annex D). To integrate two maps, the Section 1 area is selected as pilot test. Section 2 also needs to integrate in the future in order to come to full integration but section 2 is not tested in this research.

4.3. Testing Integration in a Prototype (Result on Google Sketch-up)

Figure 4-4 Representation of integrated data on Google Sketch-up (Kwak, 2011)

Figure 4-4 shows the result of Section 1 area integration: cadastral, topographic and utility data. In ArcGIS two maps are integrated and then exported to DXF file format in order to visualize on 3D in Google Sketch-up. This program makes it possible to make 3D visualization easily. In this visualization, the buildings and the water supply line were integrated to the cadastral map. The depth of pipe line was found in utility map. Each of the utility lines has utility information by '1994/PFP/Ø80/L152.4/D0.7 1994; construction year, PFP; types of material, Ø80; diameter, L152.4; length of material, D0.7; depth. The buildings height was not explained in the utility map but width and length is the same in the utility map and therefore the building height is presumed by the number of stories.

This 3D map is useful to figure out the location of utility in underground e.g. many types of utilities are laid to the same location; it is not easy to find out the order of utility in 2D map because the specification of depth is not determined yet in South-Korea.

4.4. Summary

The digital cadastral and the utility map based on the topographic map, have different geo-reference system, and different formats, attributes, usage in South-Korea. The digital cadastral map is used to represent the legal boundary of parcel whereas utility map is used to install and manage utilities. Nevertheless the possibility of integration has been shown between two maps in this chapter.

The combination of two maps can provide more exact information because the cadastral map has all the attributes of parcel with legal aspect but it does not reflect fully actual situation. On the other hand, the utility map contains actual boundaries, buildings, and type of utilities including depth of utility but it does not have any legal aspect. In addition, not only integration of two maps in 2D visualization but also 3D visualization is possible.

5. COMPARATIVE STUDIES

5.1. Introduction

In this chapter, the current situation of the cadastral/utility mapping system in South-Korea and the Netherlands are analysed for finding suitable business model in South-Korea. It will provide an overview on how utility spatial data are surveyed, formulated, registered and distributed in the two countries. In addition, the Netherlands utility system has been researched by a literature review, and interviews have been conducted to collect information on Netherlands large scale topographic map (GBKN) and utility system (KLIC) in the Dutch Kadaster located in Apeldoorn for comparative study (Annex A, B).

5.2. Current Situation of Cadastral System in South Korea

Initially, The South-Korea cadastral map was created by Japan in the 1910s. After the Korean War most of the triangulation stations, levelling marks, and also cadastral maps and books were damaged. As an effort to restore the cadastral maps and books, the computerization began in 1977 (Lee, 2001). Cadastral maps and books have been digitized in conjunction with the NGIS project (National Geographic Information System). The purpose of the NGIS is to provide and manage spatial information such as land location, resources, environment, and utilities. It consists of three stages: (1) development of a GIS infrastructure (1995~ 2000), (2) disseminating use of GIS application (2000~ 2005), (3) setting up infrastructure (2005~ 2010) (Song, 2008). Nevertheless, areas with many inconsistencies still remain and concern about 15% of county. To overcome the difference between reality and cadastral map, € 1.2 billion is needed for re-surveying and € 250 million is needed to solve these kinds of conflict each year (MLTM, 2011a).

As a result of the digitizing project, cadastral map and books are managed digitally, are published on a web site, and cover the whole country. KLIS is used to register and provide both cartographic and administrative formats. In spite of the NGIS project, it still has many data-errors because sometimes registration was done without field survey or inspection. The project only changed the format from paper to digital file with coordinates.

The cadastre registers all kinds of parcel information through the KLIS (ownership, boundary, subdivision, transforming scale, control point surveying etc). Most cadastral surveys are conducted by customer request (can be citizen or government) with payment of costs. The KCSC takes charge of almost all cadastral surveying in South-Korea but private surveying companies are able to survey only numerical areas (1:500) with digital cadastral map which is issued by government. Nowadays the 3D cadastre has been studied for providing more detailed information on how to register complex physical objects in the cadastral system as a pilot project in Seoul (Park *et al.*, 2009).

The cadastral surveying is the compulsory way to register land in case of the changed information of land rights, such as subdivision, transaction etc. After surveying, the new situation will be registered into the cadastral register books and on the cadastral map. According to cadastre Act, the surveying result should fulfill defined quality standards.

Article 27: (decision of surveying result)
① In case of connection error between survey result and audit result, the tolerance value is less than the following clauses. The decision should be based on the survey result except in cases where there are other proofs stating otherwise.

1. Cadastral triangulation: 0.20 m
2. Cadastral Complementary Triangulation: 0.25 m
3. Supplementary control
   - Numerical registered area: 0.15 meters
   - Other area: 0.25 meters
4. Boundary point
   - Numerical area: 0.10 meters (1:500)
   - Other area: (3/10)*M (M: denominator of scale); (urban and rural area; 1:500, 1:600, 1:1000, 1:1200, mountain area; 1:3000, 1:6000)

In cases the cadastral survey result is calculated by computer, the result is stored as survey document and area measure document (NARK, 2011; Song, 2008).

5.2.1. Current Situation of Utility System in Korea

The underground utilities are one of the important elements in urban social facilities. Due to insufficient underground information, several accidents happened in South-Korea which is already mentioned in chapter 1. To overcome and prevent these kinds of problems, the South-Korean government set up a plan to develop underground management system which is so called UIS (Underground Information System) based on the digital topographic map.

The purpose of this plan is to provide a safe, efficient, and environmentally sensitive transportation network that offers a variety of conveniences in a cost-effectiveness way for the people. It has collected all kinds of utility information since 2009 for making the digital utility map. The water supply and sewerage digital map are handled by government, and for other utilities the digitizing is done in organizations and companies. But this plan is in progress only for urban areas and will be ready by the end of 2011. After completing the city underground system, underground information for rural area will be started from 2012 up to 2015 (MLTM, 2011b)

However, the inaccurate information has not been solved yet in this project. Lee researched six utilities (water, sewage, electronic, communication, gas, heating) in Seoul. The accuracy of utility maps is not specified in public surveying regulation but it is possible to infer the accuracy from each different article of the public surveying regulation (article 303,169, 32). Utility positioning error of equipment 20 cm, surveying error 10 cm, mapping error (converting paper to digital) 20 cm. By means of these errors the accuracy of utility map (1:1000) should be 30 cm (Lee et al., 2007).

$$\sqrt{(\text{Equipment error})^2 + (\text{Surveying error})^2 + (\text{Input error})^2}$$

$$= \sqrt{(20\ \text{cm})^2 + (10\ \text{cm})^2 + (20\ \text{cm})^2}$$

= 30 cm

In this research, the average of accuracy of utility was 75cm (2006), 78cm (2005), 73cm (2004). It means that the accuracy of utility is not everywhere sufficient although government has tried effort to improve data quality in the period of UIS process.

5.2.2. Types of Utility in South Korea

Generally the utilities play a role as social infrastructure. Most of the utilities companies have followed their regulation to manage their business for public purpose. The main six utilities (water supply, sewerage, gas, electricity, telecommunication, heating) are doing business under MLTM.

Municipalities manage water supply and sewages. KOGAS (Korea Gas Corporation) manages gas line. KEPCO (Korea Electronics Power Corporation) manages electronics power line but telecommunication cables (fabric-optic cable) are managed separately by KT (Korea Telecom), SK Telecom, Hanaro Telecom etc and KDHC (Korea District Heating Corporation) are in charge of managing heating lines. Moreover, the management and installation of utilities also follow the related laws which indicate detailed information for each of utility to be available.

5.2.3. Collection of Utilities Information

Customarily, utilities have been laid along the main road to avoid invading private property and for convenient maintenance. But it could be laid in private property for public interests with the owner's agreement. Unfortunately, until now specific regulation/rule of depth for each utility is not fixed. Only obvious rules and regulations exist. Wherever it gets pressure from ground by vehicles or pedestrians (main road, sidewalk) etc., the laid depth is over 1.2 m but for other areas this would be over 0.6 m. The minimum space between different utilities is specified in gas regulations. The safety distance is over 0.3m in order to prevent damage to other utilities (see table 3-2).

The utility data is collected by topographic survey in South-Korea. The main purpose of the survey is to correct positioning based on topographic map which is issued by NGII. Most of utilities spatial data are collected by private construction companies or by the utility company's survey department which also have a license for surveying.

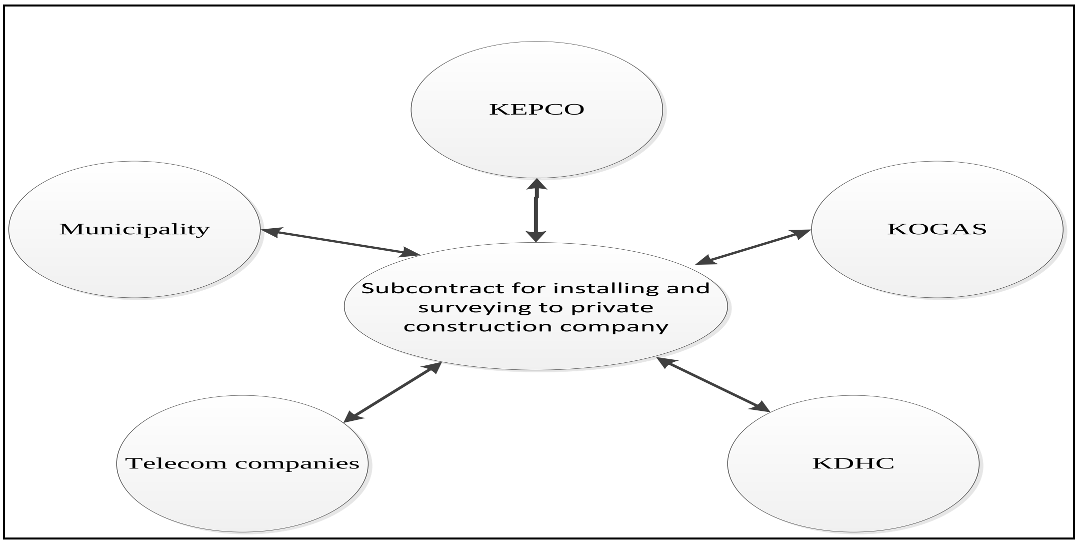


Figure 5-1 Outsourcing of utility surveying project

Figure 5-1 shows how projects are contracted to construction companies. In the first step, the utility organization/company offers the project to a construction company for installing and measuring utilities according to the project budget. Most of utility surveying is conducted at same time but sometimes it can be done in a later (after finish installation). In the second step, the drawing map (in Auto-CAD file) is submitted to the municipality or government to get approval for digging on a site.

After receiving projects from utility organizations/companies, the private surveying company makes a plan for surveying based on the topographic map. It is not suitable for surveying with small scale (1:1000) so that in order to get better results changes to big scales (1:500). The main purpose of converting the scale is to improve the readability (KASM, 2011). The utility surveying uses also almost the same methods and equipment as cadastral surveying but the only difference is the base map. Initially, utility surveying needs to set up the city control point from the national triangle point then proceed to field work for measurement using GPS, total station and plane table. After field surveying, the survey result are handed to the utility company and then submitted to government department for registration (Figure 5-2).

