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Invited Papers

Research on Managing Underground Facilities for an Intelligent City

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ABSTRACT

The objective of this project is to construct the intelligent underground facility management system based on UFSN (Underground Facility Sensor Network). Total project duration is 6-year. And first two years' project has been finished. First two years' project focused on water supply and sewage facilities among 7 underground facilities and investigated the fundamental construction technology for the underground facilities management system.

To contribute the development of systematic and scientific management of underground facilities, KRIHS implemented 3 researches for 'Underground facilities management system for an intelligent city' like followings: (1) to investigate an integration plan for current water supply and sewage management systems, (2) to derivate of water supply and sewage monitoring items for the monitoring technology development, and (3) to implement a basic research for sensor installation plans on different types of current and new underground facility systems.

This research paper contains the first two years' outcome of researches from KRIHS (Korea Research Institute for Human Settlements).

Keywords : Intelligent Underground Facility Management, UFSN(Underground Facility Sensor Networks, Water Supply and Sewage Management

요 약

본 연구의 최종목표는 7대 시설물의 주요 정보를 획득하기 위해 지하 환경에 적합한 센서 네트워크(USN: Ubiquitous Sensor Network)를 개발하여 지하시설물의 모니터링 및 긴급처리와 통합관리시스템 개발을 통하여 지능형 도시지하시설물 관리체계를 구축하는 것이며 이를 위하여 국토연구원을 포함한 5개의 기관이 공동으로 연구 과제를 수행하였다.

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총 6차년 도에 걸쳐 UFSN(Underground Facility Sensor Network) 기반의 지능형 관리체계를 구축하는 것을 목표로 우선 1~2차년 도에는 상하수도에 초점을 두고 지하시설물 관리체계 구축기반기술 연구에 중점을 두었다.

국토연구원에서는 지하시설물 통합관리 기술개발을 위해 기존 상하수도 단위 업무시스템 연계방안을 연구하였고 모니터링 기술개발을 위해서 상하수도 모니터링 항목을 도출하였으며 신규/기설 지하시설물별 센서 설치방안에 대한 기초 연구를 수행하였다. 본 연구는 국토연구원에서 수행한 1~2차년 도의 연구 성과를 토대로 작성되었다.

주요어 : 지능형 지하시설물 관리, UFSN, 상하수도 관리

1. Introduction

T 「Korean Land Spatialization Research Project」 is an innovative research project to develop the future growth engine which enables the core infrastructure. One of the key technologies in this project is the 'underground facilities management system for an intelligent city'.

The 'underground facilities management system for an intelligent city' can be classified into five different categories like followings: (1) sensors for the underground facility management and data transmission technologies, (2) USN (Ubiquitous Sensor Network) application technologies suitable for underground environments, (3) construction technologies of integrated management systems for underground facilities with urban geospatial information, (4) construction technologies of the urban geospatial information standard for an intelligent urban management, and (5) construction technologies of 3D underground facility simulation.

The objective of this project is to construct the intelligent underground facility management system based on UFSN (Underground Facility Sensor Network). The strategies to reach this goal are (1) to develop the effective USN (Ubiquitous Sensor Network) for achieving the important information from 7 underground facilities, (2) to develop the integrated management system to monitor underground facilities and to manage potential risks and (3) to construct the intelligent underground facility management system from the integrated management system.

Total project duration is 6-year. And first two years' project has been finished. First two years' project focused on water supply and sewage facilities among 7 underground facilities and investigated the fundamental construction technology for the underground facilities management system. This research paper contains the first two years' outcome of researches from KRIHS (Korea Research Institute for Human Settlements).

KRIHS implemented 3 researches for 'Underground facilities management system for an intelligent city' like followings: (1) to investigate an integration plan for current water supply and sewage management systems, (2) to derivate of water supply and sewage monitoring items for the monitoring technology development, and (3) to implement a basic research for sensor installation plans on different types of current and new underground facility systems.

2. Research Background

2.1 Research Flow

KRIHS implemented 3 different types of researches. 'Integration plan for current water supply and sewage management systems' includes literature reviews about current informatization situations of water supply and sewage facilities, case studies about introduction and operation of current informatization systems, analysis of target systems and plans for integrating. Research on "Derivation of water supply and sewage monitoring items' implemented with following steps: (1) to analyze business process of water supply and sewage management systems in old/new city sections and, (2) to derive monitoring items for informatization plans of water supply and sewage facilities from the results of business process analysis, and (3) to propose a strategic plan for intelligent facility managements from the results of analysis on priority of monitoring items. Research on 'sensor installation plan for different types of current and new underground facility systems' includes applications of UFSN based on derived monitoring items and suggestion of sensor installations.

Figure 1 shows a research procedure of KRIHS.

