PREFACE

1. Why choose topics

Water supply is a technical industry of urban infrastructure, which investment costs, repairs and upgrades are very expensive. It plays an important role for the development of production and social activities. In recent years, the pace of urbanization make population increases in urban areas, along with economic growth and rapid industrialization led to the demand for fresh water is increasing. Since our current capabilities of our water supply is at very low levels, water usage demands are creating immense pressure for the water supply industry in Vietnam. Besides, according to the progress of society, needs are raised to a new level is to use fresh water with quality, good service, and safe source.

Due to rapid economic development, the natural environment is destroyed, many existing water supply in Vietnam is at risk of decline in both quantity and quality. Investment cost of producing a volume of clean water is higher and higher. A significant part of the *water supply systems* (WSSs) became old, the percentage of damaged and leaking high, the replacement or repair takes place very slowly. Consequently, a large amount of water produced losses, significant waste of valuable resources, consumers suffer higher water prices, and state shortages expanding WSSs investment to meet economic and society development needs. With the above reasons, the topic "*Research measures to improve efficiency of water supply system management based on geographic information system testing at the Hanoi Clean Water Company No. 2*" was chosen as PhD thesis at the Graduate Training Institute of Economics – Hanoi National Economics University. The objective of the thesis is to improve WSSs management efficiency.

2. Conceptual framework and research goals

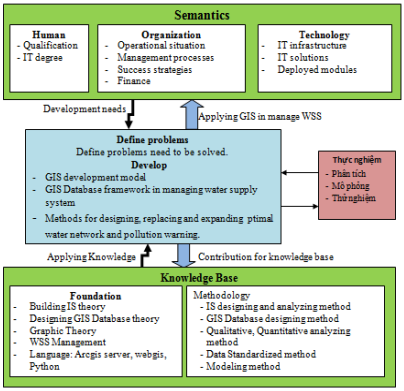


Figure 2 is a theoretical framework for the study of the thesis, based on the scientific design theory in the information system (MIS) launched in 2004 by Havner.

From overall research objectives of the thesis are: ***Build solutions to improve WSSs management efficiency with the help of geographic information systems (GIS***), and based on the above theoretical framework, the thesis should complete following specific objectives:

– *Study systematically a urgent need of innovation management in Vietnam* ***water supply companies*** *(WSC).*
– *Research GIS, GIS application process and steps for deploying GIS in Vietnam water supply sector.*
– *Propose urgent problems need to be solved; the problem may be solved based on GIS, GIS common development model, GIS database.*
– *Develop and test a number of functional modules of the system.*

3. Object, scope and method of research

3.1. Research subjects

Audience research is typical WSSs in Vietnam.

3.2. Research scope

– *In terms of space:* Includes the majority of WSCs Vietnam
– *In terms of time:* As the survey data, the secondary data collected from 2007 to 12/2015 from different sources.

– *In terms of content research:* Some problems of technical management of water supply networks; solution to the problem exists; a GIS development proposal to automate the improvement WSSs management efficiency in Vietnam.

3.3. Research Methods

To achieve its objectives, the thesis uses the method: *Approaching the system, analyzing qualitative, quantitative, standardize spatial data and attributes, modeling, analyze and design systems.*

4. Thesis structure

Besides the introduction, conclusion, appendices, the thesis is divided into 4 parts:

Chapter 1: Management of water supply system based on GIS.

Chapter 2: Current technical management status and GIS applications in this activity in the Vietnam WSCs.

Chapter 3: GIS Model Development and build database framework for WSS management in Vietnam.

Chapter 4: Apply GIS to the optimization problem of designing water supply network and water pollution warning in WSSs.

5. The discovery, new proposal from the research results of the thesis

5.1. New contributions of academics, theory

– *The thesis has analyzed completely and detail shortcomings in WSSs management in Vietnam. Since then we presents the theoretical basis and practical application of GIS to solve the urgent problems raised in order to improve efficiency of WSSs management thoroughly and firmly.*

– *The thesis proposes a general GIS development model, including: (1) overall development process model; (2) GIS elements architecture (hardware and software); (3) GIS database (DB) framework building*

process and specific components design of GIS database for WSSs in Vietnam.

