The potential of utilizing geographic information systems for the district heating networks within Fortum Heat

Therese Andersson
Abstract

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This study is a thesis work at Uppsala University initiated by the Cross Country Team for Operate Networks at Fortum Heat. The team requested an analysis of the current situation of the functions, processes and systems regarding geographic information systems, GIS, for the district heating networks within Fortum Heat. GIS software is used to store, analyse and visualize information in digital maps. This study aims to investigate in which processes the use of GIS can contribute to facilitate and make operations more effective. The potential of utilizing GIS for the district heating networks was found to be: geographic and technical documentation, visualization, maintenance management, locate potential customers, sales, customer communication, risk analysis and other types of analysis.

The situation regarding documentation, maintenance management and customer management differs a lot between the district heating networks within Fortum Heat. The general conclusions and recommendations for improvement are to implement GIS for those networks that do not utilize GIS for documentation today. These networks are situated in Plock, Czestochowa and Jelgava. A further recommendation is that there should be one target system for GIS within Fortum Heat. The advantages of using the same system in the whole heat division are that there would be more users with knowledge about the systems, which could benefit from collaboration with each other. The maintenance management system for a district heating network should include an asset register where the network is well defined and where all parts of the network are represented as individuals. Since a district heating network in opposite to a heat plant is spread over a large geographical area is a map of the district heating network necessary for planning and execution of work. To meet these requirements either a module for maintenance planning in a GIS or integration between the current GIS system of a district heating network and the maintenance management system Maximo could be used. A large potential of utilizing GIS is to locate potential new customers, sales and customer communication. More active use of GIS in when locating new potential customers and analysis of where non-connected buildings near existing district heating networks are situated would result in more targeted marketing.

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1 Introduction
Fortum Heat owns and/or manages the operation of several district heating networks in six countries: Finland, Sweden, Norway, Estonia, Latvia and Poland. Properties as length, volume, heat delivery, age and complexity differ between the networks. These properties are essential for the requirements of documentation, control of information and need for system support for each network. Geographic information system, GIS, is used to store, analyse and visualize information in digital maps. This kind of software is very suitable for handling information about systems that are widely geographic spread in an efficient way, such as district heating networks. Several regions in the heat division are already using GIS, but mainly for documentation. This study aims to investigate further in which processes the use of GIS can contribute to, facilitate and make operations more effective. A literature review together with a consultation with the supervisor resulted in a couple selected areas where GIS could potentially provide functions for control of information, visualization and analysis. The focus area was chosen to be maintenance management since it was found to be an area with large potential for using GIS, which could be improved in order to be better, adjusted to the maintenance operations of the district heating networks and where the geographic representation of the networks is important.

1.1 Aim
The aim with this project is to analyse how GIS is used for the district heating networks within Fortum Heat for documentation, maintenance, distribution optimization and customer management. Nine of the large scale district heating networks within Fortum Heat are very old, some parts are over 40 years and as the pipes gets older the risk that leaks will occur increases. Therefore, the focus is chosen to be the maintenance process requirements for maintenance systems for the district heating networks with focus on handling geographical information. Also the use of risk models will be investigated.

1.2 Limitations
This study concerns the district heating networks within the division Fortum Heat that consist of the regions Finland, Poland, Scandinavia¹, Estonia and Latvia. The Heat division also includes combined heat and power plants in Lithuania, but since Fortum Heat does not own the district heating networks in Lithuania, those networks are not included in the study. Factors such as costs and architecture issues for the IT systems are not included in the study. Areas that have not been investigated here are design of new pipe constructions and GIS tools for hydraulic calculations. This has not been investigated due to lack of time and that the focus area was chosen to be maintenance management. Distribution of heat, gas, district cooling and optical fibre cables often share the same system, but in this report the focus is heating networks.

¹ The study does not include the district heating networks in Norway. When Heat Scandinavia is mentioned it only refers to the business in Sweden, which is situated in Stockholm.
1.3 Questions
The five main questions this study aims to answer are:

1. What are the different systems for documentation and maintenance for the different district heating networks within Forum Heat?
2. What are the processes for maintenance management of the district heating networks? From planning to execution and follow-up work.
3. What are the different potentials with utilizing GIS?
4. What are the requirements of maintenance systems for the district heating networks? With focus on the structure of the asset register and geographic information.
5. How can the processes be improved?