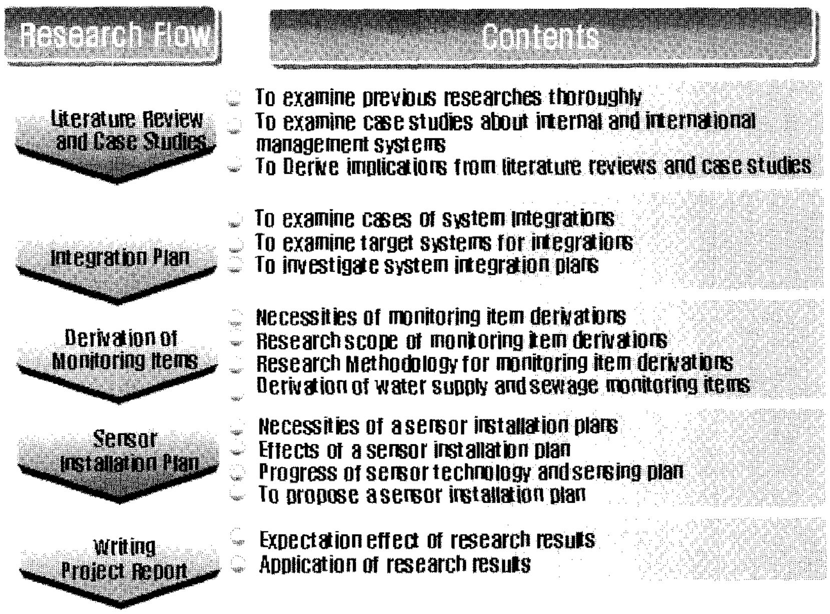

Figure 1. Research Flow Chart

3. Integration Plan for current water supply and sewage management systems

3.1 Background

There were many different accidents relating to underground facilities. One of the most dangerous accidents is gas explosion. One reason of gas related accidents is caused by other works relating to underground facilities. Daegu gas explosion in 1995 can be one example of accidents cause by other underground facility related works. The number of casualty was more than 200 and property damage was more than 60 billions. The objective of integration plan is for prevention of this kind of accidents. Water supply, sewage, gas, electronic power and many other pipes located at underground. Therefore, excavation works without underground facility management system can be the potential threaten to citizen.

To prevent underground facility hazards, Ministry of Land, Transport and Maritime Affairs (MLTM) proposed the standardization of spatial data for facilities which can be used for excavation works. But, spatial data scope is limited and appropriate data renewal is not easy. Expectations of previous and current underground facility management systems were the prevention from the overlapped investment and the synergy effect of informatization through sharing and practical use of relevant information. But, real situation is different from expectations. Sharing and practical use of relevant information have a difficulty because of various underground facility management agencies.

A systematic and scientific management of underground facilities, which is directly related to urban safety, is in great demand. And, it is important to consider an integration plan for different management systems from various management agencies.

3.2 Examination of Target Management Systems for the System Integration

The first step for the system integration is to examine target management systems. To integrate current management systems, it is necessary to examine objectives, characteristics, functions, and data in each current management system. After examining each system, a potential system integration model can be achieved. After the derivation of this system integration model, an potential integration plan can be achieved with analysis on detail connection works, target data for connecting, and functions of each system.

3.2.1 General-Purpose Program for Water Supply and Sewage Management

This research focused on three different management systems. First one is 'General-Purpose Program for Water Supply and Sewage Management'. This program is for supporting local governments. It is the result of underground facility computerization. The common works for the management of water supply and sewage of each local government are derived

Table 1. Functions of 'General-Purpose Program for Water Supply and Sewage Management'

	Functions	Explanation
Basic Function	· Screen Operation · Search Function · Print Function · Data Conversion	Basic Functions for Map Operations
Editing	· Editing Function · Editing Option · Editing Preference	Function for input, editing, and deleting map and facility data
Function for Water Supply and Sewage	· Construction · Pipe Information · Pipe attachments · Management statistics	Map and register information of Water Supply and Sewage

Table 2. Data of 'General-Purpose Program for Water Supply and Sewage Management'

		Data	Explanation
Basic Data		index map, datum, altitude point, contour, administrative boundary, building, river and so on	Topographic Digital Data
Facility Data	Water Supply	water pipeline, stand pipe, transformation, hydrometer, flowmeter, construction, reservoir, filtration plant, manhole and so on	Facility Data of Water Supply
	Sewage	water pipeline, ventilating opening, sewage disposal, manhole, drainspout and so on	Facility Data of Sewage
Other Data		RFID facility, remote control facility, measuring instrument and so on	Additional Management Data of Local Governments

and computerized. Through this process, 'General -Purpose Program for Water Supply and Sewage Management' was constructed to save money and keep safety.

Around 60 of 84 local governments use this system. Important functions of this program is like a following table.

Important data for this program includes basic topographic digital maps, water supply and sewage facility data, and other data. Following table shows detail information about these.

3.2.2 Underground Facility Integration Management System

'Underground Facility Integration Management System' is the system for local governments to share information about electronic power, gas, turpentine, heating and so on with other relative agencies after the introduction of 'General-Purpose Program for Water Supply and Sewage Management'. This system is not only for local governments but also other relative agencies to manage underground facilities. Therefore, this system has more data about underground facilities.