- *The thesis has proposed four "urgent" problems need to be solved in order to improve WSSs management efficiency in Vietnam. These are: (1) The problem of property management and maintenance planning to water supply network; (2) The optimization problem of design, replacement, and expanding water supply network; (3) The problem of leak control of WSSs in real time; (4) The problem of detecting and warning of water pollution in WSSs.*
- *The thesis has solved completely (from the questioning, modeling and solution selection, building help toolkit to auto solve the problem on a computer) two important problems in WSSs management activities: that is optimization problem of replacing and expanding and design water supply system; and the problem of water pollution alert in WSSs.*

5.2. New contributions from the research results of the thesis

- *The test, research results, of the thesis is reference materials and basic guidelines for the development of GIS systems to manage WSSs in Vietnam all the way. The toolkit is built can be used immediately to solve practical problems.*
- *The thesis not only states and solves some basic problems for the management of WSS by GIS applications in the conditions of Vietnam, but also pointed out various problems and new technologies apply-oriented in order to continue to implement the research and applications of GIS more comprehensive and more efficient for water supply industry.*
- *GIS database framework building process for WSSs management can also be applied for building GIS database management framework of another system which need to use the spatial data.*

CHAPTER 1 - MANAGING WATER SUPPLY SYSTEM BASED ON GEOGRAPHICAL INFORMATION SYSTEMS (GIS)

This chapter analyzes management activities of Vietnam WSS, introduces the characteristics of GIS and water supply tasks, trends in the future. Since then, we propose the management problems for the water supply industry to complete above missions and objectives. Finally, we present the issues need to be considered when building and developing a GIS management WSS in Vietnam.

1.1. Management of water supply system

1.1.1. Brief history of the development of WSS in the world and in Vietnam

According to historical records, the earliest WSS appeared in Rome in 800 BC. In XIII century, European cities have WSS. In Vietnam, WSS is started by drilling in 1894. Currently, most urban areas have WSSs.

1.1.2. Water supply system

1.1.2.1. The concept of water supply system

The water supply system is a complex of constructions with functions such as water-collecting, water processing, transportation, governor and water distribution.

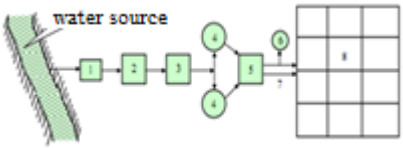


Figure 1.1. Model of water supply

In which: 1.W*ater-collector; 2. Level 1 water pump 1; 3.water processor; 4. water tank; 5. Lever 2 water pump 2; 6. Fountain.7. Water pipes; 8. Water Distribution Network.*

1.1.2.2. The concept of clean water

Clean water is safe water, which is carefully tested to reach all allowed limit prescribed norms.

1.1.2.3.Water Supply Safety

Safe water supply is guaranteed: Maintaining pressure, provide stable, sufficient amount of water, quality assurance, have the solution to deal with unexpected incidents may occur, contributing to the protection of health communities, reduce water-related diseases, contributing to reduced wastage, saving water resources and environmental protection.

1.1.2.4. The management of water supply system

WSS management including: *asset management and scheduling replace-maintenance; operational management; manage leaks and incidents; bill, water clock and customer management; replacement design management and network expansion; water quality management*.

1.1.3. Tasks and trend of Vietnam's water supply to 2025, Vision 2050

Some tasks and trends of Vietnam water supply to 2025:

- *Service coverage (%): 90% (grade IV cities) or higher.*
- *Capita consumption (liters / person-days): 120 liters.*
- *Leak rate: 18% lower.*
- *Water Quality: Applying advanced standards, processes, and rules.*

1.1.4. The parties involved in water supply

The process of manufacturing and trading of WSC closely related to many different organizations in society. These organizations have the different roles in water supply safety.

1.1.5. The management problem posed to WSSs

1.1.5.1. Data analysis of urban water supply industry

There are 17 indicators to assess WSSs activities. Some of important criteria: *service coverage ratio, the amount of water per capita per day, wastage, water quality*.

General comments on the production of WSSs

- Coverage of our services is still low (80%), water volume per capita reached 116lit / person-days (Hanoi). Compared with the world and the

region 2, this fact are low. Current needs of our country are great, the pressure for the WSSs development and management is increasing.

– The water needs pressuring not only the water industry but also to the sewerage sector.
– Enhancing the capacity of the plant operators in the future is very difficult because the contained water level is lowered continuously.
– The rate of water loss is very high (26.86%). From 2007 to present, this rate only can 1% reduce annually. Our goals from 2015 to 2020, the loss reduction of 18%, i.e. 1.4% per year. Compared to the actual improvement of recent years, this number is quite large, if there is no breakthrough solutions, this number will only happen on paper.