1.4 Disposition
The disposition of the thesis work is the following: after the introductory chapter comes the background with descriptions of district heating networks and geographic information systems. The background chapter also include a list of the most important system mentioned in the report and thereafter follows the method. The first part of the result is presented in chapter 4, the as is study. The as-is study is the result from written questions and interviews about documentation, usage of GIS, maintenance etc. for the district heating networks in the different regions. Chapter 5 presents the second part of the result, the potential of utilize GIS for the district heating networks. The result is followed by the discussion and finally conclusions and recommendations. In this last section there will be general recommendations for all regions and additional recommendations only for Heat Scandinavia.
2. Background

2.1 Fortum Heat
The Heat division of Fortum consist of eighteen Combined heat and power plants (CHP:s), and thirteen large scale district heating networks. The combustibles used are varies from waste, wood chips, bio-oil, fossil oil and coal. Customers are both business and private consumers. Heat sales volumes of the Heat Division in 2012 amounted to 19.7 TWh and power sales volume amounted to 4.2 TWh. The regions in the Heat division are Finland, Poland, Sweden, Norway, Estonia, Latvia and Lithuania. (www.Fortum.com, 2013). The organizational structure of the Heat division is shown in figure 1.

![Organizational Structure of Fortum Heat Division](image)

**Figure 1 The structure of the Fortum Heat division**

2.2 District heating and district heating networks
A district heating system is built up by large scale centralized units for heat production, either plants with only heat production or combined heat and power production. The energy source can be of various types as burnable waste from households and industries, bioenergy as wood chips, wood pellets or bio-oil or fossil fuels as coal and oil. The flexibility in choice of combustible is one of many benefits of this large scale heat production compared to small scale combustion units. Others are that higher efficiency’s is reached with combustion in large units, better local environment due to a better combustion and high chimneys. There are many benefits with few large scale combustion units compared to multiple small combustion units, but one disadvantage is that disturbance in the heat delivery results in major consequences. Which makes it important that heat plants and distribution networks function properly. (Fredriksen and Werner 2011)
The heat is distributed by water in pipes and delivered to buildings with waterborne heating system by heat exchanges in substations. The district heating network consist of pipes and other components required to transport the water from the heat production units to the substations around the city. At normal operation should the pressure conditions at all parts of the network be such that building standards of operation indoor temperature requirements and heating of domestic hot water is satisfied for all subscribers. Furthermore, the distribution network should be dimensioned for required flow at dimensioned outdoor temperature according to building standards and chosen water supply temperature at the district heating water. (Ekström. Et. al. 1998)

A district heating network is divided into feed and return pipes, allocation pipes and service pipes. An allocation pipe goes from a feed pipe and supplies e.g. a small city district or a block. A service pipe goes between an allocation pipe and a single substation. The main types of pipes are plastic culvert, preinsulated pipes and steel pipes in concrete culverts. A small part of the pipes are placed above ground and inside of buildings, but the main part of the district heating network are underground and some of the pipes are located in tunnels. (Data sheet: Fortum Heat large scale dh network, 2011) It is important that each one of the large amount of valves in a district heating network are in good condition and can be operated whenever needed if a leak or an accident occur. Valves and other components as junctions, compensators, pumps, measuring together which venting and draining device are situated in wells. Wells are available for the technicians from the street and large wells can technicians climb down in and inspect. In concrete culvert systems, monitoring of wells from the pipeline system allows a possibility to observe leaking water by inspections. In plastic culvert systems with electronic moisture alarm do wells provide the ability to place equipment for the alarm system. (Fredriksen and Werner 2011)

2.3 Geographic information systems (GIS)

As mentioned, GIS software is used to store, analyse and visualize information in digital maps. When a system has been documented in a GIS software, the data is connected to locations in the map. This way of managing and presenting data in the map provides an overview of a system and illustrates how the components are connected. Hence it makes the documentation of a system more comprehensible compared to having the data presented in tables or hierarchical structures. Several regions in the heat division are already using GIS, mainly for documentation. This study aims to investigate further in which processes where the use of GIS can contribute to facilitate and make operations more effective. Several units in the heat division are already using GIS to store and analyse information about district heating networks.