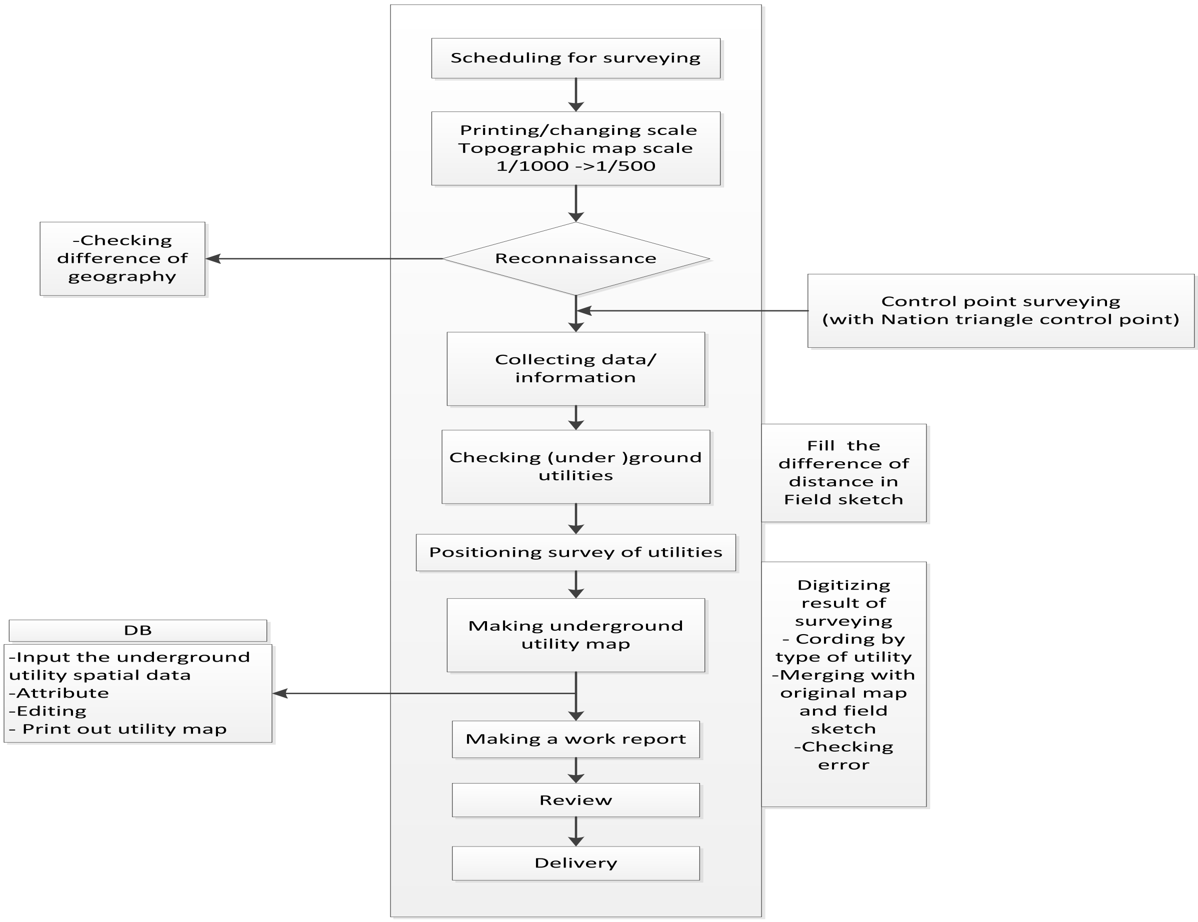


Figure 5-2 Work flow of utility surveying (Source: KASM)

This workflow of utility surveying is performed by law. The utility companies/organizations should observe the law which is related the Road Traffic Act. It is written in Article 21: submission and management of completed drawing

① According to Act 33, conductor who installed of main underground utilities and general utilities are submitted with completed drawings (including e-drawings), The following matters should be included

1. Floor Plans (Scale 1:1200 or more). However, in accordance with Article 17 (1), if attached floor plans are the same, it is excluded
2. Longitudinal cross-section (longitudinal section 1:1200,cross section: 1:100)
3. Cross section (Scale: 1:100 or more)

4. The information of installing location: 1:1200 or more
5. Detail drawing for other important parts: over 1:10 and below 1:30 (NARK, 2011)

There are different types of methods to obtain utility data such as using GPS, total station, but the base map is the topographic map that contains information on buildings, road boundaries and it is useful for distinguishing objects such as fire hydrant, lamppost, etc. The reason for using topographic maps in utility surveying is because topographic maps show the actual road boundaries. Construction of utilities can lead to conflicts between land owners and utility companies because the legal situation in reality and the representation of the legal situation reality on cadastral maps do not always match.

Table 5-1 addresses the tolerance of utility survey according to object and length, wherein the margin of errors can be different. The investigation of underground utility is rarely performed under government supervision.

Table 5-1 Tolerance of utility survey (Source: KASM)

Object		Margin of error	
		Surface position	Depth
< 3 meter	Metal pipe line	±20cm	±30cm
	Non-metal pipe line (Pipe diameter: > 100mm)	±20cm	±40cm
> 3 meter	Metal pipe line	±20cm or 20 % of depth	±30cm or 20 % of depth
	Non-metal pipe line (Pipe diameter: > 100mm)	±20cm or 20 % of depth	20 % of depth

5.2.4. Different Results

As mentioned above, the methods of measurement are the same for above and underground objects. Nevertheless results could be different according to geo-reference and basic map.

Hong (2005) examined 2 city control points in Dongducheon Bulhyundong areas to compare based on 2 cadastral control points. To observe city controls points, the auxiliary point was used. Table 5-2 shows the results of measurement of the distance of city control point and cadastral control points.

Table 5-2 Difference of city control point and cadastral control point (Hong, 2005)

City control point			Cadastral control point			Errors
Point name	X	Y	Point name	X	Y	
61	488082.81	207305.77	1	488081.93	207103.55	2.39m
62	488070.83	207436.96	2	488069.88	207434.73	2.42m

Hong also found that city control point had 0.51 m errors compared with map distance and real distance because it used the offset method for utility surveys in the past. The offset method is the traditional way to record objects in the utility map. It is used to find out the specific object position with distance from other object such as house, lamp post, and fence without coordinates. With this data, a utility measurement conducted in this area would be registered incorrectly.

Another different result was founded in a KCSC conference paper. The results are shown between two organizations (KCSC and KCEI). KCSC is specialized in cadastral survey meanwhile KCEI is expert of cave survey using topographic maps.

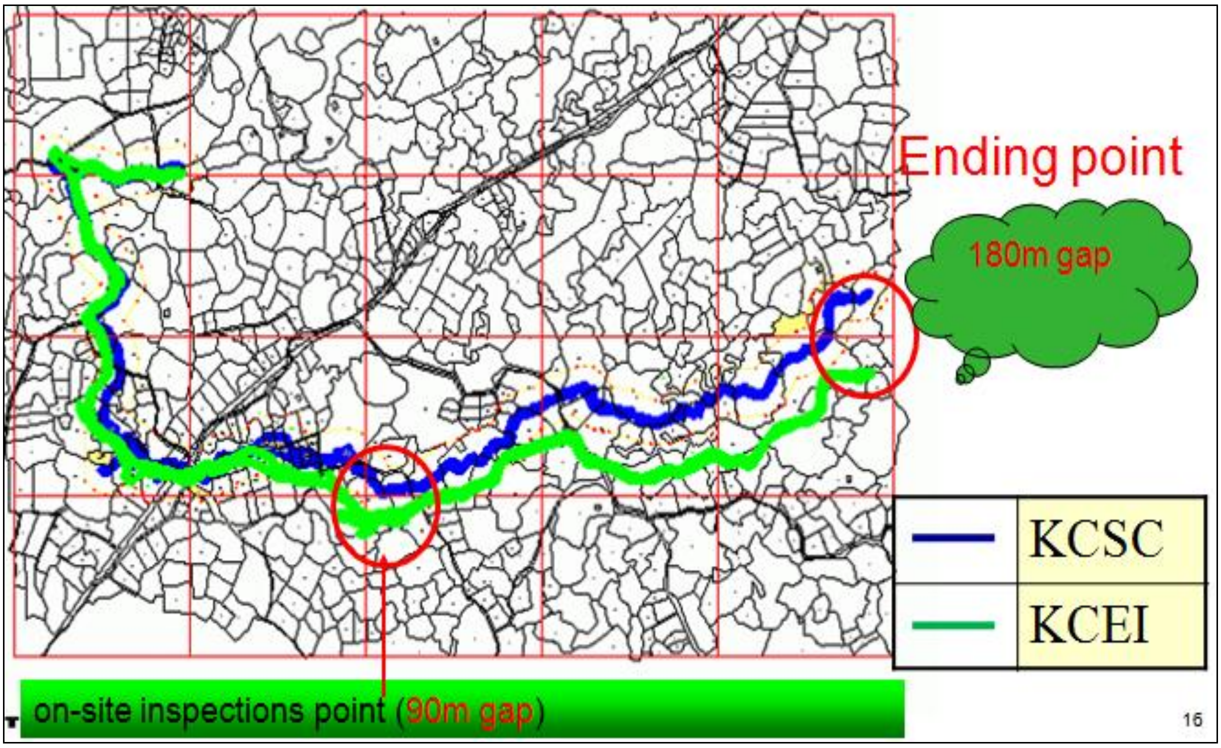


Figure 5-3 Different results of cave survey between KCSC and KCEI (Jo, 2011)

Due to the particularity of caves, most of caves have been measured by KCEI (Korea Cave Exploration Institute) using topographic maps, GPS and total station used to establish the control points. The main business of KCEI is cave surveying, for which it develops exploration techniques (KCEI, 2006). For this reason, the government relies on the KCEI results. At the moment, the government is considering construction and development such as roads and houses in this area, and thus the designation of protection area is needed for preservation of the cave.

To designate the protected area, subdivision in parcels is needed to compensate to land owners however the subdivision survey is not allowed to use topographic map because only the subdivision works is allowed in cadastre. For this reason KCSC measured the cave with a cadastral map and control point. The difference of results is shown in Figure 5-3 (Jo 2011).

5.2.5. Summary of South-Korea

The cadastre and utility system have dissimilarities in Act, rules and surveying regulation. The former presents and registers scope of ownership within parcel boundary. The latter presents actual parcel boundary without right relationship. Currently, utility surveying is conducting without the ownership rights in South-Korea. As a result, the utility is laid in private area (Jo, 2004). The invasion of other public or private parcel boundaries is not allowed but it happens in many areas in South-Korea. A dilemma has been found out in the cave survey result wherein a different map and procedure is used for registration. These differences are not opened to the public.

Technically, the methods of measurement are almost the same between cadastral surveying and topographic surveying. The difference is that it uses different geo-reference that consequently leads to different surveying results (Hong, 2005). In addition, the acquisition of depth (Z) on control points is not needed in the cadastral system. However, the topographic map calculates Z from mean sea level but cadastral map does not calculate depth now.

The South-Korean government expects that the UIS will be used in urban planning, environment, and management with high quality accuracy for data sharing. However, the underground data has limitations in data categories due to the fact that it is used separately by organizations and companies due to security reasons; and land rights are not included. To present relationship of rights and geo-information in the UIS, the utility information should be integrated with cadastral maps because utilities are laid not only on the unseen property but can also be in parts of property.

5.3. Situation of Cadastral System in Netherlands

Cadastral systems include spatial referenced land data, which is a set of procedures and techniques for collection, updating, processing, distribution of data and homogeneous spatial reference system (van Oosterom & Lemmen 2001). In the Netherlands, the cadastre has existed since 1832. The original maps have 1:1250 (built up areas), 1:2500 (rural areas), and sometimes 1:5000 scales. These maps has been updated for over one hundred years and during the 1930's many built up areas have been remapped and re-measured for eliminating accuracy inconsistencies in the cadastral map. In the 1980's the cadastral map has been digitized. This was completed by the end of 1997 (Salzmann *et al.*, 1997). The cadastral map is a seamless map now with nationwide coverage. The presentation scales today are for built up area (1:1000) and rural area (1:2000). The contents of cadastral maps are cadastral boundaries, parcel ID, main buildings, and street names/house numbers (Figure 5-4).

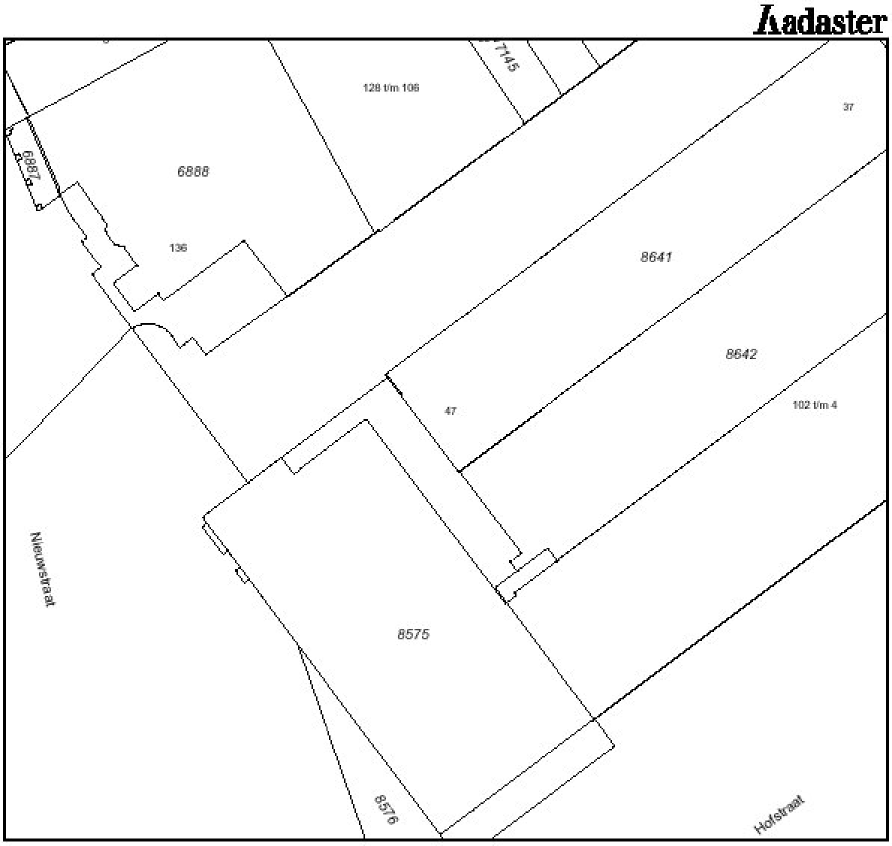


Figure 5-4 The cadastral map of Netherlands (Source: Cadastral Template- Country data)

To fulfil high quality standards for the cadastral map, five required components should be satisfied (Salzmann et al., 1997):

1. Geometric quality: geometric accuracy of the map is stated by means of relative precision, in rural area (1:2000) better than $40\sqrt{2}$cm, in built up (1:1000) area better than $20\sqrt{2}$cm.
2. Completeness: parcels, main buildings, street names and house numbers

3. Attribute accuracy: the address information should comply with national postal service
4. Consistency: all parcels are closed and, this means areas can be calculated
5. Up-to-datedness: the cadastral map should depict the legal situation based on field observations as up to data as possible

The Dutch Kadaster (the Cadastre, Public Registers and Mapping Agency) is responsible for managing cadastral databases to support the real estate market activity. This includes a legal/administrative aspect (the registers which contain the actual status of real estate titles) and a technical aspect (cadastral surveying and mapping).