Table 3. Functions of 'Underground Facility Integration Management System'

	Functions	Explanation
Basic Function	· Map Management · Layer Management · Legend Editing · Print · Spatial Query · Location Finding	Basic Functions for Map Operations
Facility Information Management	· Searching Facility Information	Searching Facility and Querying Attribute
Analysis on Cross Section of Terrains	· 2D Analysis · Continuous Cross Section Analysis · 3D Analysis	2D, 3D Analysis
Other Function	· Drawing · Area of Interest Management · Statistics · Web board	Functions for the convenient of users and system manager

Table 4. Data of 'Underground Facility Integration Management System'

		Data	Agency
Water Supply		manhole, pipeline, ternal, valve, hydrant, water-tower,	Local Government
Sewage		manhole, pipeline, open sewer, underdrain	Local Government
Electronic Power	Supply	manhole, electric pole, underground pipeline, electric culvert, circuit breaker, transformer, ventilating opening	Relative Agency
	Transmission	manhole, underground pipeline, electric culvert, ventilating opening	Relative Agency
Communication		manhole, communication pole, underground pipeline, communication culvert,	Relative Agency
Gas		manhole, pipeline, static port, valve, electronic potential observation	Relative Agency
Heating		manhole, pipeline, water leakage detector, hand hole, air vent	Relative Agency
Oil Pipeline		oil reservoir, pipeline, protect equipment, pressurization, valve station, valve box, oil leakage detector	Relative Agency

Around 30 of 84 local governments operate this system. Important functions of this system is like following table.

Data for this system is much more than 'General-Purpose Program for Water Supply and Sewage Management'. Table 4 shows important data for this system. As can be seen, electronic power, communication, gas, heating, oil pipe line data are added to water supply and sewage data through the cooperation with other relative agencies.

3.2.3 Intelligent Water Supply and Sewage Management System

'Intelligent Water Supply and Sewage Management System' is the system for effective underground facility management and prevention from disasters with real-time monitoring based on UFSN. In here, UFSN technology is the low voltage communication sensor network technology for the management of underground facilities. Core technology for UFSN is (1) solution for self providing electronics, (2) durability more than 2 years, (3) strong communication technology for underground environment, and (4) strength standing underground environment. KETI has been developing this technology since 2007.

This system is the final system to construct from this project. Previous two systems are for effective operations with the result of computerizations. But, 'Intelligent Water Supply and Sewage Management System' is the high technology management system to achieve facility information, to monitor, and to manage emergency situations in real-time. Therefore, after the construction of this system, it is possible to prevent from waste of money and time for overlapped investment, to minimize damages caused by inadequate information, and finally to contribute for the construction of the ubiquitous national territory. Table 5 shows potential functions for this system. The major difference from previous two systems is 'facility monitoring function' in

Table 5. Potential Functions of 'Intelligent Water Supply and Sewage Management System'

	Functions	Explanation
Basic Function	· log in · web board	Basic Functions for System Operations
System Management	· User Management · Sensor Management · Basic Map Management · Facility Map Management · Sensor History Management	Detail Functions for System Application and Management
GIS Function	· Basic Function · Additional Function · Theme Map · Statistics Function	Basic Functions for Map Operation
Facility Information Searching	· Basic Information · Photography Information · Section of Interest Search	Facility Information Searching
Water Supply Facility Management	· Water Supply Pipeline and Facility Monitoring	Facility Monitoring Function
Sewage Facility Management	· Sewage Pipeline and Facility Monitoring	
Other Function	· Alarm Function	Alarm function for emergency situations

Table 6. Potential Data of 'Intelligent Water Supply and Sewage Management System'

		Data	Remark
Basic Data		index map, datum, altitude point, contour, administrative boundary, building, river and so on	Basic Data for Facility Management
Facility Data		Basic Facility Data such as pipeline	Facility Data
Sensing Data	Water Supply	· Pipeline : leakage, crack, corrosion · Flowmeter : flux, breakage, leakage, corrosion · Meter : amount used, condition, temperature · quality of water, etc.	Real-time Facility Sensing Data through UFSN
	Sewage	· Pipeline : leakage, crack, corrosion, amount used, fetor, accumulation · Manhole : crack, abrasion, loss · Waterspout : crack, accumulation, loss · quality of water, etc.	
Other Data		Other Data for System management	

real time. It is possible to alarm for emergency situations immediately because of this monitoring function.

Potential data for this system can be categorized by three different types. First one is water supply and sewage facility data, second one is real-time monitoring data, and third one is other data. Important data for this system is 'sensing data'. Sensing data include conditions of facilities and water quality. These real-time data can make a possible to check conditions of facilities and manage situations of every possible emergency. Detail information is like following table 6.

3.3 System Integration Plan

After examinations of current systems, we suggest two potential system integration models based on each different objective. First objective of system integration is to manage underground facilities of local governments with real-time updating data through UFSN. Second objective of system integration is to use current various facility information as fundamental information of underground facility management system through UFSN.

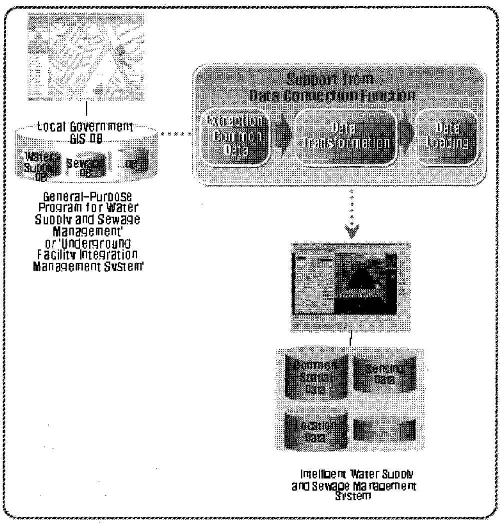

Figure 2. System Integration Plan based on ETT Application

3.3.2 Application of Real-Time Updating Data

System integration model for the first objective is to connect 'Intelligent Water Supply and Sewage Management System' to current management system such as 'General-Purpose Program for Water Supply and Sewage Management' or 'Underground Facility Integration Management System'. Therefore, service is provided from 'Intelligent Water Supply and Sewage Management System' and target systems for integration are current management systems.