GIS can be used for many different purposes and is a common analysis tool for researchers studying phenomena linked to geographical locations. For example analysis of how a district heating network has been developed during many years (Henriksson and Magnusson, 2009) or to demonstrate the opportunities for expansion of district heating by visualizing the heat sources and heat sinks in a city (Finney et.al 2012). In this study, the term GIS is used not only for geographic analysis but also for documentation, visualization and analysis of networks. A more suitable term for that might be net
information system, NIS, since the focus of applications useful for the Heat division are information about district heating networks. Even though topography, buildings and the environment around the networks are also important. Nevertheless, since GIS is a commonly used term for this kind of technology in the Heat division the term GIS is chosen to be used in this study including both geographic information and information about the networks.

The basic use of GIS for district heating networks is documentation. Once a network has been documented in GIS, more functions can be added to simplify and make operations more effective in several areas such as maintenance, planning, design of new pipes and customer management. GIS provides the ability of a clear overview of district heating networks and additional functions are reporting, statistics and analysis. One benefit of geographic information system is that many employees have access to information at the same time and see modifications made by others such as where works are carried out at the moment. A user of the system can be assigned only to the applications required for that persons work. The applications can for example be administration or just a viewer application. One possibility is to define user privileges by geographical areas for example for an extern consult that is only allowed to see the area he or she is working with. The users of GIS are network owners, project managers for new constructions, investigators/planners, maintenance personnel, sales- customer service- and marketing staff as well as business management. (Stavenius, 2005)

2.4 List of systems

GIS systems

dpHeating – The geographic information system dpHeating by Digpro is based on an oracle spatial database. DpHeating is referred to as “GIS värme” within Heat Scandinavia and its previous name was Facilplus.

TeklaNIS - TeklaNIS by Tekla is based on an oracle database. TeklaNIS is referred to as Xheat within Heat Finland.

Microstation – Microwstation is a CAD based GIS software from the supplier Bently together with the database management system Microsoft SQL Server 2005.

Mapinfo – Mapinfo by Pitney Bowes is based on an Oracle database.

GISela - The special developed GIS software used for hydropower in Fortum renewables in Sweden. There is integration between Maximo and GISela in one direction, by which work orders are sent from Maximo to GISela.

Powergrid - Powergrid by Tieto is used for documentation and design of the power distribution grid in the division Electrical Solutions and Distribution, ESD.
Maintenance systems

Maximo - Maximo by IBM is a system for asset-, work-, resources- and inventory management thus a maintenance management system for monitoring equipment status, management of stocked items, cost analysis and more.

Distribution optimization systems

HeatDisp - Heatdisp is a calculation tool for simulating district heating networks in different conditions. Heatdisp is also very useful for planning new plant connections or pipeline constructions to remote areas.

Termis - Termis by Schneider electric is an advanced and powerful calculation-tool for simulating district heating networks. Simulations can be done for new constructions, where a fictive case is created offline or to perform real-time simulations of the district heating network online, in order to plan the production.

Grades Heating – Grades Heating by process vision Oy is a tool for simulations and calculation of district heating systems.

Other systems mentioned in the report

Pipeplan –A tool for project planning of district heating networks used in Heat Finland.

TOPI - A tool for real-time monitoring of power plant processes.

3 Method

The study began with a literature review and outlining of the topic and the organisation. An as-is study (case study) has then been made in order to find out the processes for documentation and maintenance of the district heating networks and which systems that are currently used. This was done by interviews together with demonstrations of GIS and maintenance system for Heat Scandinavia and Heat Finland and by written questions for Heat Poland, Heat Estonia and Heat Latvia. The as-is study was then followed by investigation of further potential of using GIS and finally conclusions and recommendations. The work process is illustrated in figure 2.