1.1.5.2. WSSs development and management problems

a. Develop a WSS

Table 1.2. WSS development and management activitieseffective targets

Need	Activities for demand		
	Solutions need to perform	The frequent problem mainly	Some indicators of development and basic efficiency
Demand quantity	1. Build the new system (adding new supply) 2.Khai capacity utilization has (increased supply)	*1. Design extension / replacement pipe network*	1. Coverage Service 2. The water / capita date of
	3.Nang level, repair, maintenance (maintenance, ensuring water supply was available)	*2. Asset management and network planning repairs* *3. Leakage control*	3. The rate of loss 4. Expense ratio assets / m3 production costs.
Demand for quality	4. Keeping the water supply safe solutions	*4. The problem of water safety management*	5. Water safety standards achieved
Demand Management	5. Make Your Business	*5. The business management problem*	6. M3 of water service costs 7. Quality of water supply services 8. Average profit / m3 of water services

Make good the problems
Problem 1
Problem 2
Problem 3
Problem 4
Problem 5

Table 1.2 gives a visualization of the entire process of investment and management of a WSS, and the problem need to solve to improve the management efficiency.

Figure 1.3 shows, the good performance of the tasks (problems) frequently and its impact on the management effectiveness targets and long term goals of WSS.

b. The WSS management problems need to be solved

Problem 1: *The problem of asset management and scheduling replacement, maintenance of water supply network under the effect of environmental and related constraints.*

Problem 2: *The problem of designing replacement and expanding the water supply network.*

Problem 3: *Detect and fix leaks point on WSS in real time.*

Problem 4: *Warning of water pollution and early detecting of pollution sources in WSS.*

1.2. An overview of geographic information system

1.2.1.GIS definition

There are many different definitions of GIS, typically: *GIS is a set of principles, methods, tools and reference space data is used for updating, storing, analyzing, modeling, simulating the events on earth, in order to produce practical information to support decision-making...*

1.2.2. Related Concepts

The used concepts are: *objects (f*eatures*); map as realistic modeling; point, linear, region; relations in space (*to-po*); Data model (*Raster, Vector).

1.2.3. Manual GIS and computerized GIS

Manual GIS combines spatial data and attributes on traditional forms of media such as paper maps, transparent paper layers, etc ... and visual inspection, manual handling and speculation.

1.2.4. History of applying GIS

GIS was born in the early years of the 1960s, and in recent decades has developed fast thanks to the advancement of computer industry, computer graphics, spatial data analysis and database management.

1.2.5. Components of GIS

GIS has 5 components: *data, knowledge base, software, hardware and people.*

1.2.6. GIS database

GIS Database (DB) is a repository of spatial data and non-spatial data.

1.2.7. The functions of GIS

The basic functions of GIS include: *data import function (input); data preprocessor function (Processing); data analysis functions (Analyzing); Data export functions (output).*

1.2.8. The advantages and disadvantages of GIS

GIS has several advantages such as: Manage many types of data, export the results in many different forms, computer processors, etc. Some disadvantages: GIS requires more effort and time to build initial database, need a lot of devices, knowledge and skills of experts, costly...

1.2.9. GIS application trends in the world

GIS application trends more and more diverse as: GIS combines remote sensing, GIS and Web technologies, open GIS and global positioning system.

1.3. The problems of WSSs during GIS construction

1.3.1. Preparation phase

The construction of GIS starts from problems need to be solved by GIS. Thereby determining the necessary information, the attribute in any proportion, and more...

1.3.2. The problem in developing and deploying GIS

GIS development and deployment problems concern:*Human Resources and personnel training, equipment maintenance, collecting and managing standards, data storage sources and organization, financial.*

1.3.3. GIS building cost

GIS building costs are very high especially ones relating to equipment, building and development of the database.

1.3.4. Technologies supports GIS

The GIS-support platform technology include: American GIS ESRI environment and MapInfo technology, in addition to OpenGIS.

1.4. Deploy GIS application problems

Deploying an application problem need steps: *Define the problem objectives -> Related scope -> Modeling -> Finding solutions -> Define the data required for model -> Development process programs and add data into database-> Carry out testing and complete program -> Present results -> Write documentation using tools.*

CHAPTER 2 – PRACTICAL TECHNICAL MANAGEMENT AND GIS APPLICATIONS IN VIETNAM WSCs

This chapter study the technical management activities, analyze technical management data to clarify the shortcoming in the current technical activities. Since then, affirmed to improve and enhance the efficiency of these tasks through GIS. The survey results show the status of GIS applications, make recommendations with a scientific basis and practice for successful GIS applications; and limited issues when deploying GIS in Vietnam WSCs to overcome.