The integration procedure for this objective is DB Replication[1] connection with application of ETT (Extraction, Transformation, Transportation). ETT is to extract necessary data from various systems, to transform suitable data format for corresponding system after extraction, and to transport to corresponding system. Based on ETT, current system information can transport necessary data to intelligent management system automatically on schedule. Following figure shows this procedure.

3.3.2 System Integration to use Current Facility Information

Contrary to the previous model, current facility management systems provide services and target system is 'Intelligent Water Supply and Sewage Management System' in this model.

There are two different types in this model. Firs one is 'connection with DB Access', and second one is 'acquiring UFSN Data in real-time'.

DB Access based connection is to connect directly with 'Intelligent Water Supply and Sewage Management System' and current systems can search real-time monitoring facility information of connected 'Intelligent Water Supply and Sewage Management System'. This one is relatively easy but DB between systems are same type. Following figure 3 shows the procedure of this model.

'Acquiring UFSN data in real time' is to get facility information based on UFSN without connection with 'Intelligent Water Supply and Sewage Management System'. This one has a strength to acquire data directly from facility information in real-time. But, it is overlapped with 'Intelligent Water Supply and Sewage Management System' and time and money to

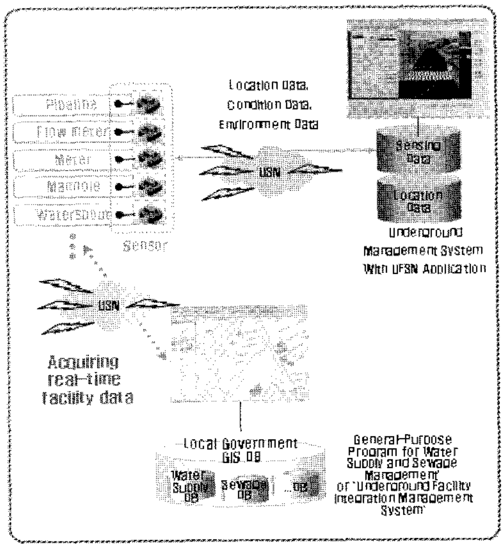

Figure 3. Connection with DB Access

1) DB Replication is to integrate target system information with corresponding system information through replication of target system information to corresponding system information with static cycle.

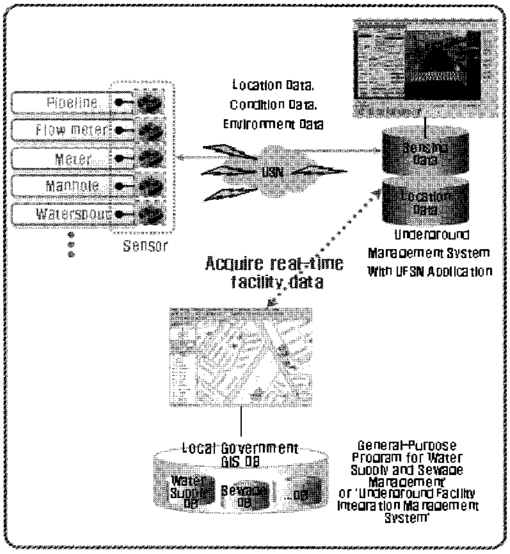

Figure 4. Acquiring UFSN data in real time

construct new function to use UFSN are necessary. Following figure shows this procedure.

4. Derivation of water supply and sewage monitoring items for the monitoring technology development

4.1 Background

As mentioned in previous chapter, monitoring items are fundamental and important information for the construction of intelligent underground facility management system. There is a high demand of intelligent underground facility management from various agencies. Local governments try to construct intelligent facility management with sensor application technologies. Therefore, it is necessary to derive standardized monitoring items for meeting demands.

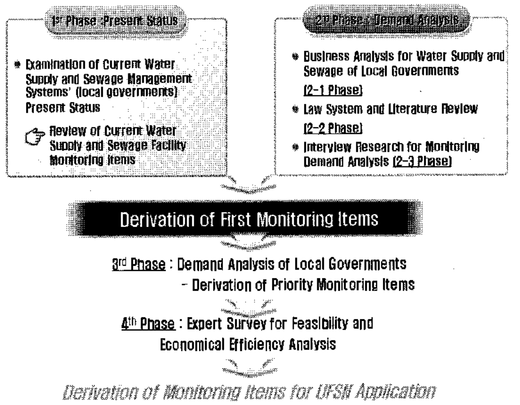

Figure 5. Research Flow Chart for Derivation of Monitoring Items

The methodology to derive monitoring items includes literature reviews, interviews and survey. Figure 5 shows the flow chart for this research.

As can be seen in the figure, KRIHS conducted following procedures.