The method of data collection is either quantitative or qualitative. The type of produced data defines the method. When a method generates numbers and countable answers and facts is it a quantitative method. When the method produces non-quantitative information as descriptions and observations is it a qualitative method. Quantitative studies often include a larger number of respondents than qualitative studies. The advantages of quantitative methods are therefore the ability to generalize and create statistic data from a number of predetermined questions. But quantitative methods do not give the opportunity to adjust focus depending on the response during the study. Qualitative studies are more explorative, flexible and non-standardized than quantitative methods. Qualitative studies goes deep into a specific empirical field where the aim is to collect detailed information and to interpret these in relation to its context. The factors that determine the choice of method are the situation, time and resources. (Harboe, 2010)
Qualitative questions gives more detailed information but on the other hand, the answers might be harder to compile and analyse. The methods for this study has been chosen to be qualitative since there are a few people in every region that has good knowledge about GIS systems and therefore, the number of respondents small. In-depth interviews have been performed with several people in Heat Scandinavia, who are working with GIS, maintenance, locating potential new customers, customer communication in the heat division and also with two persons from the Fortum renewables and one person from Fortum electrical solutions and distribution in Stockholm. The author of the report has also participated in a X-country team meeting and in a demonstration performed by IBM to show new functions of the new version of the maintenance management system Maximo. An interview with a GIS expert during a full day meeting was carried out in Heat Finland together with demonstrations of the GIS software. A different response approach was used for the other regions namely written questions due to limited opportunity to visit all regions in person. The answer sheets consisted of excel files contained written open questions without answers alternatives, but with examples of answers, have been sent in two different excel sheets within an interval of one month. The first questions were about GIS in general and the second set of questions focused on maintenance management. Although the scope for the project are the district heating networks in the whole Fortum Heat division, the as-is analysis, the processes and systems for the district heating networks in Heat Scandinavia and Heat Finland, will be more detailed described since the interviews gives more detailed information than the written questionnaires.

Figure 2 The flowchart illustrates the work processes during the study.

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2 Maximo is the target system for maintenance management at Fortum and will be described in section 5.3.1.
4 The as-is study
The result of the as-is study describes the current processes and systems for documentation and maintenance management of the district heating networks within Fortum Heat. The study also includes risk models and customer management that will be presented in coming sections for two of the regions: Heat Scandinavia and Heat Finland.

The information of the systems and processes in the different regions as descriptions and requirements are compiled from written questionnaires (Poland, Estonia and Latvia) and interviews (Finland and Scandinavia) with people working with issues regarding the district heating networks at different positions in the division. The descriptions are more detailed for the regions where there has been interviews and less detailed where there has been written questions. The information quality also differ between the different networks depending on how the respondents have experienced the questions and how detailed the answers from the respondents have been. The questionnaires can be found in the appendix. The focus in the as-is study is how the different networks are managed regarding documentation and maintenance, and there is also some information about distribution optimization and customer management.

4.1 Heat Scandinavia
In Heat Scandinavia there are three large scale district heating networks situated in Stockholm named the south, central and north-west network. The three networks have a total length of 1160 km and are supplied from five CHP, one heat plant and 21 peak load units. The district heating networks in Stockholm is very old and has been remodelled and expanded during many years, the oldest pipes in the networks are over 40 years old (Data sheet: Fortum Heat large scale dh network, 2011). Therefore the networks are very complex and meshed. A connection between two of the large networks, the central and the south was made in year 2008. (Henriksson and Magnusson, 2009)

Documentation and geographic information
According to the GIS manager and the GIS expert at Heat Scandinavia, the GIS software used for the district heating networks in Heat Scandinavia is called dpHeating (the previous name was facilplus). It is based on an oracle spatial database and supplied by the Swedish company Digpro. Technical information about the district heating network and information about subscribers are documented in dpHeating. There is information about pipes: length, dimensions (x, y and z-coordinates), material, manufacturer, year of construction etc. Wells: manufacturer, year of construction, components in the well as pumps, valves etc. Valves: function, type, manufacturer etc. Furthermore are location and information about substations, heat loads, detailed drawings of pipes situated inside buildings, easements and contracts with estate owners documented and linked to the map.