Land registry and cadastre are the main concepts of the cadastral system for recording of the relationships between people and land through a formal right. The right as such should be legally recognised, namely belonging to the closed system of real rights as mentioned in the Civil Code. The right should therefore be precisely identified in the deed. According to the legal rules, buildings, subsurface features, surface air column belong to the land. However buildings and minerals can be registered separately from the landownership such as superficies (van der Molen, 2006).

Apart from legal certainty cadastral information is used by many governments, basically providing source data in order to support the government (all levels). It can be applied to the municipalities as main source data for their taxation. It should be noted that the co-ordinates from the cadastral map are not used for reconstruction purposes in case of disputes. In that case the original field-data are used (field sketches).

5.3.1. Topographic Map in Netherlands

The large scale base-map of The Netherlands, known in Dutch as GBKN (Grootschalige BasisKaart Nederland) is the topographic map with national coverage. The production of this map was completed in January 2001. It took more than 25 years to produce this map. It is provided at 1:500 or 1:1000 scales in urban areas, 1:2000 scales in rural areas (GBKN, 2011).

The content of the map has three classifications: first, well- identifiable topographic objects ('hard' topography) such as buildings, constructions. Second, the infrastructure objects and other topographic object ('soft' topography) waterways and features hedges, fence etc. and third, semantic information (street names, house numbers, names of waterways etc (GBKN, 2011). Most users of this map are municipalities, utility companies (electricity, water, telecommunications and gas supply services), water management boards, cadastre, developers etc. Examples of usage are planning and design for construction and infrastructure works throughout the country (Annex A); asset management; support in maintenance of infrastructures and other objects; basis for quality improvement of the cadastral map; support in disaster management, etc. Above all it is a homogeneous reference base in SDI (Spatial Data Infrastructure). The map it is consulted around 1,800 times a day.

Topographic maps (Figure 5-5) contain buildings, roads (names), house number, utilities, railways, rivers and canals presented as line, point, symbol, text. The accuracy of map is in urban area 0.2 m and 0.4 m in rural area for construction points (well identified points such as buildings). Access to the data comes at difference prices via a subscription one can access the digital data on internet.
As with the cadastral map the field data for the maintenance of the GBKN are kept available for reconstruction purposes.

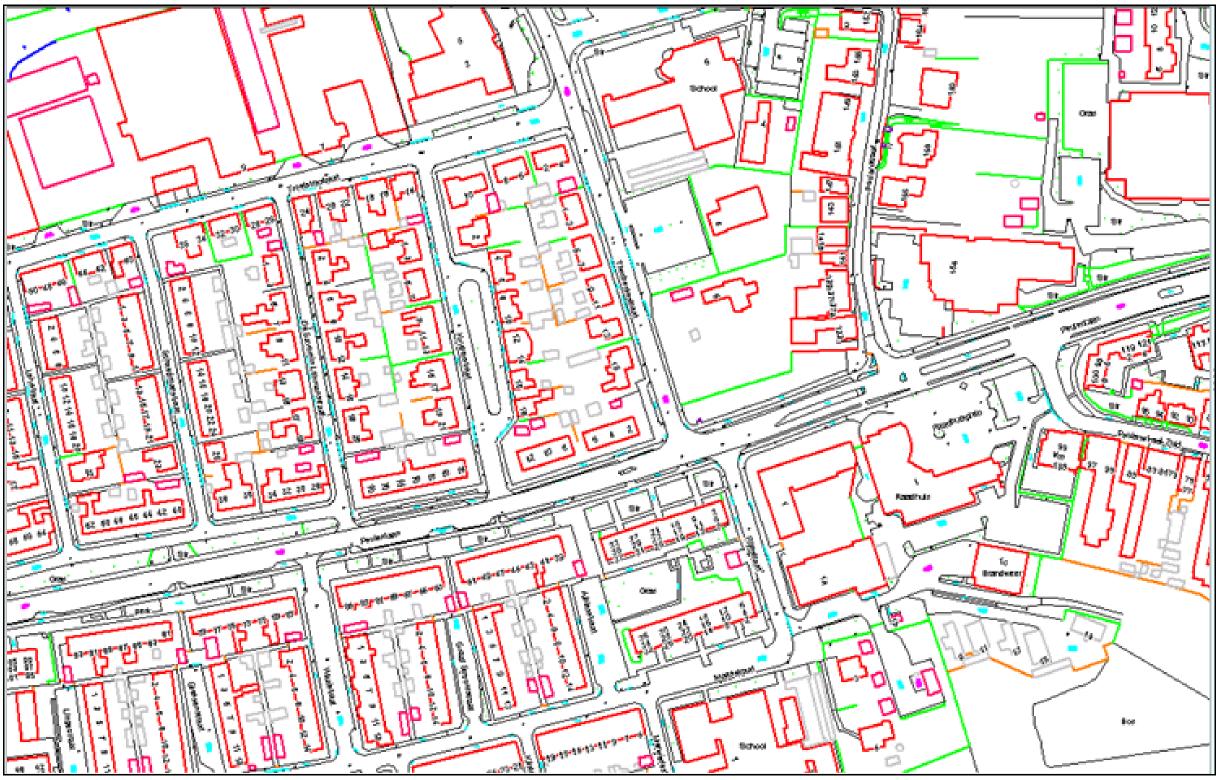


Figure 5-5 Topographic map in Netherlands (Source: GBKN)

5.3.2. Map Renovation in Netherlands

Nevertheless increasing frequencies in use of the cadastral map and large scale base map there were many accuracy-inconsistencies in case of superimposition of the two map series. Those inconsistencies in accuracy were in the cadastral map, the GBKN had a homogeneous quality. Reason is in the fact that no quality upgrade has been made for many cadastral map sheets during their 150 years existence (Salzmann et al., 1997). Note: this quality issue does not appear for rural areas where land consolidation took place or for new urban areas. Those areas have already a good quality, the remaining areas not.

Therefore the government of the Netherlands has set up the plan for coinciding cadastral map and large scale map which is called 'map renovation'. This was implemented by 'reconciling' the cadastral map with the base map. Reconciliation is performed in digital operation with digital maps. To achieve reconciling two objectives are fulfilled: no more misinterpretation due to overlay and geometric quality of the cadastral map equals the base map. There are three steps for renovation: first, corresponding points or objects should be selected (well-identifiable points; buildings). Based on these connection points, the cadastral map is locally fitted into the base map. Second, the buildings in base map 'moved' into the cadastral map. Third, the cadastral boundaries are compared with topographic objects in the base map. This is the reconciliation step. This method was used to reduce the costs (Salzmann et al., 1997); a re-survey would be enormous expensive.

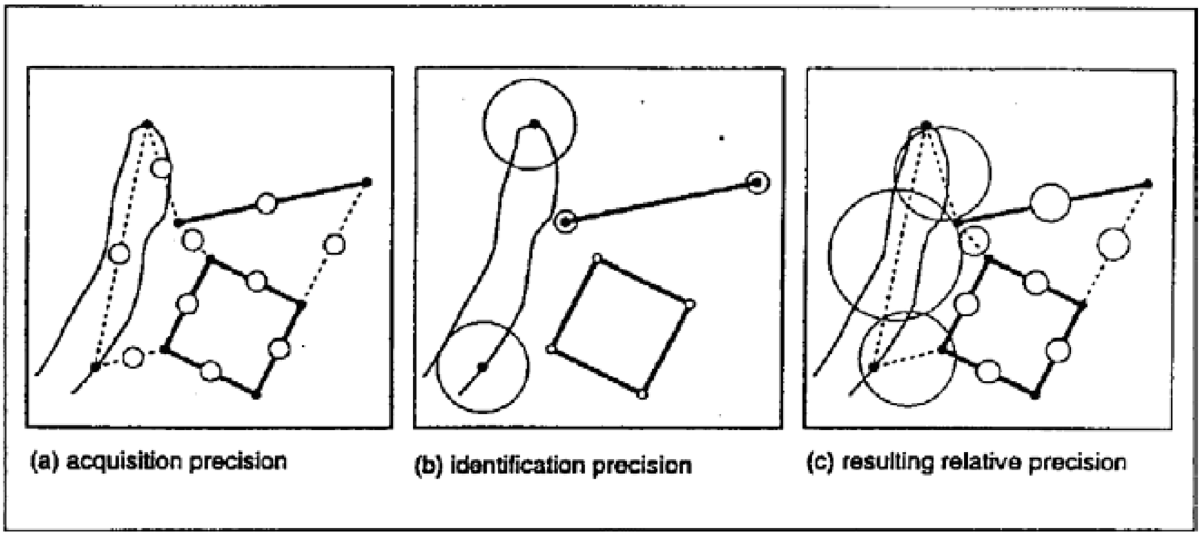


Figure 5-6 The concept of relative precision: (a) acquisition precision; (b) identification precision; (c) the resulting relative precision (Salzmann et al., 1997)

Figure 5-6 shows the concept of acquisition precision and identification precision to improve geometric data quality. The precision is represented by error ellipses it means that the acquisition precision is independent from the distance between points. As a result relative error ellipses have equal size (a).identification precision varies from point to point according to characteristics (b). Resulting relative precision between points is a function of the acquisition precision and the identification precision (c) (Salzmann et al., 1997).

To obtain higher geometric quality, the HTW-manual (in Dutch: Handleiding Technische Werkzaamheden) had been used in map renovations. The HTW-manual has been developed in collaboration between the Dutch Kadaster and Delft University of Technology. It contains not only background knowledge in the fields of adjustment and testing theory, geometric quality control and connection of point fields, but also field surveys (including GPS), map renovation and large-scale aerial photogrammetric surveys. It is expected that the adjustment procedure removes inconsistencies in the connection points and allows statistical testing for model errors(Heuvel & Salzmann, 1996).

The followings are the steps to improve data quality. These processes are executed by all steps or some of the steps depending on the situation such as quality of maps (Salzmann et al., 1997).

First step, Pre-processing and transformation: although the two maps (the cadastral and the base map) use the same national grid, because these data were positioned apart. Therefore a transformation should be performed in begin after that gross errors can be eliminated and homogeneous parts of two maps cab be selected. The transformation computations are performed inactively between two maps.

Second step, connection adjustment: inconsistencies in the connection points e.g. line elements are eliminated after adjustment.

Third step, interpolation: all points are not perfectly connected so-called free points also should be corrected. This correction is performed in comparison with a connection point nearby.

Fourth step, local adjustment: to improve the local relationships in the map, additional information use such as surveying measures and geometric relationships as collineartity and orthogonality.

Last, Post-processing and reconciliation: This can be performed by manually or automatically to decide which boundary coincides with a topographic element in the base map. Therefore it requires many comparisons; cadastral field sketches are needed sporadically. As a result of these procedures, the renovated map is accomplished (Figure5-6).