2.1. Some concepts of WSCs technical operations

2.1.1. Maintenance and repair

a. Maintenance: A chain of tasks in order to maintain and restore the operation of the device to achieve a defined status**.**

b. Maintenance scheduling: Identifying maintenance cycle of each type of pipe, each type of installed equipment and planning for each maintenance period.

c. Repair water network include: unexpected repair, scheduled repair and there are 2 types: small repair and overhaul.

2.1.2.Management and operation process

a. Management Process: The process should be taken to ensure the operation of all stages in the chain is operated synchronously, smoothly, scientifically to ensure the business stable and progress.

b. Operating process (in normal conditions): is implemented steps to warrant WSS activities sequent under condition that all the equipment, stages are working normally.

2.1.3. Risks and Hazards

a. Risks: equipment, structures are damaged or stop working irregular (random), etc...

b. Threats: actual or potential, direct or indirect risks threat to the safety and operation of WSS and water supply activity. Those are: P: - Physics. - B: Microbiology. - C: Chemistry.

c. Risk control measures: The implemented methods to prevent and stop threats, and handling incidents.

d. Troubleshooting process: The applied process when an incident that occurred in WSS.

2.2. The technical management processes in WSS

To ensure good operation, the WSC has developed technical management processes for transmission networks, distribution networks and service networks. Currently, WSCs mainly implement this technique processes manually, so efficiency is not high.

2.3. Technical management state and the problems of the WSC

2.3.1. Risks in technical operations

The degree of success in the technical activities of WSCs is measured by the value obtained from overcoming the risks.

2.3.2.Method of determining risk

The WSC determine the level of risk by means of semi-quantitative matrix.

Risk = (frequency of occurrence) x (severity level)

Risk assessment scale is divided into the following levels:

- *From 0 to 5 points: low risk level, risk tolerance.*
- *From 6 to 15 points: The level of medium and high. Measures must be taken to minimize risks, prevention and timely response.*
- *From 16 to 25 points: Cannot take risks.*

2.3.3. Analysis of risk assessment in Vietnam WSC

Basing on the survey results: *Risks are generalized into 123 threats which are equivalent to 1335 hazards in the system.* There are 36 risks which have hazardous levels >15 and WSCs do not have effective prevent

methods. It is those types of risk that causing leakage, water loss, high maintenance costs, recovery time delays, resulting in low efficiency of WSS management.

2.3.4. The measures to control and prevent risks

To implement safe water supply programs, the WSCs must build measures control and precautions methods that correspond to each type of risk.

2.4. GIS applications in the operational activities of WSC

2.4.1. Objects and methods of investigation

Interview combines with sending question tickets are conducted to 68 WSC in Vietnam. Retrieve 59/68 feedback results.

2.4.2. survey results

47 companies have not applied GIS yet (71%), 11 ones have applied GIS (16%) and 9 ones refused to answer.

2.4.3.Comments on the status of GIS applications

- *54/59 companies knew about GIS and affirmed: Application of GIS in management will certainly improve the efficiency of WSS management.*
- *The GIS application companies still lack of methodical, spontaneous, and divided into 02 groups: Self-study building GIS and hire another company to deploy commercial available GIS software packages. Each group has its own advantages and disadvantages. However, WSCs expects building GIS consistent with the level of organization, with reasonable prices.*
- *Companies often lack of research department which specialized in data updates and maintain system activities, not to be able to develop further applications, and more...*
- *The exchange of information between the departments during operation of the system is unclear.*

2.5. Some recommendations on applying GIS to manage WSS

2.5.1. The problem and the contents to apply GIS

A. Water Supply Network Management

– *These problems need GIS applications:* Plumbing network asset Management; leakage management, replacement design or expanding water pipe network, managing the decline of pressure and water flow in the pipe.

– *The stages in a management process:* Need to automate a number of stages in the process of maintenance management, maintenance and repair of the pipe network with the help of GIS.

B. Water Quality Management

Safe water supply issues can apply GIS to solve: *surface water management; groundwater quality assessment of an area; monitoring water quality deterioration in the pipeline; determine the concentration of chlorine in the system; water pollution warning system.*

2.5.2.A number of restrictive problems in deploying GIS in Vietnam WSC

Some issues that limit the deployment of GIS applications such as: high GIS investment cost, lack of GIS in Vietnam, do not have a complete implementing process, etc...