Distribution optimization
The software for calculations is Termis, delivered by Schneider electric. Termis is an advanced and powerful calculation-tool for simulating district heating networks. In Termis simulations can be done for new constructions, where a fictive case is created offline and Termis can also perform real-time simulations of the district heating network online, in order to plan the production. There is an
integration between Termis and dpHeating currently under implementation. Termis will then import technical information of the pipes and the positions of the pipes from dpHeating. (schneider-electric.com, 2013)

**Maintenance**
The information about maintenance management in Heat Scandinavia has been compiled from interviews with a maintenance engineer and a technician, who has been working with maintenance of the district heating networks in Stockholm for many years. The description of the workflow, from work request to execution and the picture showing the as-is maintenance process for DH networks in Heat Scandinavia have been made by the author, based on the information from the interviews.

The maintenance management system in Heat Scandinavia is Maximo by IBM, which is the target system for Fortum regarding maintenance management. Maximo is used for maintenance both for power plants and district heating networks in Stockholm. Maximo has a well-defined hierarchy/structure for the equipment in the power plants but there is no graphical display of district heating networks in Maximo, which means that it lacks the ability of providing geographical information about the district heating networks. In most cases have places, which are being inspected and maintained regularly an address connected to it written in free text but an address does not always provide the exact given information required for executing the work. Therefore are GIS and Maximo being used side by side by the personnel working with maintenance of the district heating networks, simply because the district heating network cannot be maintained without knowing where works are going to be executed.

**From work request to execution:**
The following steps explain the process from when a fault occurs at the district heating network until the work has been executed.

1. A fault occur on the district heating network
2. A work request is made by operation personnel, the work request includes:
   a. Number of the work request i.e. FV123456
   b. Description of the fault
   c. How urgent the fault is, suggested start and end date and time for correcting the fault.
   d. Which section of the district heating network the fault concerns
   e. Staff group
3. Maintenance engineers search out the work requests for their area of responsibility, create work orders and have meeting with technicians where allocation of work to technicians with the right skills are made.
4. The maintenance engineer responsible for the work order plans time and resources for the work. When the work is planned a purchase order is made by the person responsible for the work order, if needed.
5. Execution, the technician that will execute the work needs the following:
   a. Work order
   b. GIS-map
   c. A drawing from GIS (not always needed)
   d. Material and tools

Work orders have different statuses during the process: waiting for approval, approved, in progress, complete, waiting for invoice and closed. This is in order to clarify where in the process the work order is. A maintenance engineer working with maintenance administration prints out the work order and a map from dpHeating, and marks out the places where work is going to be performed. Fortum employees print out their own work orders from Maximo and maps from GIS and report back when the work has been executed, but subcontractors do not have access to Maximo. Work descriptions for corrective, unplanned works needs of course to be written for each specific occurrence. Work descriptions of how inspections will be executed for planned preventive maintenance are documented in the documentation system, DM. Although there are descriptions, they are not always included in the printed work orders.

Material is not assigned to work orders. The reason is that maintenance engineers often purchases turnkey, where the complete work is purchased from the subcontractor, including resources and material. The need to attach material to work order according to the respondent is small since spare parts needed for the networks are standard spare parts and not as specific as for example a spare part for a turbine model in a power plant. The consequence is that a number of for example one type of valves are in stock and technicians take out the spare part when needed and the cost for the item is then linked to the corresponding work order. Therefore is the advantage of having material linked to a work order already from the beginning not large, it would probably lead to more administration and time consuming for the maintenance engineers.

**Description of the representation of the district heating networks in Maximo**

There is no automatic connection between Maximo and dpHeating but there are ID-numbers for places where components e.g. well are situated, which need to be inspected regularly. Those ID-number are the same in Maximo and dpHeating. It means that a location for an object in a work order in Maximo can be found by searching for its ID-number in dpHeating. But if a work will be executed somewhere at a pipe then there are no standardized way to describe the location in Maximo, which means that the specific geographical location is well defined for the labelled places but not for a random place on a pipe where a leak may occur. Some pipe sections located in tunnels are included as objects in the Maximo hierarchy. But for other pipes do the hierarchy only come down to a type of pipe in a certain area, not the geographical location of the pipe section where the work is going to be performed. This needs to be written in a describing text, often as an address. Example of hierarchy in Maximo for a pipe section is described in figure 3.
Figure 3 Example of the Maximo hierarchy for a group of pipes in the district heating network.