First, KRIHS examined the present status of underground management systems used by local governments. This examination is focused on current water supply and sewage facility monitoring items of underground management systems. After examination, potential monitoring items are derived.

Second, KRIHS conducted a demand analysis with business analyses, literature reviews including related law, and interviews. This procedure also selects potential monitoring items.

Third, demand analysis of local governments is conducted with selected potential monitoring items from first and second procedures. After this procedure, priority monitoring items are derived.

Forth, finally selected monitoring items should be economically and technically feasible because of limited money and time. Economic and technical feasibility of selected priority monitoring items are analysed with the help of experts. After the expert survey, final potential monitering items are selected.

4.2 Present Status and Demand Analysis

To derive potential monitoring items, various related laws and related work instructions of governments are reviewed. For examination of current water supply and sewage management systems' present status, 5 local governments (GwangJu, Iksan, Guri, Gwacheon, Gimhae) are selected based on characteristics of local governments such as population size and informatization level such as GIS introduction. After reviewing water supply and sewage management items of 5 local governments and related law review, derived potential monitoring items are classified by two different types. Firs one is about related facilities and second one is about water itself.

For water supply monitoring items, 6 targets from facility and 3 targets from water supply are selected. Total number of water supply monitoring items is 18. Detail information of these two types of monitoring items are like table 7.

Table 7. Potential Water Supply Monitoring Items

<table>
<tr><th colspan="2">Monitering Target</th><th>Monitering Items</th><th>Work with Intelligent Censor</th></tr>
<tr><td rowspan="16">Facility</td><td rowspan="4">Pipeline</td><td>leakage/crack</td><td>leakage estimation from flux/velocity sensing</td></tr>
<tr><td>corrosion</td><td>constant estimation of corrosion</td></tr>
<tr><td>pressure</td><td>constant estimation of pressure</td></tr>
<tr><td>connecting part</td><td>estimation of condition of connecting part</td></tr>
<tr><td rowspan="2">Flowmeter</td><td>flux</td><td>real-time flux estimation</td></tr>
<tr><td>leakage/crack/corrosion</td><td>using self examination system</td></tr>
<tr><td rowspan="3">Meter</td><td>amount used</td><td rowspan="3">constant monitoring and management of flux with sensor</td></tr>
<tr><td>condition</td></tr>
<tr><td>temperature</td></tr>
<tr><td rowspan="2">Pressure Pump</td><td>pressure</td><td rowspan="2">monitoring pressure and flux in real-time</td></tr>
<tr><td>flux</td></tr>
<tr><td rowspan="2">Reservoir</td><td>pressure</td><td rowspan="2">management of reservoir with supersonic based fluxmeter</td></tr>
<tr><td>flux</td></tr>
<tr><td rowspan="2">Filtration Plant</td><td>pressure</td><td>pressure estimation with censor</td></tr>
<tr><td>flux</td><td>flux estimation in real-time</td></tr>
<tr style="display:none"></tr>
<tr><td rowspan="3">water supply</td><td>Water Supply</td><td>quality</td><td rowspan="3">constant estimation of water quality with sensor installation at specific locations</td></tr>
<tr><td>Watering</td><td>quality</td></tr>
<tr><td>Water Tank</td><td>quality</td></tr>
</table>

Table 8 shows the list of potential sewage monitoring items. 5 targets from facility and 2 targets from sewage are selected. 21 monitoring items are selected from first and second phase of 'Derivation of monitoring items' research.

These monitoring items are used for third phase of 'Derivation of monitoring items' research. Following chapter explains the demand priority of these selected monitoring items.

4.3 Demand Analysis of Local Governments

This chapter is the result of conducted survey based on derived potential monitoring items. The objective of this part is which monitoring item is more important than others based on the demand of local governments

For this demand analysis, 25 local governments are selected with the standard of informatization

Table 8. Potential Sewage Monitoring Items

Monitering Target		Monitering Items	Work with Intelligent Censor
Facility	Pipeline	leakage/crack	leakage estimation for
		corrosion	constant estimation of corrosion
		flux	constant estimation of flux
		accumulation	constant estimation of accumulation using height measurement sensor
		pressure	constant estimation of pressure
		fetor	constant estimation of fetor
		gas	constant estimation of gas, immediately coping with emergency
		influx	constant estimation of influx based on flux and pressure
	Manhole	leakage	support repairing in the case of leakage/corrosion
		corrosion	
		depression	estimation of location information and support repairing
		loss	
	Waterspout	leakage/ crack	support repairing
		accumulation	constant estimation of accumulation using height measurement sensor
		depression	estimation of location information and support repairing
		loss	
	Back Siphonage	water level difference	constant estimation of water level difference using height measurement
		floating matters	constant estimation of amount of floating matters
	Flowmeter	amount used	constant estimation of amount used and various items for management
Sewage	Discharge	quality	estimation of water quality with sensor installation at specific locations
	etc.	quality	

level, population size, urban characteristics, and so on. Selected local governments are like a following table.

Based on survey results, priority monitoring items are derived. Figure 6 and 7 shows the selected priority monitoring items. Figure 6 shows the priority level of each water supply monitoring items.