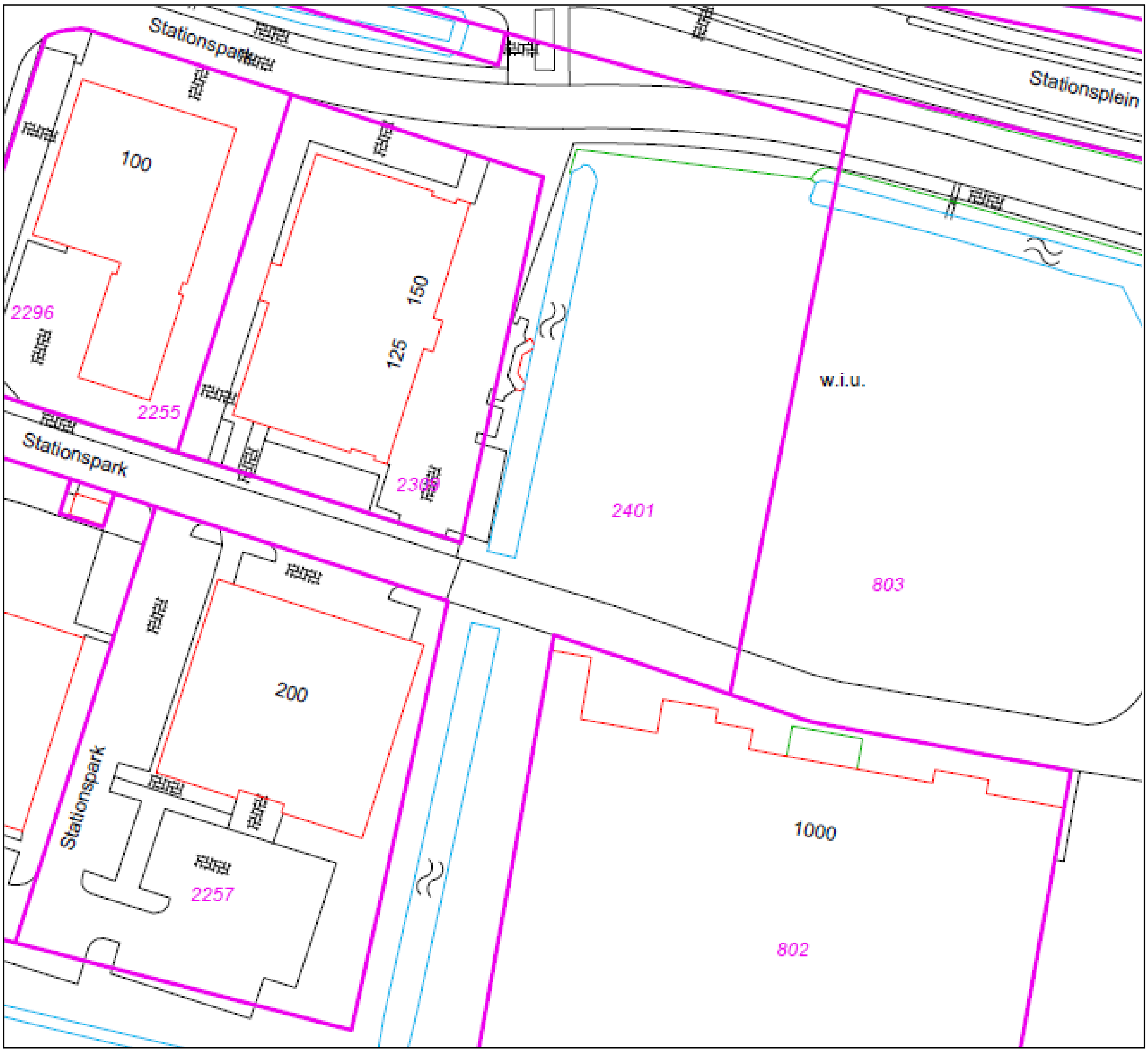


Figure 5-7 renovated map (Source: GBKN)

5.3.3. Utilities Information System in Netherlands (KLIC)

The registration of utility networks and distribution of utility data is conducted in KLIC (cable and pipeline information centre). The purpose of KLIC is to minimize excavation damage that may occur around the network, to provide up to date information on the underground (cable and pipe) networks at the excavation site (KLIC gets those data from the utility companies), and to manage the electronic information archive of documents provided to managers and contractors for their purpose. There is 1.75 million km cable and pipeline in the Netherlands and about 40,000 damages are reported annually which incurred € 40 million direct loss and € 80 million indirect loss in a year. In 2008 the KLIC has been integrated to the Dutch Kadaster (Wouters, 2007) see Annex B.

The Ministry of Economic Affairs, representatives of contractors, representative of networks owners and the Dutch Kadaster are involved as parties in KLIC. By the end of 2006 underground Cables and Pipelines Information Exchange Act was enacted. The following are some important highlights of the act.

- When digging mechanically > 50 cm: request obligated
- The request should be available 3 days before digging
- The provided information is valid for a maximum of 30 days
- When the validation period is expired new request is obligated
- Network owner has to send the utility information to Kadaster < 24 hours after the request

One thousand one hundred cable and pipe line companies are registered in KLIC, including their network areas and network types and other relevant attributes (cables, pipelines, connection devices etc.) which are projected on 1:1000 large scale topographic maps (GBKN). The Dutch Kadaster works as an intermediary since they give information regarding the utility company to the contractor whenever they receive requests. Figure 5-8 shows the work flow of KLIC.

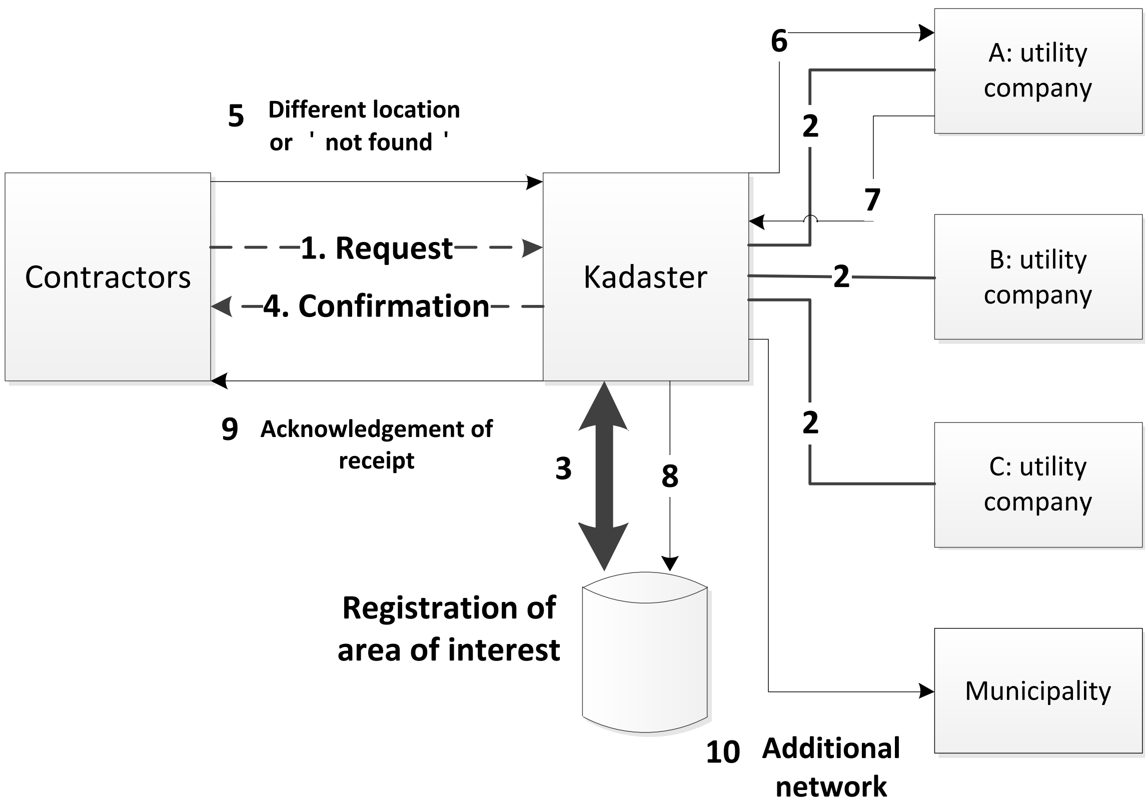


Figure 5-8 Work flow of KLIC (Source: Dutch Kadaster KLIC)

- The case of work process

General request (1-2-3-4): The contractor requests information on the areas they are about to dig. The Dutch Kadaster checks the area and then sends the received request to the cable and pipeline companies to ask for their data which are on the requested area (Figure 5-9).

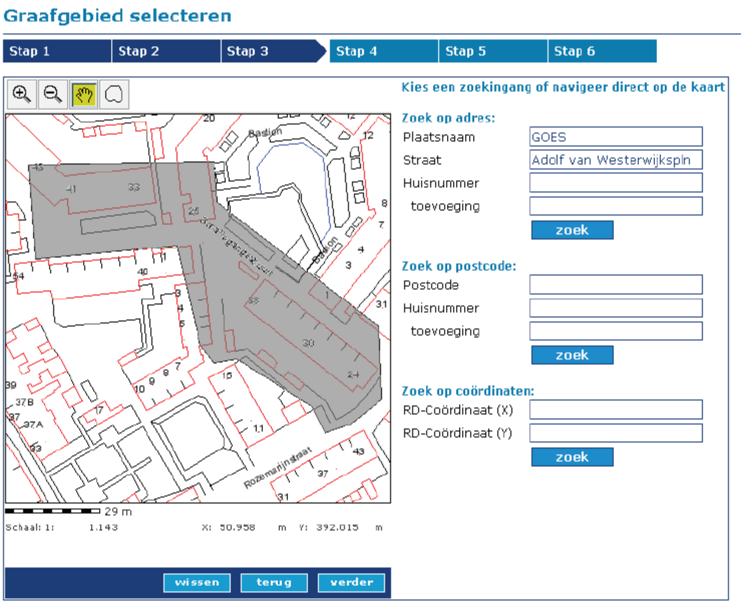


Figure 5-9 Apply request through Kadaster web site (Source: Dutch Kadaster KLIC)

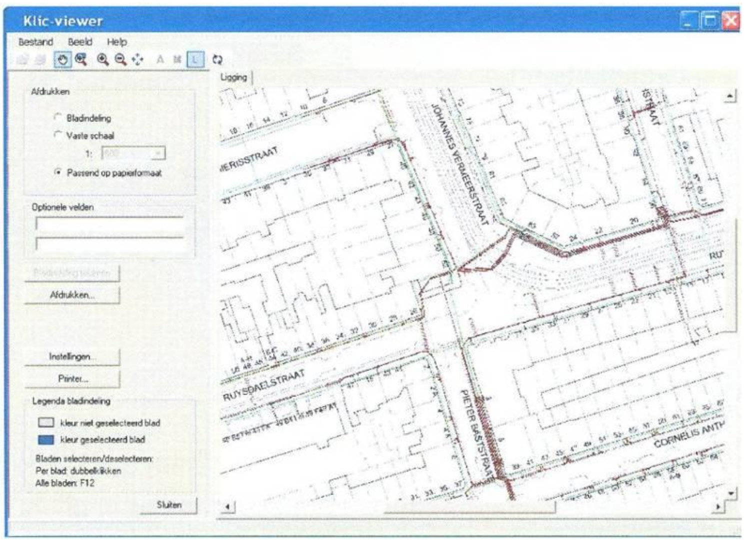


Figure 5-10 Integration topographic map and utility data (Source: Dutch Kadaster KLIC)

After the integration of utility data which is collected from the utility companies and the topographic map in the Dutch Kadaster database, Kadaster provides the resulting maps to the contractors (Figure 5-10).

It is possible to integrate all kinds of spatial information in the Netherlands. According to Act, all utilities from all companies should use same geo-reference, this is the GBKN. Standards for access exchange and file formats have to be used. Centralization of all the data to Dutch Kadaster is the most efficient way but cables and pipelines companies do not want to open their core information to the public.

Different location or not (5-6-7-8-9): the contractor should inform this situation to the Kadaster, and Kadaster should send this message to the (A) utility company. After receiving the confirmation from the utility company, Kadaster will send the new information to the contractor and will update its database.

New or additional (5-6-7-8-9, 10): it also has to follow same approach, but it should also be notified to the municipality (Annex B).

In addition, anyone who will perform mechanical excavation work is required to give a notification to KLIC ahead of time. This applies to both contractors and individuals.

The cost of per request is € 24 and 330,000 requests had been notified in 2010. It covers the annual budget of KLIC and about 40 staff works in the KLIC department. The prime utility information is not provided from utility companies because it is their core information in business.

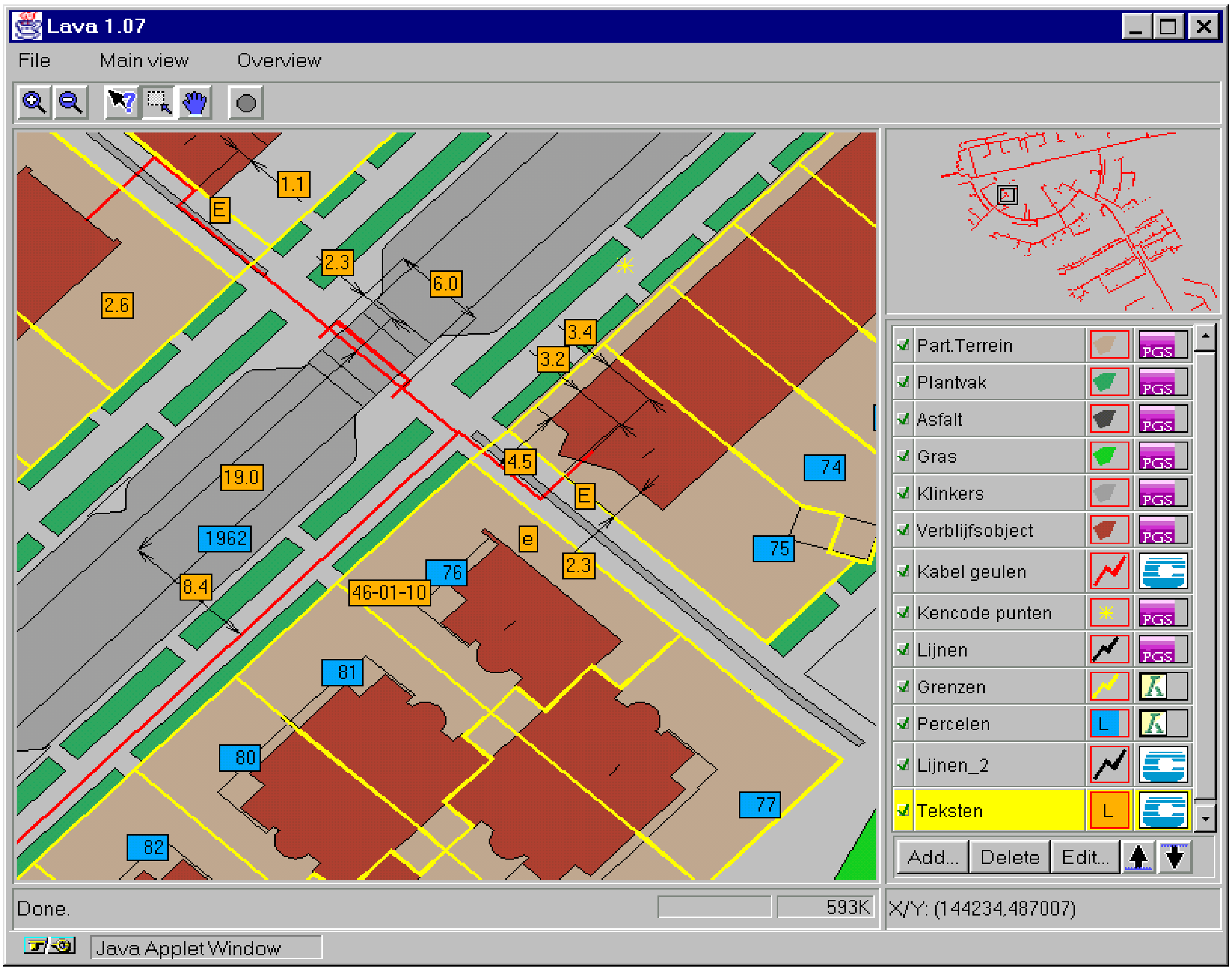


Figure 5-11 Combine cable information and boundaries information (Source: Dutch Kadaster KLIC)

Figure 5-9 presents information by layers; part terrain, plant box, asphalt, grass, cable channels, boundaries, plots. It is integrated with the cadastral map. But most of utilities information doesn't contain the depth value; only location is available recently. The main reason is that the utility information is provided by utility company and Kadaster does not check the quality information because Kadaster plays a role as intermediary for exchanging information.