CHAPTER 3 – GIS DATABASE FRAMEWORK DEVELOPMENT AND CONSTRUCTION MODEL FOR MANAGING WSS IN VIETNAM

This chapter proposal: Models of development of a GIS system, WSS management GIS architecture model, a full GIS database frame to generalize WSS management in order to improve effectively WSS management.

3.1. Development model of a GIS system

3.1.1. Deployment of GIS applications

The deployment of a GIS is simultaneously deployment of the application requirements.

3.1.2.General model to develop a GIS system

Develop a GIS, should follow 6 steps of Figure 3.2.

In particular, in step (2), include *the specification of data and specification of processing*. After step (4), we have a GIS database and functional modules for solving given problem. To solve the problem, add the specific data of problem (5). Finally use the tools to solve problems and get results (6).

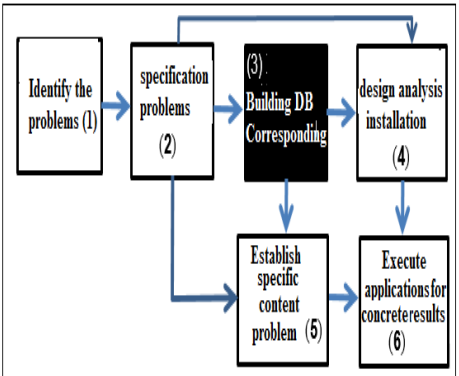


Figure 3.2. General schematic model developed GIS

3.2. GIS Architectural model for managing Vietnam WSS

3.2.1. The system hardware architecture model (Figure 3.3)

3.2.2.System software architecture and technical standards (F 3.4)

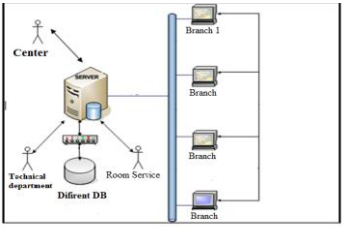


Figure 3.3. Hardware GIS system model for WSS

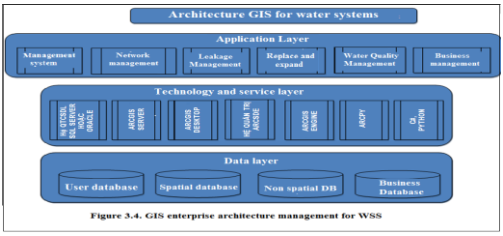


Figure 3.4. GIS enterprise architecture management for WSS

3.2.2.3. Applied technical standards

GIS applications Vietnam WSS based on these criteria: The technical standards of IT application in state agencies; water supply GIS map database must meet the national technical standards for given basic geographic information standards; Technical standards of product have to suit the national technical standards for basis geographic information standards.

3.2.3. Some basic requirements

The main requirements of the GIS managing WSS include: Design Client / Server model; the system is open; meet the requirements of security, safe information, and more ...

3.2.4. Some of the data layer requirements

The system must ensure certain requirements on the data layer such as: GIS map data must be GIS database standard forms; background map must be established from cadastral maps; the map objects to be clarified into map layers, etc....

3.3. Develop GIS database framework for WSS management

3.3.1. Question

According to GIS development model (Figure 3.2), building a database is a mainly important step, take a lot of time, effort, requiring a step ahead to ensure the comprehensive development of GIS.

3.3.2. Research Methods

3.3.2.1. Methodology of GIS Database Construction (Figure 3.5)

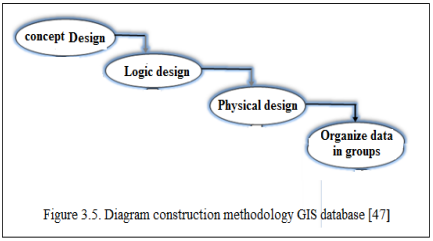


Figure 3.5. Diagram construction methodology GIS database [47]

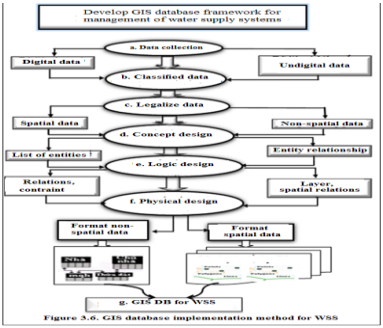


Figure 3.6. GIS database implementation method for WSS

3.3.2.2. Database deployment method

Because GIS database has addition space data and topological relationship, it should have certain difference compared to other databases.

3.3.2.3. Các bước triển khai CSDL GIS cho HTCCNS

The GIS database implementation steps follow Figure 3.6.