The highest demand of water supply monitoring item from local governments is a pressure of water pipelines. Flux of flowmeter, flux of pressure pumps, quality of service water, flux of filtration plants are followed by pressure of water pipeline. In the case of water pipeline pressure, 44 percent of responses is 'very necessary' and 37 percent is 'necessary'. Only 4 percent is 'not necessary'. 6 monitoring items of water supply are selected from this survey.

In the case of sewage monitoring items, the highest monitoring demand is 'accumulation of pipelines'. In here, 'accumulation' means accumulation of silt or sand in pipelines. Therefore, 'accumulation of pipelines' is directly connected with the emergency caused by a flood. 36 percent of responses is 'very necessary' and 31 percent consider 'necessary'.

Sewage management related monitering items such as leakage or influx is relatively high. But,

Table 9. 25 Selected Local Governments

Province	City
Metropolitan City	Gwangju, Daegu, Incheon, Ulsan
GyeongGi-Do	Gwacheon, Suwon, Gunpo, Gwang Myeong, Siheung, Bucheon
Chungcheong-Do	Gyeryong
Gangwon-Do	Taebaek, Samcheok, Sokcho, Gangneung, Chuncheon, Wonju
Gyeongsang-Do	Sacheon, Andong, Geoje, Jinju, Gimhae
Jeolla-Do	Namwon, Naju, Gimje, Jeongeup, Iksan

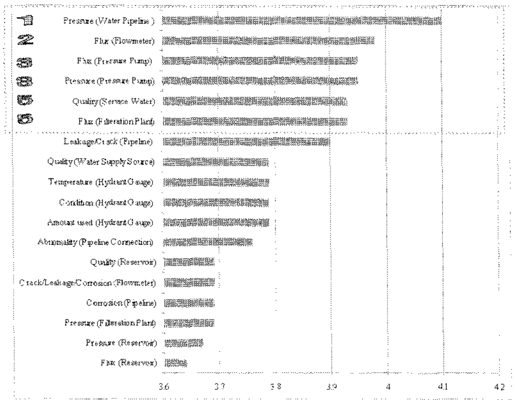

Figure 6 Result of Demand Analysis (Water Supply)

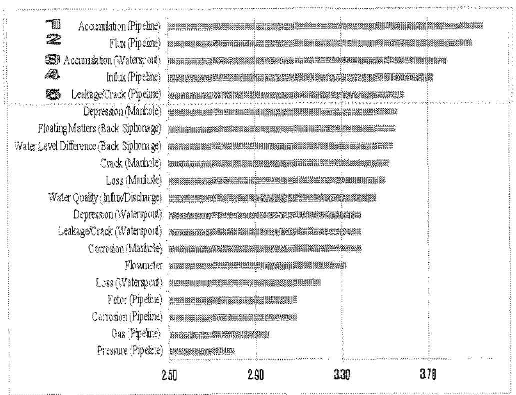

Figure 7 Result of Demand Analysis (Sewage)

environment related items such as 'fetor of pipeline' or 'gas of pipeline' is relatively low. 5 sewage monitoring items are selected from this survey. Figure 7 shows the result of sewage items demand analysis.

4.4 Expert Survey for Feasibility and Economic Efficiency Analysis

After achieving potential monitoring items from third phase, this research investigated technical and economic feasibility of selected monitoring items. Methodologies for this analysis are 'matrix analysis' and 'decision tree'.

'Matrix analysis' is to locate two different variables on x and y axis and to give x and y coordinate to each subject. Therefore, each subject has two different variables. In this research, economic feasibility and technical feasibility are used as variables and subjects are selected monitoring items from previous analysis.

'Decision Tree' is an diagram which has a tree structure. 'Decision Tree' is usually for classification and prediction. The strength of this diagram is easy to understand and interpret. So, it is simple to understand which subject is more important than others. There are many different algorithms for 'Decision Tree' such as CHAID, CARD, C4.5. In this research, CHAID algorithm of SPSS Answer Tree program is used.

Figure 8 shows the result of technical feasi-

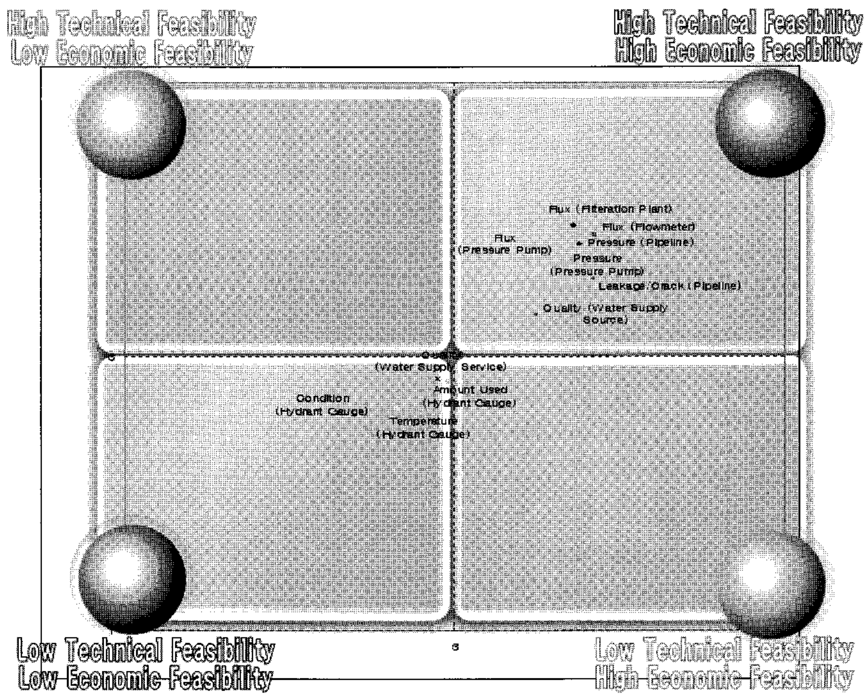

Figure 8. Result of Technical Feasibility and Economic Feasibility (Water Supply)