5.3.4. Summary of Netherlands

The nature of the relationship between the cadastral map and the topography differs, depending on the country's cadastral system. The cadastral map and the Large Scale Topographic Base Map of the Netherlands are coordinated. After a map-renovation process, the cadastral map is fully reconciled with the topographic map at boundary level as the map series share building-data. Both maps (databases) are extensively used by governments, utility companies, and private companies for their own activities (van der Molen, 2006). In spite of the high accurate spatial data in the Netherlands, the spatial information has not been completely integrated yet (e.g. utility companies don't provide core information). Moreover, The Dutch Kadaster relies on the utility company's information. It means that the accuracy of the integrated data which is issued from Kadaster to contractor is not completely assured. But the possibility was found for the spatial data integration in terms of using same geo-reference and dataset as Netherlands.

5.4. Overall Comparisons

In South-Korea, the utility map is prepared based on the topographic map which is produced by NGII. It uses another geo-reference system than that of the cadastral map. For this reason the linkage with cadastral is not executed in South-Korea which means that the ownership is not considered in utility maps. The accessibility of utility data is not available to the public because most of the utility data is managed in different companies and organizations.

The South-Korean government has been developing the UIS since 2009 to integrated seven utility maps. It contains type of utility, buildings, road boundaries, elevation, and (incomplete) parcel boundaries which are represented in poly lines, texts, and polygons. It has coordinate and depth information. The scale of 1:1000 is being used for utility surveying. It is also rescaled to 1:500 for readability and editing.

The Netherlands uses the same geo-reference for topographic maps and cadastral maps. The GBKN makes the integration of the two maps possible. The utility maps contains buildings, roads (names), parcel number (ID), utilities, railways, rivers and canals which are presented in poly lines, points, symbols and texts. The accuracy of map in urban area is 0.2 m and 0.4 m in rural area for construction points. The utility map does not have the ownership information but it has a cadastral parcel boundaries. Thus, it is possible to find out the utility position where the utilities laid private land or not.

The KLIC is the utility information provider and works as an intermediary in the Netherlands. When the contractor requests the utility information to KLIC, it checks the area then asks the utility information to utility companies which is related in that area. But the provided data from KLIC may not be assured because they don’t produce it themselves but just collect utility information from utility companies and the consistency between their data and utility data are not checked while integrating. Moreover, the utility information is also open to the public.

To summarize situation of utility system between the Netherlands and South-Korea, the main differences between them is the geo-reference system they use. In Netherlands, they use the same geo-reference with cadastral map but South-Korea use the different geo-reference. In addition, regarding the availability of utility data, all kinds of spatial data are open in Netherlands but on the contrary, the utility data is not accessible in South-Korea.

6. DESIGNING BUSINESS MODEL

6.1. Introduction

As already mentioned in chapter 5 the spatial data (cadastral maps and topographic maps) is practiced to each domain separately in Korea. The differences between reality and cadastral map are also found. According to a MLTM annual report 2011, 14.8% of the entire number of parcels (37millions) i.e. approximately 5.5 million parcels are mismatched if the situation in reality (where boundaries are concerned) is compared to the boundaries on the cadastral maps.

There are many possibilities to create conflicts in ownership if the owner realises this. Moreover the Korea UIS (Underground Information System) does not take care about the differences. UIS just integrates the utility information which is provided by utility companies that means the prime data is not verified. In this chapter, a new business model is introduced as a possible solution.

6.2. Requirement of Business Model

All kinds of spatial data are integrated at national level. Spatial information makes an effect to and supports decision making (government plan and business) and management of space. It can be accessible to public with high accuracy. Making an outline for providing information is not easy because it cannot calculate a consequence when the information is distributed to society (van Oosterom & Zlatanova, 2008). Network users expect efficient and flexible geographic data browsers (van Oosterom & Lemmen 2001).

In South-Korea UIS has been developing the integration of seven main utilities based on the topographic map and it depends on the utility company data. In fact, utility data is solely provided by utility companies and organizations. Also the different Acts and maps including methods of measurement are applied. To integrate spatial data (cadastral map and utility map which based on topographic map) institutional, organizational, technical requirements are addressed to design a new business model in South-Korea.

6.2.1. Map Renovation

Before designing the business model, the spatial data integration method should be organised in advance. The difference of topographic maps and cadastral maps can be integrated in spatial adjustment which was tested in chapter 4. It is also necessary to note that the map renovation (topographic maps includes utility and cadastral maps) is one of efficient methods to build a high accuracy map as Netherlands did. But resurveying is also needed in some complex areas such as mega cities because it is not easy to distinguish the object ID through the desk work (satellite image, aerial photogrammetric and terrestrial LIDAR etc.). In urban areas very complicated situations exist such as overlapping and intersecting boundaries. The benefit of resurveying is it allows a discussion with stakeholders about their boundaries with agreement on site. For these reason the integration should be accompanied by two methods.

Furthermore the different amounts of area which are already registered and the newly calculated ones should be considered in the integration process of the two maps. The increasing or decreasing of areas should be made known to the land owners.

6.2.2. Data Integration Methods

The KLIS has been implemented since 2005 over the county through governmental web server. It contains information such as addresses, land uses, areas, cadastral parcel boundaries, ownership, cadastral control points etc. All graphic units consists of polygon, text, point with coordinates. KLIS is also used to share land attribute and spatial information in South-Korea. KLIS is applied to planning, taxations, land use zoning etc. But it only provides land information not utility information. To overcome this, UIS has been developed since 2009. If UIS is complemented to KLIS, it will provide more useful land information.

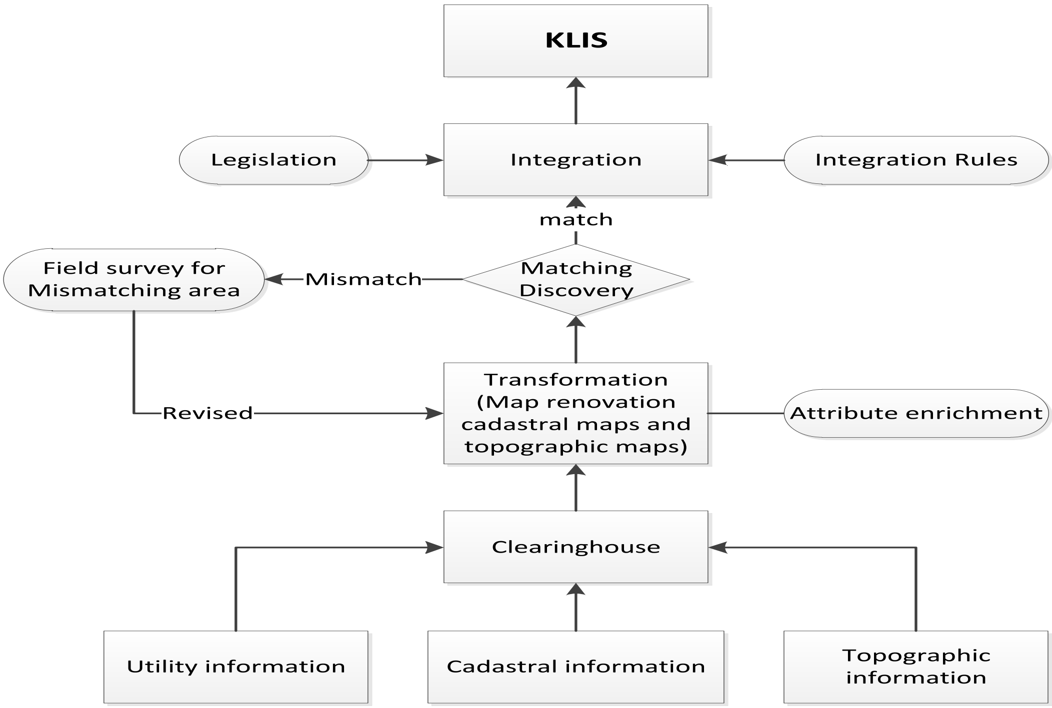


Figure 6-1 Integration process

- Collecting data; UIS (Utility and topographic) and cadastral information are collected to clearinghouse for the transformation.
- Transformation (spatial adjustment); Geo-reference (WGS-84), coordinates (X, Y, Z), scales, all kinds of attributes to be registered on the cadastral map. The cadastral map does not have buildings and Z coordinates information but topographic maps don't have parcel information. The combination of two maps is able to provide more reliable information. After integration, the integrated control point should be used to survey.
- Matching Discovery; the missing area/attribute, examines differences between cadastral information and topographic information. If a difference is found, field survey is request to revise mismatching areas. In these stages, the different size of area (registered area and newly calculated area) should be considered in order to get confirmation from owner.
- Integration; according to legislation and integration rules, all the data should be integrated. Then the integrated data is updated on KLIS

This integrated information is distributed to local level municipality for updating and sharing. The users (contractor, cadastral surveyor, utility companies, and municipality) have to use the same format data and follow the legislation under government supervision.

6.2.3. Institutional Requirements

Legislation, policy, regulations: From the field work, some lack of legislation, policy and regulations was found in processes of UIS. In South-Korean law, the definition of the range of the land ownership (so-called 3D rights) is not yet defined 'The range of ownership extends to above/under the land within legitimate interest' (Civil Code, article 212). Article 31 explains estimation of using above and underground space 'In case of using above/below land for public purpose, compensation should be conducted to the landowner'**4**.

The act that has been prepared since 2009 for developing UIS however, but not considered the ownership of property which reflects a real situation (including 3D volume) in field. It means that the same mistake will drive as the cadastral did; as above mentioned the cadastral map of South Korea had been digitized based on the paper. For this reason the mismatching between maps and reality still exists. The dilemma lies on the level of priority. Normally, in case of land, the documents are more priority than the reality in South-Korea.

Nevertheless, the UIS is going to make the same error because the ownership is not included in this system. UIS deals only with gathering utility spatial information from utility companies. To create high quality system, the actual boundaries and cadastral boundaries should be matched. The methods on how to register and represent ownership on UIS should be established. Maps and reality should be homogenous to avoid problems e.g. to get utility information to the contractors who have to pay to the municipality but the provided information may be incorrect in the construction site. If contractor damages others utilities, the contractor is fully responsible for damage because currently there is no legislation for incorrect information.

The data sharing; the concept of UIS is centralization of utility information to government and distributions to use for the public just like the KLIC. But one thing to look deep into UIS, from field work all utility companies replied about data sharing 'It is impossible to access to the government database to check other utilities information'. At this moment a contradiction concept is found that the utility information is core part to manage their business and it is confidential information as found from field work. If so, it is impossible to check the data quality by government.

Until now there is no rule about the range of ownership, data sharing and responsibility for providing incorrect information. To integrate all spatial information a special law is required to make reliable land information system including underground information.

4 E.g. KEC (Korea Expressway Corporation) built a tunnel in Gyung Buk. It has built under 22m~ 96m and KEC used the sand, stones to construct road which from private underground. After land owner realized took this situation to Court. The judgement of court was € 20,000 compensation to owner 'the ownership extends above/under the ground in this reason the material from underground is belong to land owner'. There is no definition of how many meters above and blow of land. But the range of ownership should be prepared to prevent of this problem.

6.2.4. Organizational Requirement

The spatial information is used for different purposes in South-Korea. The cadastral map is used to represent private or governmental land ownership rights including legal behaviour of superficies. It is managed under government and only KCSC is able to use the cadastral map for cadastral surveying through the KLIS which is updated daily on local level. Otherwise the topographic map is used for utility surveying and construction sites.