3.3.3. Design GIS database framework for WSS management

3.3.3.1. Data groups: shown in Figure 3.7

3.3.3.2. Design data layers structure (Figure 3.8)

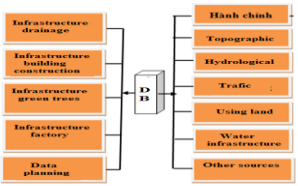


Fig 3.7. The group GIS data management water supply systemsystem

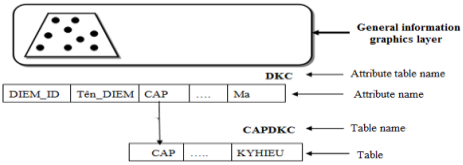


Figure 3.8. A layer data structure

3.3.3.3.Space objects linking diagram

Linked space objects diagram in the GIS describes the spatial relationships of objects in groups of data.

3.3.3.4. Organize data warehouse for management techniques

Group the proposed data groups into 4 warehouses on usage demand of the professional activities. These 4 data warehouses will help identify what data each business needs, and which layer data belong to, etc...

CHAPTER 4 – GIS APPLICATION FOR MAINTENANCE DESIGN PROBLEM - OPTIMAL NETWORK EXPANSION AND WATER POLLUTION WARNING IN THE WSS

This chapter presents methods to solve 2 problems: *replacement design and network expansion and water pollution warning with data provided by Hanoi water company No. 2*. In addition, the this chapter presents some test results and give some comments.

4.1. Preamble

Here, apply process of solving GIS and GIS database problem which has been proposed in the earlier chapters to solve *the optimization problem of designing replacement and expanding the water supply network, and water pollution alerts.*

4.2. Optimization replacement design, expanding the water supply network

4.2.1. Question

Maintenance, replacement and development of new pipeline networks take place frequently. Most of WSCs are doing this manually. Need to use the help of GIS technology and automation to improve the efficiency of these activities.

4.2.2. Addressing the problem

Water supply network of an area is divided into the water cell. Maintenance, expanding pipes scheduling in a water cell is popular. The sub-network design for a cell can be considered as a sub tree graph of a larger one. In particular, the water supply point and the source point is the coordinates attached peak of graph. The line connecting above points are the edges of the graph. The cost to install pipes for each edge will include: *expenses for piping and equipment, construction costs, management costs, and so on....* The task is to design a pipeline network to ensure the technical requirements with the least total cost, and has the most potential benefits.

4.2.3.Common modeling for problem

a. The objective function of the problem

The objectives function of the problem:

$$\sum_{i \in U} c(i) \longrightarrow \text{Min} \qquad (1)$$

Where: **U** is the set of edges of the original graph, **i** is an edge, and c(i) the cost of the edge i.

b. The constraints of the problem

Designed water pipe network has to satisfy the constraints: *Network is interconnected; the pipeline must meet the design standards (follow roads, not under architectural objects, not in the contaminated area, the slope in permitted range ...).* In fact, these constraints can be more or less without prejudice to the process of solving the problem. The problem is that *GIS database must have available background data necessary for establishing constraints.*

4.2.4. The algorithm for the proposed problem

Original water pipe network is a flat graph, connected. A **spanning tree** will include edges connected from the original point (supply source) to all vertices (water usage points). The problem of finding the optimal pipeline network lead to finding the minimum spanning tree which edge length is overall cost of installing pipes for that edge. Prim's algorithm was chosen to solve the problem because it's simple and effective.

4.2.5. Using GIS database

Using data layers: *water supply infrastructure; Traffic; Administration; Hydrological; Drainage infrastructure; Topographic; Trees, lighting; Land usage; Factory - Industrial zone; Solid waste; Plannings*.

4.2.6. Establish specific models for problems

Mapping the water supply points, the water used point in the region, and selecting them as a set of vertices in the graph. Then, create a connected graph by adding edges between two given vertices. At a

maximum, we have complete graph. With this graph, creating problem constraints by displaying each background graph constraint help to eliminate constraints' violations. May require adding new vertices, edges to ensure the network is connected and follow roads. Setting up constraints in this way is intuitive, simple, easy to carry, etc... If representing constraints by the mathematical expression is very difficult, because the variables are space objects. Moreover, constraints can be expressed, but lack of data to implement them, and if the problem had established constraints also difficult, it is hard to find a suitable algorithm to solve because of complexity. Once we have the network which satisfied graph constraints, determine the cost of edges, and solving optimal network design problem using the tool set.