bility and economic feasibility of water supply monitoring items. As can be seen in this figure, economic feasibility is on the x axis and technical feasibility is on the y axis. The subject for analysis is each monitoring items from the result of demand analysis.

Total number of interviewees for this survey is 68. The result is like a following figure.

As can be seen in the result, 'flux of filtration plant', 'flux of flowmeter', 'flux of pressure pump', 'pressure of pipeline', 'pressure of pressure pump', 'leakage/crack of pipeline', 'quality of water supply source' have relatively high economic and technical feasibility while 'quality of service water', 'amount used of hydrant gauge', 'condition of hydrant gauge', 'temperature of hydrant gauge' have low economic and technical feasibility. Monitoring items with high economic and technical feasibility can be the priority of development for the intelligent underground management system.

Figure 9 shows the result of this analysis for sewage. In the case of sewage, 'flux of pipeline' and 'influx of pipeline' are the group of high economic and technical feasibility'. 'leakage /crack of pipeline', 'loss of manhole', 'accumulation of waterspout', 'accumulation of pipeline' have high economical feasibility but low technical feasibility. 'Depression of manhole', 'water level difference of back siphonage', 'floating matters of back siphonage', 'crack of manhole' have low economic and technical feasibility.

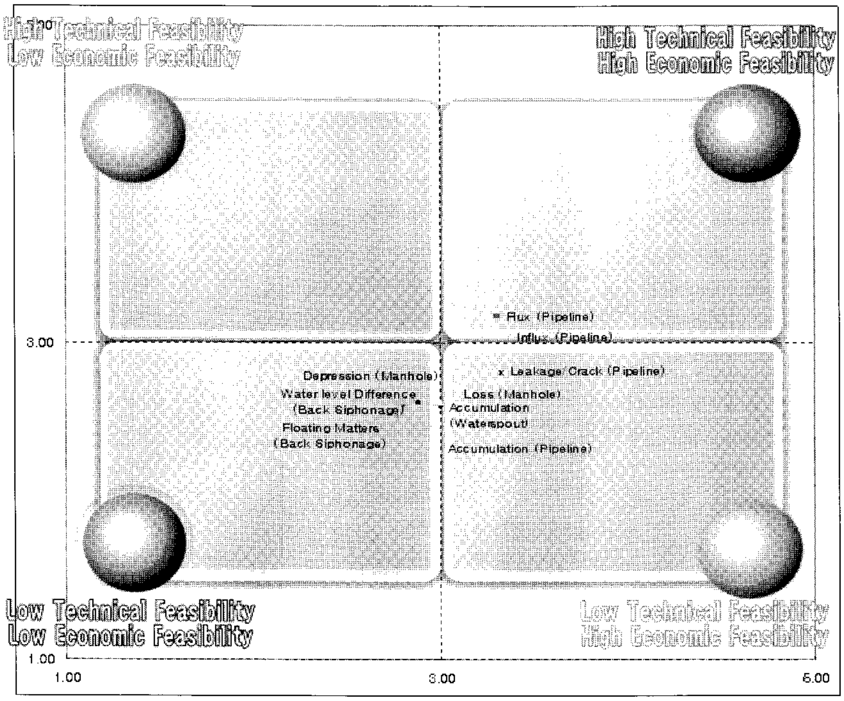

Figure 9. Result of Technical Feasibility and Economic Feasibility (Sewage)

The strategy for the intelligent sewage management system may have following procedures: (1) Monitoring items with high economic and high technical feasibility should be developed first, (2) monitoring items with high economic but low technical feasibility should be developed next, (3) finally developing monitoring items with low economic and technical feasibility.

It is necessary to develop monitoring items with higher economic and technical feasibility first for better effects with limited time and money.

5. Sensor Installation Plan for Different Types of Current and New Underground Facility Systems

5.1 Background

This research is for the plan of ubiquitous sensor installation for effective management of intelligent underground facilities. The procedure of sensor installation plan for water supply and sewage management system is like following figure.

As can be seen in figure 10, first procedure for this plan is to examine the present status of sensor technology. After examination of current sensor technology, characteristics of buried environment are investigated. Depending on the characteristics of buried environment, sensor types and sensor installation plans can be changed to achieve effective sensing results. After that, characteristics of each facility should be examined for effective sensor installations.

As mentioned in introduction chapter, this research is on-going project. And first two years' research is finished and four more years' research is left. 'Sensor installation plan' is still on-going part. Therefore, this chapter does not provide a detail sensor installation plan.