In addition the NGII produces the topographic map by using satellite images which is updated biennially or less often. In spite of the fact that the topographic map should be representing the actual situation, there is some incorrect information because of irregular updating. Both organizations (NGII, KCSC) are doing similar business with profit-making for public interest under governmental supervision. Nevertheless there is no cooperation between two organizations.

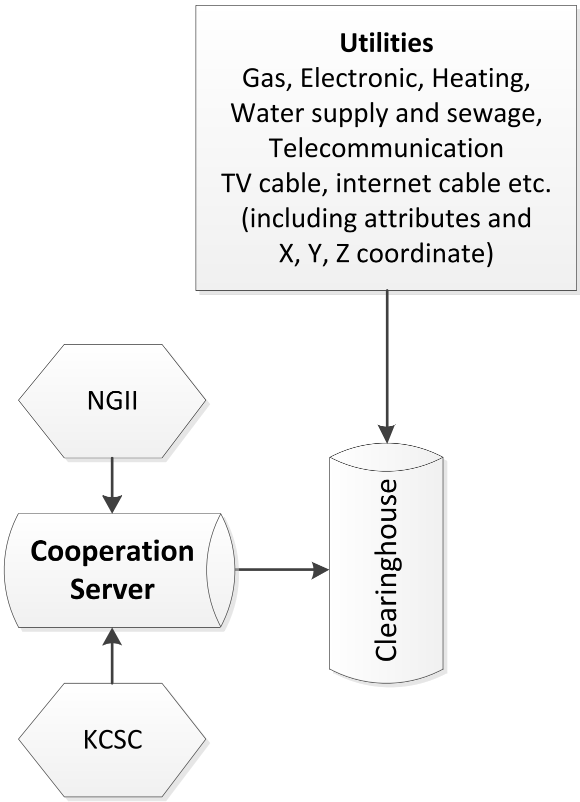


Figure 6-2 Spatial data integration in organization requirement

Figure 6-2 shows the relationships between organizations and utility companies. After map renovation, the base map will be used in all organizations and utility companies. To maintain data quality the organizations and utility companies should cooperate with each others.

Between two organizations (NGII, KCSC) the cooperation server is needed to update and share the information. In case where the cadastral information is changed e.g. subdivision of parcel, transaction KCSC should deploy the alteration to cooperation server. NGII also follows same process.

In the clearinghouse all types of spatial information are integrated in order to register KLI+UIS.

6.2.5. Technical Requirement

The renovated map contains all kinds of information which relates to land. It shows that all the information of parcel, types of utilities, rights, location etc. In order to manage this unified map, the following technical requirements are fulfilled.

- Accuracy of data

The surveying methods should be the same for utility and cadastral map after integration for updating. The following tolerance of utility is proposed by (Lee, 2007); 30 cm vertically and horizontally according to public surveying regulation (article 303,169, 32). Since cadastral maps and utility maps are integrated, tolerance of cadastral map need not to be considered but that of the utility should be used in cadastral system. The different tolerance can be adapted according to urban area and rural area.

- Data quality assurance

The same data format, geo-reference and surveying methods should be used to all level of organizations and companies. It makes possible to use high accurate equipment such as total station and GPS including Z coordinate and softwares (Arc-GIS, CAD and so on). With this standardization all kinds of surveying data is qualified to have equal data quality.

- Sustainable quality

To manage this business model the data should be regularly kept on updating. The results of surveying data from the field work are checked by KCSC and then the data is updated to KLIS + UIS systematically. The data quality is one of the elements to operate a successful business model.
In case of changes such as parcel subdivision, new utility installations and other editions should be synchronized in the software.

- Information security

The information security needs to be balanced between data clearinghouse and government. Only clearinghouse is able to edit integrated data. Limitation should be set to organizations in their mode of operation and implementation in order to monitor performance and achieve compliance while also providing adaptability to emergent conditions (ISACA, 2012).

- Spatial data management

In addition to creating a successful business model, the SDI (Spatial Data infrastructure) should be interoperated to all levels in nationwide coverage. This will help the business model find efficient ways for data sharing and transferring by electronic documents. It helps to reduce the cost of workflow and the time consumption. As an important part ICT (Information and Communications Technology) infrastructure should be prepared to support SDI in order to keep the balance with the spatial information which is changing rapidly with technologies as the web-base, GPS, high resolution satellite imagery, and communication technologies.

SDI is a critical component of land administration infrastructure. SDI consisted of people, a clearinghouse/access network, technical standards, an institutional framework and framework data such as typically the geodetic, topographic and hydrology, land parcel, road network, geographic name layers (Wiliamson & Ting, 2001). SDI is a dynamic and inter-jurisdictional system. It is important that the understanding between all levels and institutions based on partnership for sharing land information and spatial data. Beside SDI supports sustainable development, economic development and environmental management and social stability (Wiliamson, 2000).

6.3. Proposed Organization

In this business model the clearinghouse is proposed as a new organisation. The role of clearinghouse is to approve spatial data integration and it registers into land information system including underground information under governmental supervision. To manage this organization, essential factors are organized such as member of the board, legal status, responsibility of members, authority of organization, and financial policy should be organized

- Board

The board consists of representatives from each of the organizations and utility companies who also have a right to vote to make a decision for important issues. In addition, the utility damages are happened in construction site due to incorrect information. The board decides the percentages of compensation to the information providers and contractors. The following is the information of member.
Mapping organizations: KCSC, NGII
Utility organizations: KOGAS, KEPCO, KDHC, KWRC
Utility companies: Telecommunications

- Clear legal status

The following is the proposed Act of utility data

- When digging mechanically > 50 cm: request obligated to municipality
- It should request 7 day before digging
- Information is valid for 30 days
- When expired the validation: new request obligated
- Municipality send the utility information to contractors < 1 hours from request
- The new utilities data (completed map) should be examined by KCSC
- The member of board consists of representative of each organization under government supervision
- The clearinghouse board is responsible for the incorrect information
- The utility information should contain ownership data to prevent invading private land
- In case of using private land, the compensation should be discussed with owner, utility company, and municipality.

- Financial policy

Initial investment for creating the proposed organization, will be funded by each of organizations and utility companies investment. The percentage of investment should be organized to share profit. The following is an example of Netherlands. In 1992, the Public Private Partnership was launched to make base-map. All parties involved in the production process including the financial support: utility companies 60%, municipalities 20% and cadastre 20% (GBKN, 2011). It can apply to South-Korea business model but the percentages of initial investment should be discussed.

According to annual report of (MLTM, 2011b), 32,000 notifications are requested for excavation per district (69 districts in Korea. Approximately 2,200,000 notifications might be received a year for requesting utility information. If the board puts the proper price of request, it might support the initial investment too.

- Responsibility

The integrated data should be guaranteed by the government. In case of damage due to incorrect information, the responsibility should be shared according to board decision.

6.3.1. Role of Clearinghouse

In this business model the clearinghouse plays a role as one of organization for the spatial data integration under government supervision. All types of spatial data should be integrated and discussed with representatives of different organizations. The following are to be performed in clearinghouse:

- Integration of cadastral maps and large scale topographic maps (including utilities information) in order to provide high accuracy map. The field sketch (utility companies and KCSC) is considered as reference documents
- Web-based interface should be standardized to have the same file format, geo-reference, and surveying methods
- The existing laws (including responsibility, sharing of information) need to be discussed and implemented
- Feedback from user should be accepted to improve integrated data
- SDI is organized to connect other organizations for data sharing/exchange
- Each organization has to transform the provision of products and services using ICT.
- To prevent duplication of spatial information, the integrated data should be updated to KLIS+UIS only. Government cannot directly change original data in KLIS+UIS
- The clearinghouse should continuously be updated to improve geometric accuracy of maps and spatial data infrastructure

6.4. Design Business Model

The integration of KLIS and UIS is one of key points to prevent errors on integrated spatial data in South-Korea. In this chapter the business model is designed to improve the KLIS and UIS in South-Korea.

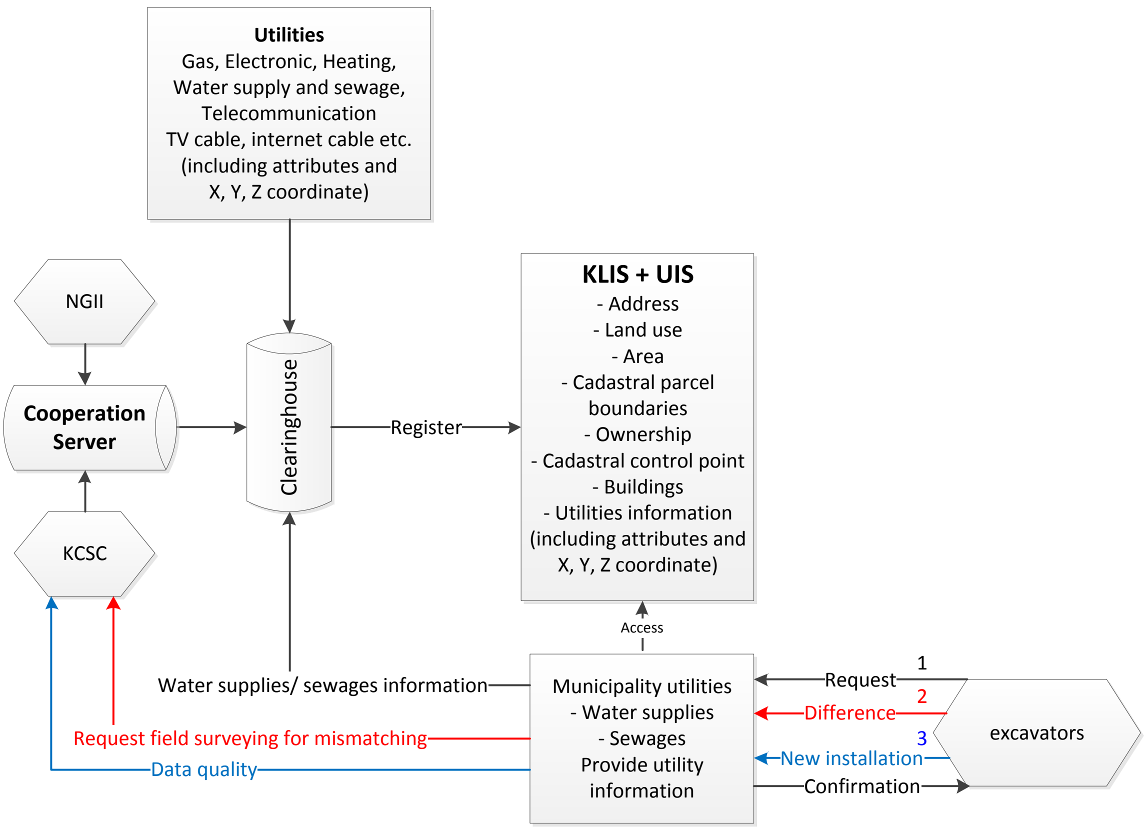


Figure 6-3 Business model of KLIS+UIS

Figure 6-4 addresses the business model of KLI+UIS. As a result of above integration methods, the integrated data is already registered in KLIS+UIS under government supervision. All steps in this model are conducted in electronic documents form through web. The following are the steps according to type of request.

- Case of request process

1. Contractor requests utility information to municipality. The municipality accesses the KLIS+UIS and collect the utility information then provides the information to contractor
2. After receiving utility information from municipality, if contractor finds any difference (location, number of utilities present) comparing with provided information, inform to municipality about difference then KCSC check the actual situation on a field surveying
3. In case of new installation contractor submits the completed map to municipality. According to municipality order, KCSC examine a data quality, register to KLIS+UIS

KLIS+UIS contain all kinds of land information. In this system, the height of building is not registered because the current topographic map doesn't have height information. One of the options to obtain building information is using construction drawings.

In addition the advantage of clearinghouse is to reduce the frequency of excavation in terms of sharing utility companies work plan (e.g. one digging to install utilities together).

Municipalities work as a data distributor and utility information provider. In case of receiving contractor's request, municipality access to the KLIS+UIS then provide utility information to contractors. The payment is in advance to the request for utility information. If the contractor finds any difference of location (X, Y, Z) then they must inform the municipality.

6.5. Summary

The UIS has been developing since 2009 to collect all types of utility with topographic map without ownership. The South-Korean government expects that most of underground problem will disappear after UIS is developed. The UIS gathers utility information which is provided from different utility companies. Still many differences between geo data and reality remain because the different between cadastral map and reality is not solved yet.

To solve this problem the map integration (map renovation) is proposed. With this integrated data the new business model is also proposed with three requirements. Until now municipality works as main key register in South-Korea. But all participants in clearinghouse can be key register in this model. To implement this new business model, many things have to be changed e.g. municipalities handle all types of works which relate to land information such as registration, editing attributes and providing civil service etc. Those responsibilities have to be shared with other organizations.

7. CONCLUSION AND RECOMMENDATIONS

7.1. Introduction

This chapter presents the conclusions of this research according to the research sub-objectives and research questions. The overall conclusion is derived from those sub-objectives. The recommendations are presented which related to this research.