4.2.7. Introducing the solution toolkit

4.2.7.1. Programming language

Python is the chosen language because it has many advantages in the GIS.

4.3.7.2. The functions of the toolkit

The toolkit is implemented through two functions: **network design to create original network** satisfying constraints and **searching optimization network** by minimum spanning tree algorithm. Also allows you to **adjust and publish the results** to a certain device.

4.2.7.3. Some toolkit interfaces

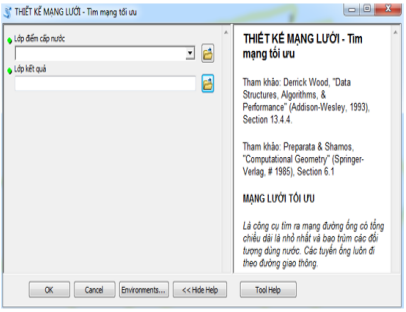


Figure 4.1. The interface of the toolfind optimal pipeline network

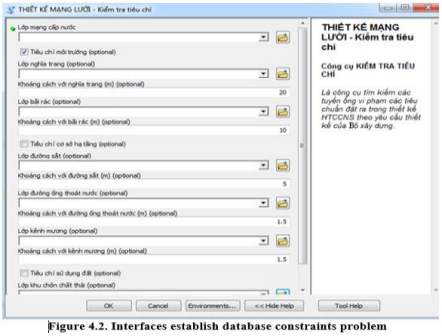


Figure 4.2. Interfaces establish database constraints problem

The QC_06 region is an area with old pipe network, need for replacement design. Using above tools give results as follows: The total length of the current network: **2130.33m**. The total length of the proposed optimization network is: **1917.73 m**. Proposed network is shorter than current network: 212.6 (m). According to the current unit price and then it is saved around 2.7 billion. Proposed pipeline network fully comply with the design standards, run time for 32 points is 3 minutes. The benefits are enormous.

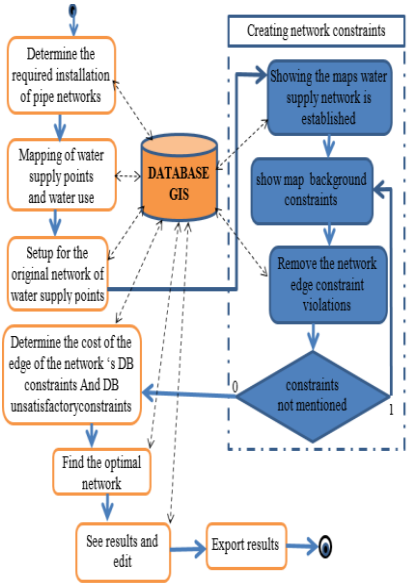


Figure 4.3. Diagram the steps solve the optimal network configuration from the toolkit

4.3. GIS applications to the water pollution warning problem

4.3.1. Question

Safe water supply is mentioned for years, but the water quality is not yet stable. Because WSS is stretched in space, built in different periods, the changes of the environment and so on ... to the system, making it contain possible changes that are difficult to control. Therefore, water in many places of Vietnam does not ensure the desired quality.

4.3.2. Describe the problem

To manage water quality, WSCs usually sample at certain positions. When system water samples are detected pollution, need to find the pollution cause, sources quickly and accurately to overcome.

4.3.3.The solution to the problem posed

"**Prevention is better than cure**" oriented solution is built in pollution maps. Through GIS, it will be periodically updated, built and give

the contamination risk warning map for each region. Upon detection of contaminated water points in the region, this map will help to check quickly to find out the source of pollution which is the cause for a plan to overcome.

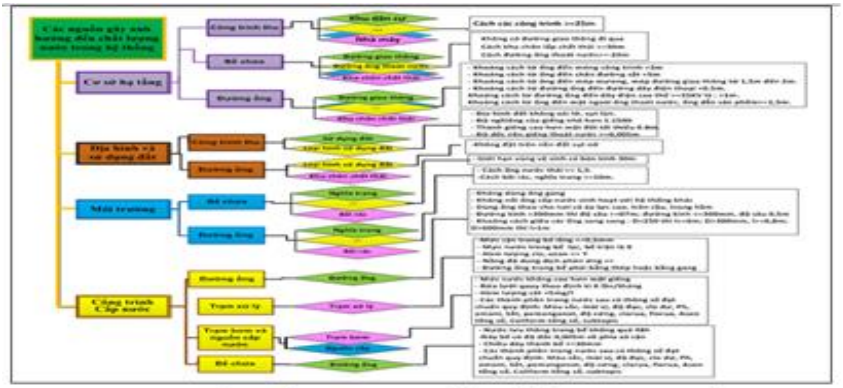
4.3.4. Steps to build the solution

4.3.4.1. Identification of risk factors affecting water quality

Factors affecting water quality from the group: *water supply projects; topography and land usage; infrastructure; pollution environmental and different regions, ...*