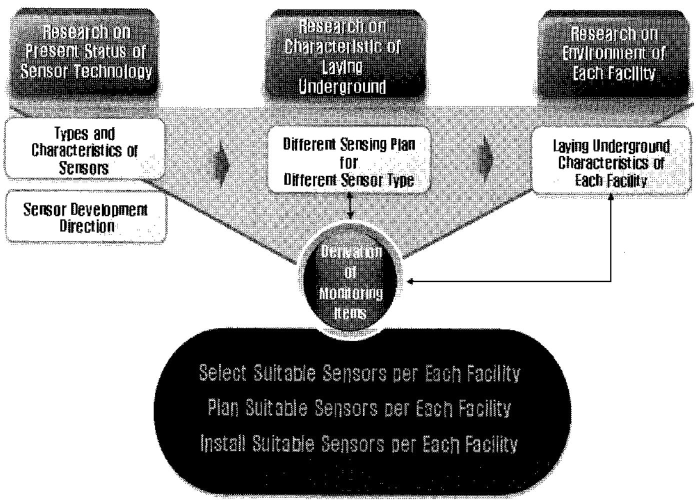

Figure 10. Procedures for the Sensor Installation Plan

5.2 Present Status of Sensor Technology

The objective of the research on present status of sensor technology is to select effective sensors which is suitable for selected monitoring items.

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. Because a sensor is a type of transducer, it changes one form of energy into another. For this reason, sensors can be classified according to the type of energy transfer that they detect. In general, types of Sensors are classified by mechanical sensors, magnetic sensors, photo sensors, radiation sensors, acoustic sensors, thermal sensors, chemical sensors, and bio sensors.

The sensor market has been constantly grown since 1995. Average growth rate is 10.3%. But, importation of sensors are increasing even demands of sensors are larger because of limited sensor technology. Current domestic sensor market is mainly based on thermal sensors, image sensors, gas sensors, optical sensors, and pressure sensors. This is slightly different from international market which centers on industrial sensors.

Current trends of sensors are miniaturization and integration. In other words. sensors are smaller but integrates more functions. This trend of sensor technology can make it possible to develop more effective intelligent underground facility management systems.

5.3 Sensor Installation Plan with Considering Buried Environment

Chapter 4 explains how to select potential monitoring items. Sensor installation plan is with these selected monitoring items. In the case of water supply monitoring items, measuring

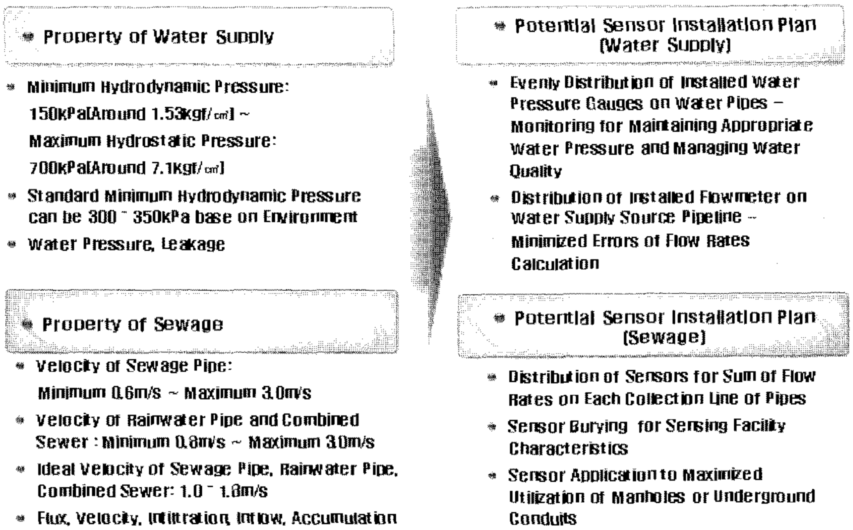

Figure 11. Example of Relationships between Properties and Installation Plans

pressure, flux, quality, temperature, amount used, and facility condition is important for a proper sensor installation plan. Different measuring item demands different sensor types. For example, mechanical sensors and acoustic sensors can be good for measuring pressure.

The brief result from first two years' research considering a sensor installation plan with considering buried environment is like following figure.

Figure 11 shows the relationships between characteristics of underground facilities and potential sensor installation plans. Considering buried environments and characteristics of water supply and sewage, effective sensor installation plans are decided. Figure 11 does not show every considering factors for the installation plan because this part is still going on project. This can be one example of the decision of one part of sensor installation plans. After investing more detail properties of water supply and sewage, more effective potential sensor installation plans can be developed.

6. Conclusion

The final objective of this project is to construct the comfortable and safe intelligent city with new IT integration. Systematic and scientific management of underground facilities, which is directly related to urban safety, is in great demand. This systematic and scientific management of underground facilities can be achieved through developing from current 'passive' urban management systems to 'active urban management system'. To contribute the development of systematic and scientific management of underground facilities, KRIHS conducted three different researches for first two years. These researches can show the fundamental and the important results for the intelligent city such as system integration plans, derivations of monitoring items, and sensor installation plans.

4 more years project is still going on. After 4 years, the result of this project can definitely contribute to 'the development of the ubiquitous national territory for comfortable and safe Korea' with high sensor network technologies and system integrations.

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