7.2. Conclusion

The main objective of this research is to design an approach for an integrated and more accurate representation of underground utility-information on 3D cadastral maps. Further, designing of a new business model for 3D underground data combined with cadastral data. Five sub-objects were defined to achieve the main objective.

1st sub-objective: To analyze the differences of represented underground utilities and boundaries represented on the cadastral map (comparison of data quality)

Q 1) What is difference between cadastral map and underground utility in Korea?

The difference between cadastral map and utility map is in contents, reference system, completeness, publication restrictions and responsibilities. The cadastral map is registered based on the cadastral book but the utility map is registered by utility company information without ownership information.

The digital cadastral map uses six scales (1:500, 1:600, 1:1000, 1:1200, 1:3000, and 1:6000). It contains ownership, land history (subdivision, merge), areas, ground control points, parcel boundaries with X, Y coordinates and parcel ID (address) and parcel area. It has representations of objects as polygons, poly lines, points, texts, number with colour. It also specifies by layers. Moreover, the cadastral map is used for governmental purpose.

The utility map use digital topographic map (1:1000) which contains road lines, buildings, building's name, X, Y coordinates, type of utility including construction year, type of material, diameter, length, and depth (Z). But there are incomplete parcel boundaries. It has representations of objects as polygons, poly lines, points, texts, number with colours. It is also specifies by layers. Also it is used to construction site (Chapter 3.5).

2nd sub-objective: To analyze the implementation, mapping and surveying and spatial data provision tasks of utility companies and cadastral organizations in the law

Q 2) What are the main reasons of different representations for the same object measured between utility companies and cadastral organizations?

From the field work, initially, two maps are used which are produced with different methods, geo-reference, scale, register methods (management) and responsibilities.
First, the cadastral map was made on paper base then digitized to digital format in 2005 and cadastral information stored to KLIS. But it follows the traditional geo-reference (Bessel 1841) and six scales are used in cadastral survey. KCSC is conducting cadastral surveying. The accuracy of surveying is written in

cadastral survey Act article 27. According to the law, KCSC is responsible for the results. The cadastre information is possible to access through the governmental web-site (Chapter 3. 5, Chapter 5.2).

Second, the utility map is based on the topographic map which is obtained from satellite image (geo-reference GRS80). NGII produces the topographic map. It has many scales from 1:1000 to 1:500000 can be used. Generally 1:5000 scales is used in geodetic survey. For the utility map 1:1000 scales is used but normally 1:500 scale (re-scale 1:1000 to 1:500) is used for readability. Different format (paper or Auto-CAD file) is used according to utility companies. All utility companies use the same exchange format after UIS plan has been established in 2009. In the field, the constructor is responsible of surveying results and installations of the utilities. This is executed by the utility company themselves or by subcontractor using city control points. Utility information is not accessible to the public (Chapter 5.3, 5.4).

Complexity is in the fact that the cadastral map is a correct representation of reality by law even if the represented parcels are with a very low accuracy.

3rd sub-objective: To analyze business cooperation in case of data sharing with a focus to spatial data

Q 3) How to organize sustainable cooperation between utility companies and organization for data sharing?

From field work it was observed that there is no cooperation between utility organizations and companies where spatial data management is concerned. Since 2009 the government has been developing UIS but until now accessing to other utility information is not allowed (Chapter 3.5).
In proposed business model, the utility and cadastral information are integrated for data sharing. To improve the data quality, the changed information and new additional information are checked by KCSC. Integrated data distributes to the public through governmental web (Chapter 6.2). To manage this business model, the data should be regularly updated because the data quality is one of the keys to operate the business model in a successful way (Chapter 6.2.5).

4th sub-objective: To identify bottlenecks in the process of managing underground utility data and self-accountabilities in organizations and companies

Q 4) What is the companies and organizations self- accountability?

The utility companies and organization keep the utility information in secret to prevent leakage of confidential information. It is used only by utility companies and organizations themselves for construction and maintenance of utilities. According to utility companies and MLTM respond, there are no of damages in records kept (Table 3-2).

Q5) Is the 3D cadastral map needed for presenting underground facility and structure?

The results of the pilot test performed are presented in chapter 4. The purpose of this test is to find out the possibility of data integration between topographic map and cadastral map on 3D cadastral map. From the field measurement, the possibility was found because the legal situation as in reality and the legal situation as represented on the cadastral map are harmonised (Chapter 4.3).

The 3D cadastral map might be needed in complex areas to figure out the position of utilities easily. On the other hand KLIC methods could be another option by adding layer in sequential order according to depth.

5th sub-objective: To design a new business model for co-operation between 3D spatial data providers

Q 6) How should the business model for proper information supply look like?

Cadastral and utility spatial data are being used separately in each domain. The cadastre uses the cadastral map and the utility use the topographic map with different geo-references and attributes. To implement the proposed new business model, the map renovation should be done in advance. In order to manage new business model the clearinghouse plays a role as new organization. The clearinghouse all spatial data are integrated with board agreements under government supervision. The integrated spatial data is registered to KLIS+UIS. And local government levels (municipalities) work as a data distributor and utility information provider to the public (Chapter 6.4).

In addition creating successful business model, the SDI should be interoperated to all levels in nation coverage. It provides efficient way for data sharing and transferring by electronic documents. It drives to reduce the cost of workflow and time consuming (Chapter 6.2).

Q 7) How does integrated (spatial and non spatial) data effect to land information (3D underground data)?

The utility data has been stored to each of organization for the construction and maintenance. To improve this situation South-Korea has been set up the plan for integration of utility information. But still the third party utility companies cannot access to other utility information because the utility information is core of their business and related secret.

The integrated data brings cost effectiveness. The South-Korea has estimated budget for resurvey in order to overcome difference of reality and cadastral map. Approximately € 1.2 billion is needed for re-survey and € 250 million is needed to solve these kinds of conflict a year (Chapter 5.2).
The frequency of digging also will be reduced because all utility companies share annual new installation work projects in clearinghouse (Chapter 6.4).

7.3. Overall Conclusion

In South-Korea, the utility is managed by different companies and organizations. Two different maps provide different output. This divided system lead to problems among companies, organizations and citizens. As a solution, the data integration is done as the pilot test on prototype. In addition the new business model is introduced to improve South-Korea spatial data infrastructure.

7.4. Recommendation

A business model is proposed in this research. The geo-information should be handled as a part of the national infrastructure. The geo-information provides reliability to decision makers. The following should be considered more in detail.

It is recommended to:

- Prepare legislation to make utility data (more) public available
- Use one reference system for all geo-information providers and users
- Establishes integration of all utility information and cadastral information with the responsibilities in one environment (NSDI). The integrated spatial data is to be registered to KLIS+UIS.
- Provide budgets
- Provide access to all utility data in all utility companies, organization and governmental authorities in those areas where construction or maintenance take place
- The integrated data is accessible through web base for the public
- After map renovation the difference of area should be considered by compensate or tax reduction or.

All kinds of spatial data are integrated in clearinghouse with broad agreement. This integrated data is expected to be used in many areas such as disaster management, city plan, utility infrastructure management, administration of property, real estate agency etc. The integrated data is to provide a safe, efficient, and environmentally sensitive transportation network that offers a variety of convenience for the people.

References

Aien, A., Rajabifard, A., Kalantari, M., & Wiliamson, I. (2011). *Aspects of 3D Cadastre- A Case Study in Victoria*. Paper presented at the FIG, Morocco. http://www.fig.net/ pub/fig2011/papers/ts02g/ ts02g_aien_rajabifard_et_al_4935.pdf

Beck, A. R., Cohn, A. G., Parker, J., Boukhelifa, N., & Fu, G. (2009). *Seeing the Unseen: Delivering Integrated Underground Utility Data in the UK*. Paper presented at the GeoWeb 2009 Academic Track - Cityscapes. http://www.isprs.org/proceedings/XXXVIII/3_4-C3/Paper_GeoW09/paper07_ beck.pdf

Beck, A. R., Fu, G., Cohn, A. G., Bennett, B., & Stell, J. G. (2007). *A Framework for Utility Data Integration in the UK.* Paper presented at the Urban and Regional Data Management: UDMS 2007. 26th Urban Data Management Symposium, Stuttgart, Germany.

Cypas, K., Parseliunas, E., & Aksamitauskas, C. (2006). *Storage of Underground Utilities Data in Three-Dimensional Geoinformation System*. *Geodetski vestnik 50*(3), p481~490.

Döner, F., Thompson, R., Stoter, J., Lemmen, C., Ploeger, H., van Oosterom, P., & Zlatanova, S. (2010). *4D cadastres: First Analysis of Legal, Organizational, and Technical Impact With a Case Study on Utility Networks*. *Land Use Policy, 27*(4), 1068.

FIG. (1995). The FIG Statement on the Cadastre. Technical Report Publication 11: Federation International des G'eom'etres, Commission 7, 1995.

GBKN. (2011). *A Map That Took 25 Years to Complete* Last visited 08-12-2011, from http://www.gbkn.nl/nieuwesite/downloads/Gimdef.pdf

Heuvel, F. A. v. d., & Salzmann, M. (1996). *Standards For Large-Scale Photogrammetric mapping*. Paper presented at the International Archives of Photogrammetry and Remote Sensing, Vienna.

Hong, S. Y. (2005). *A study on the Improvement of Underground Facility Management System Linked with KLIS*. Msc, University of Seoul.

ISACA. (2012). Business Model for information Security Last visited 23-01-2012, from http://www.isaca.org/Knowledge-Center/BMIS/Pages/Business-Model-for-Information-Security.aspx

Jo , J. J. (2011). *Establish the 3D Spatial Information Using Laser Scanning*. Paper presented at the KCSC journal conference, Seoul, Korea.

Jo, M. S. (2004). *A Study of Utility Map System with Cadastral Map*. Msc, Gyungki University.

JSSGP. (2011). About Jeju Last visited 15-11-2011, from http://english.jeju.go.kr/contents/index.php?mid=0101

KASM. (2011). Utility Survey Last visited 23-11-2011, from http://www.kasm.or.kr/board/home_bbs _lst.jsp

KCEI. (2006). *What is KCEI?* Last visited 03-01-2012, from http://caving.kr/?mid=institute&document _srl=218

Kumar, R. (2000). *Research methodology : a step by step guide for beginners*. London etc.: Sage.

Lee, C. K. (2001). *Investigation of Cadastral and Topographic Survey for Proving Collapsed Land s under the Sea*. Paper presented at the FIG Working Week 2001, Seoul, Korea http://www.fig.net/pub/proceedings/korea/full-papers/session13/lee.htm

Lee , Y. W., Heo , M., Lee , J. O., & Baek , H. (2007). *A Study on Status and Accuracy of Underground Facilities Maps*. *Korean Society of Surveying, Geodesy, Photogrammetry and Cartography*, 223-230.

Lemmen , C. H. J., van Oosterom , P. J. M., Uitermark , H. T., Zevenbergen , J. A., & Cooper , A. K. (2011). *Interoperable Domain Models: The ISO Land Administraion Domain Model ITS External Classes*. Paper presented at the ISPRS, Delft, the Netherlands.

MKE. (2011). *Civil complaint* Last visited 05-10, 2011, from http://www.mke.go.kr/minwon/main.jsp

MLTM. (2011a). Reports of Resurveying Last visited 23-10-2011, from http://www.mltm.go.kr /USR/NEWS/m_71/dtl.jsp?id=95068463

MLTM. (2011b). Underground Utility System Last visited 23-08-2011, from http://www.mltm.go.kr /USR/NEWS/m_71/dtl.jsp?id=155694313

Monnikhof, R. A. H., Edelenbos, J., van der Hoeven, F., & van der Krogt, R. A. A. (1999). *The New Underground Planning Map of the Netherlands: A Feasibility Study of the Possibilities of the Use of Underground Space*. *Tunnelling and Underground Space Technology, 14*(3), 341-347. doi: Doi: 10.1016/s0886-7798(99)00049-8

NARK. (2011). *Act of Cadastre* Last visited 15-12, 2011, from http://likms.assembly.go.kr/law/jsp/law/Law.jsp?WORK_TYPE=LAW _BON&LAW_ID=D3335&PROM_NO=00192&PROM_DT=20091214&HanChk=Y

Oosterom, P. v., Stoter, J., Ploeger, H., Thompson, R., & Karki, S. (2011). *World-wide Inventory of the Status of 3D Cadastres in 2010 and Expectations for 2014*. Paper presented at the FIG (International Federation of Surveyors).

Park, S. Y., Lee, J. Y., & Li, H. S. (2009). *3D Cadastre Data Model in Korea ; Based on Case Studies in Seoul. 17.*

Paulsson, J. (2007). *3D Property Rights - An Analysis Key Factors Based on International Experience.* Phd, Royal Institute of Technology (KTH), SE-100 44 Stockholm, Sweden.

Paulsson, J. (2008). *3D Property- Types of Rights and Management Factors*. Paper presented at the FIG Working Week, Stokholm, Sweden.