4.3.4.2. Determination of criteria and a map of the extent of influence of each factor

There are many factors that affect water quality (WQ) in the system. Each of these factors causes different levels of influence in different positions. The influencing factors include resources from: infrastructure, topography and land usage, environment and public water constructs. Based on the information about the WQ and the released criteria to determine the factors through criteria tree Figure 4.8:



F 4.8 Criteria tree for risk warnings Polluted the water supply system

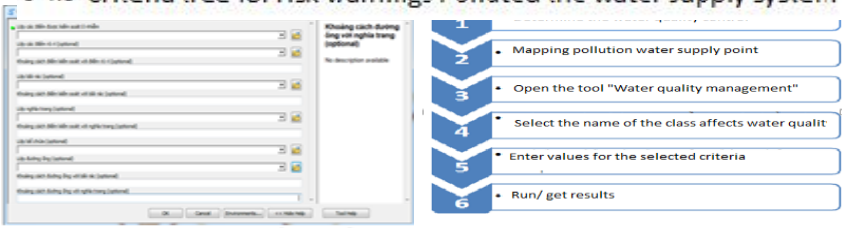


Figure 4.9. GUI tools "Managing pollution sources"

Figure 4.10. mapping steps for pollution warning

4.3.4.3. Building database

Database serves to solve the problem of pollution warning include data groups: *Background data, data of water supply, drainage data, economic-social data, and Solid Waste group data.*

4.3.4.4. Assistant toolkit interface (Figure 4.9)

4.3.5. Implementation problems with the toolkits and the results

4.3.5.1. The steps to use the tool (Figure 4.10)

4.3.5.2. Test results (F- 4.13)

In QC_06 area, using toolkits to find out the highest pollution possible positions in the network when putting into contaminated sites.

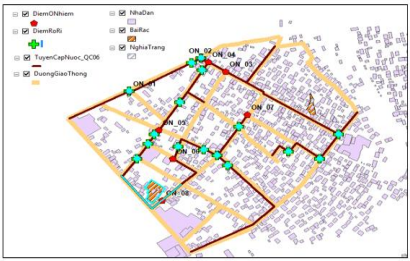


Figure 4.13. Test results tool "Polluter Resource Management"

CONCLUSION

The thesis focuses on analyzing and clarifying the status of Vietnam's WSSs management. Then detecting problems need to be resolved urgently. The thesis also research methodology as well as the method of solving the detected problems on the basis of applying new technology which is worldwide applied GIS technology. When research the application of GIS technology, the thesis has made specific proposals for the development of GIS for Vietnam WSCs and study specific solutions to solve some specific problems in WSS management. The thesis has achieved the following results:

1. Analyze and clarify the issues that need to be urgently solved in order to improve the efficiency of the management of Vietnam WSSs. Then

proposing the application of GIS technology that is able to solve effectively and thoroughly the raised problems.

2. Generalize and propose the basic WSS management content for GIS applications.

3. Presentation of the general GIS development model. Recommended overall architecture of GIS applied to Vietnam WSSs.

4. Propose GIS database framework, including objects, spatial data layers and attribute tables, the relational data model for GIS of Vietnam WSCs.

5. Research GIS application solves two important problems in technical management: *optimization water supply network design, mapping of water pollution warning*.

The above research results contribute both theoretical as well as specific methods for promoting GIS applications in water supply industry in Vietnam. Thesis contributes to solving urgent problems that Vietnam water supply industry is facing, and is an effective way to improve the management of WSSs. The thesis proposed and clarified the process and the solutions of GIS technology application to the WSS management activities. The research results also open the way to further studies in the field of IT solutions to integrate other technologies, other systems (hydraulic analysis, remote sensing, SCADA etc...) in GIS system managing WSSs, making management more effective and comprehensive. Due to the large scope and complexity of the technological solutions, there are other limitations that thesis cannot cover during the actual deployment. The author hopes to have the opportunity to continue to participate in deploying applications to improve the two modules were deployed in Hanoi WSC No. 2. The author believes that the thesis proposal will really help Vietnam WSC can accelerate the application of GIS in management to achieve the objectives, and obtain great economic and social benefits.