Paulsson, J., & Paasch, J. M. (2011). *3D Property Research – A Survey of the Occurrence of Legal Topics inPublications*. Paper presented at the 2nd International Workshop on 3D Cadastres, Delft, the Netherlands. http://3dcadastres2011.nl/documents/001.pdf

Rahman , A. A., Hua , T. C., & van Oosterom , P. (2011). *Embedding 3D into Multipurpose Cadastre*. Paper presented at the FIG Working week 2011, Marrakech, Morocco.

Salzmann, M., Hoekstra, A., & Schut, T. (1997). *Quality Issues in Cadastral Map Renovation*. Paper presented at the JEC-GI'97 Vienna. http://www.oicrf.org/

Son, H. G., Han, C. D., Kim, G. H., & Son, D. J. (2004). *Analysis of Position Accuracy of Ground/Underground Facilities. KSGPC(Korean Society of Surveying, Geodesy, Photogrammetry,and Cartofraphy).*

Song, W. H. (2008). *Cadastral Map Renovation: An Analysis of the South Korean Perspective.* MSC, International Institute for Geo-information Science and Earth Observation.

Stoter, J. E. (2004). *3D Cadastre.* Phd, Technische Universiteit Delft, Delft, the Netherlands.

Stoter, J. E., Salzmann, M. A., van Oosterom, P. J. M., & van der Molen, P. (2002). *Towards a 3D Cadastre*. Paper presented at the FIG XXII/ACSM-ASPRS, 19-26 April, 2002, Washington, USA.

Stoter, J. E., & van Oosterom, P. J. M. (2005). *Technological Aspects of a Full 3D Cadastral Registration. International Journal of Geographical Information Science, 19*(6), 669 - 696.

Stoter, J. E., & van Oosterom, P. J. M. (2006). *3D Cadastre in an international context : Legal, Organizational and Technological Aspects*. Boca Raton: Taylor & Francis CRC.

Stoter, J. E., & Zevenbergen, J. (2001). *Changes in the Definition of Property: A Consideration for A 3D Cadastral Registration System*. Paper presented at the FIG Session 27 - 3D Spatial Information Seoul, Korea

Ting, L., & Williamson, I. P. (1999). *Cadastral Trends : A Synthesis* (Vol. 44). Sydney, Australie: Institution of Surveyors.

van der Molen, P. (2003). *Institutional Aspects of 3D Cadastres. Computers, Environment and Urban Systems, 27*(4), 383-394. doi: 10.1016/s0198-9715(02)00038-8

van der Molen, P. (2006). *Cadastral Template in Netherlands* Last visited 04-01-2012, from http://www.cadastraltemplate.org/countrydata/nl.htm

van Oosterom , P. J. M., & Lemmen , C. H. J. (2001). *Spatial Data Management on a Very Large Cadastral Database. Computers, Environment and Urban Systems, 25*(4-5), 509-528. doi: 10.1016/s0198-9715(00)00052-1

van Oosterom, P. J. M., & Zlatanova, S. (2008). *Creating spatial information infrastructures : towards the spatial semantic web*. Boca Raton: CRC.

Wiliamson, I. P. (2000). *Best practices for Land Administration Systems in Developing Countries*. Paper presented at the International Conference on Land Policy Refor, Jakarta, Indonesia.

Wiliamson, I. P., & Ting, L. (2001). *Land Administration and Cadastral Trends — A Framework for Re-engineering. Computers, Environment and Urban Systems, 25*(4–5), 339-366. doi: 10.1016/s0198-9715(00)00053-3

Wouters, R. (2007). *What Next After the LIS is Completed in the Netherlands*. Paper presented at the International Workshop, Ulaanbaatar, Mongolia.

ANNEX A: INTERVIEWS

The Dutch Topographic Map (interviewed in Apeldoorn)
The type of scale of topographic map

- Large scale: 1:1000~ 1:2000 (GBKN)
- Medium scale: 1:10000 (Top 10NL)
- Small scale: 1:25000~1:1000000

Progress
Cadastre received governmental order in 1975. But the financial problems in 1980s, after few years reached agreement in financial part in 1992 (national foundation: Joint Venture). Topographic map Finished in 2000 with Public Private Partnership purpose (PPP) for the whole country and it updated annually.
The contents of Joint Venture is to save money, agreement on content of map, calculating fee of participation/percentage of cost depends on the each organizations benefit. Legal part also formed.
Member of participating Organizations (Percentages of Foundation)

- Municipalities (20% of budget)
- Cadastre (20% of budget)
- Utility organizations (Water, Energy, Telecom etc) (60% of budget)

Implement
But the content of map is not the same depends on organizations needs. The scale of map from 1:500 to 1:2000, reference for exchange information, expended 25 years, €200 Million as part of NSDI. It is used by cadastre, municipalities and utility companies, telecom providers, water boards, provinces etc.

It is applied to planning, managing in rural estate and assets. Membership can access the digital data on internet, in case of personal can access with difference price.

The map contains buildings, roads, railways, rivers and canals are made in lines, points, symbols, text. The accuracy of map is in urban area 0.2m in rural area 0.4m for construction points.

ANNEX B: INTERVIEWS

The Dutch Kadaster KLIC (interviewed in Apeldoorn)

KLIC General Introduction

- Application of KLIC in Netherlands (usage data): could you please give a general introduction?

Data acquisition

- Which basic map is used in KLIC?
- How to get the utility spatial data? Is primary data from utility companies? Or is it based on measuring by surveyor from Kadaster? Same question for attribute data?
- How to register new cable, pipe line: procedures, legislation, requirements for registration, same for updating? Distributing: is there a website?

Data Quality

- Who is responsible for the quality of data? Utility company or KLIC
  -If data is not correct who is liable for that (if there is damage because of incorrect data, which has to pay the damage)?
- In case of utility has been (by accident or because of incorrect information) digging on private land, how to solve this? Who is responsible?
- Number of damages (accidents) in field: before KLIC was developed, after KLIC was developed

Cooperation

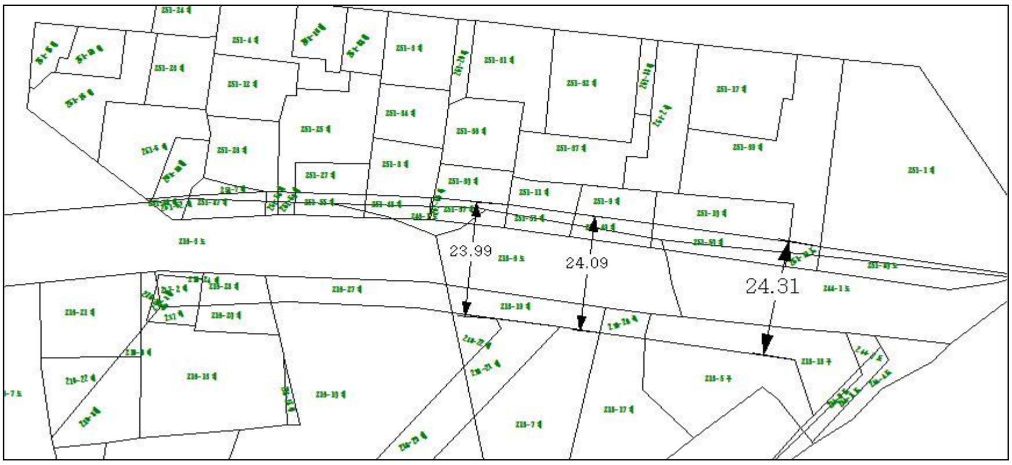
- All information on land is shown in KLIC? (Cadastral attributes as ownership, location), large scale map, utility map)
  If not, why are those data not integrated?
- What is role of Kadaster/ in the organization of KLIC?
- The KLIC is open source data to the public (people)? If not: are there plans to do so?

Business

- How utility data where managed before KLIC was developed?
  - By utility companies or by municipalities?
- How many utility companies are involved in KLIC? Is it compulsory to join?
- How many departments are in KLIC and what is the role of departments? Budget? Is the budget is enough? If not: why not?
- How many users are there? How many employees are working in KLIC department? Which competences, which education?

ANNEX C: COMPARISION OF UTILITY AND CADASTRAL MAP

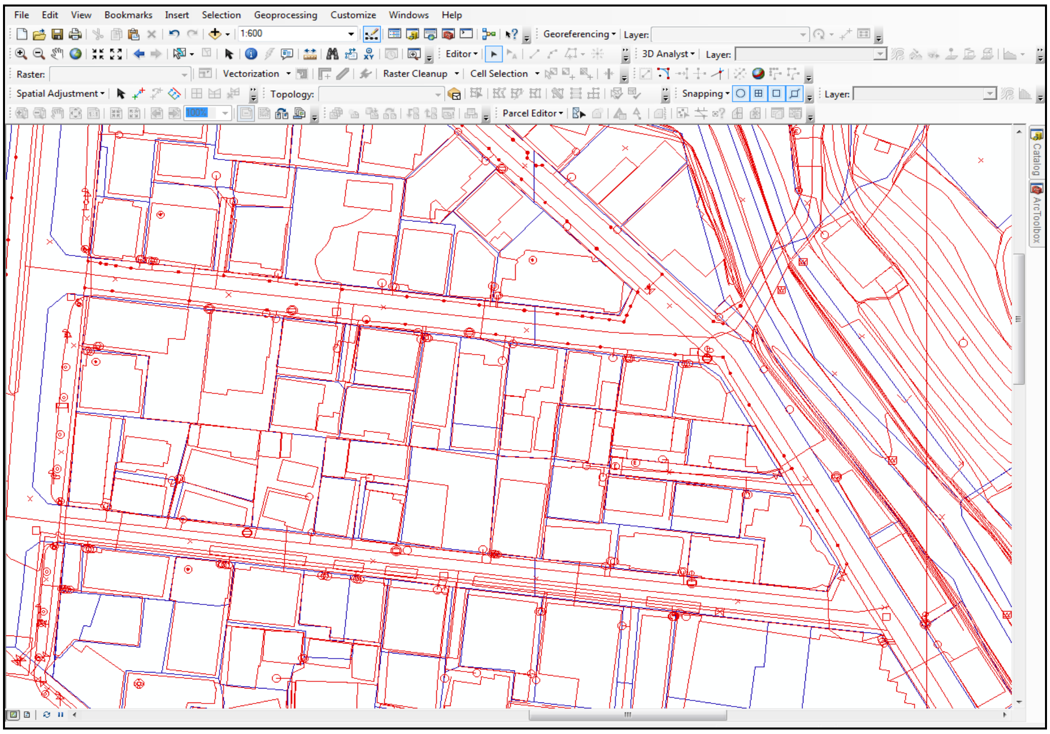
1. Utility map: Road wide about 12.0m



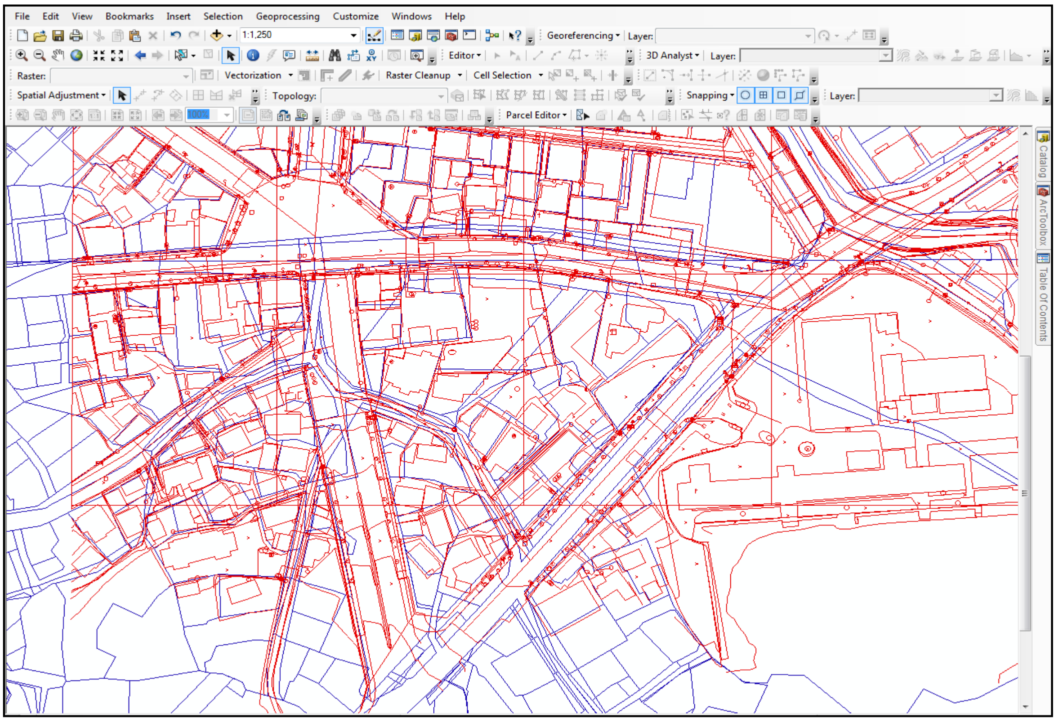
2. Cadastral map: Road wide 24.0m

3. Satellites image from Korean map service (Source by Daum map)

ANNEX D: THE RESULT OF SPATIAL ADJUSTMENT



Section 1 (blue: cadastral map, red: utility map based on topographic map)



Section 2 (blue: cadastral map, red: utility map based on topographic map)