The hierarchy for objects are more detailed than the hierarchy for pipes since each component has its own unique number e.g. DJ12. The exact position for where the maintenance is going to be executed can then be search for in dpHeating by using the unique ID-number for the place. Figure 4 gives an example of the hierarchy in Maximo for a component of the district heating networks that needs to be inspected regularly e.g. a well or a valve.

Figure 4 Example of the Maximo hierarchy for a particular well in the district heating network.

When an inspection is going to be executed at a location with several objects, there is a list of assets in Maximo to choose from that for example can look like the example in. In this example there are two valves: valve 1 and valve 2 (1 Luftningsventil and 2 Luftningsventil). But in reality the valves are not labelled, only in Maximo. If they were labelled also in reality it could be easier to make analysis and statistics of which kind of valves that often brakes and which does not. And technicians would by the labelling instantly know which component that is broken if it is not visible on the outside of the component.

DJ12 Inspektierbar kammare gata:

- 151853:DJ12 Betäckning
- 158291:DJ12 Stege
- 161415:DJ12 Smide
- 166208:DJ12 Rör
- 169876:DJ12 Betong
- 185876:DJ12-1 Luftningsventil
- 185877:DJ12-2 Luftningsventil

Figure 5 Components in an inspectable well

An opinion from one technician is that it would not be suitable to have pipes represented as objects in Maximo since the pipes are not point objects. The requested technician means that it would be very useful if it would be possible to click on a point at a pipe or on a component on the GIS-map and open the work orders for objects in Maximo. The technician also thinks the strength of GIS is that one can see and understand the network in a perspicuous way and that it is easy to search for components on the
map. Even though it works using Maximo for the maintenance management of the district heating network in Heat Scandinavia there is a need for fine-tuning of the functions in order to decrease the administration time. For example are failure classes and failure codes not adjusted to fit the components and common faults at the district heating networks. One disadvantage is also that photos can be added to a work order but not to a work request. Since it is often technicians out in the field, who take pictures and also produces work request an improvement would be if they could add photos directly to the work request. Today the situation is that a technician, who finds a fault writes a work request and if he or she also take photos he or she have to send them by email to the maintenance engineer, who later upgrades the work request work order later and also add the photos.

**Leak reporting and “stop jobs”**
Since Maximo lacks in ability to provide an overview of district heating networks GIS is used for some maintenance related functions for examples visualization of where there are and has been leaks and where “stop-jobs” are situated. To document the locations where leaks have occurred are those marked at the GIS-map. The leaks are documented also in Maximo as work orders but the ability to visualize these are more clear and obvious by symbols at the map. By just a look at the map one can see where leaks has occurred and the cause of the leaks are also documented. From this can statistics be produced, which is used as input for decision making of reinvestments.

“Stop-jobs” are maintenance work only able to execute when the flow in the pipes are switched of, but in the same time not urgent enough to stop the heat distribution right away. “Stop-jobs” are dealt with when the flow in the pipes in that area are going to be turned off for other reasons for example, connections of new heat consumers. GIS is therefore used to visualize where “stop-jobs” are situated so that the personnel working with new constructions can see those locations and contact the maintenance personnel when the flow in those pipe sections will be turned off. This cannot be done in Maximo as easily which is why the maintenance personnel came up with this solution to visualize those works.
The as-is maintenance process for DH networks in Heat Scandinavia

Figur 6 The figure describes the process for maintenance in Heat Scandinavia and is made by the author, based on the information from the interviews with maintenance engineers and technicians.

GIS in other divisions

Renewables
GIS is also used for documentation and visualization for hydropower stations in the division Renewables in Scandinavia. They have their own special developed GIS software called GISela, where coordinates are marked out for large dam elements as the dams or spill gates. GISela is primarily used as a pure map function and needs to be further developed with a better search function but there is integration between Maximo and GISela in one direction and by which work orders are sent from Maximo to GISela. The advantage of the integration is that it simplifies the administration work for technicians at the hydro power stations since the information are at one place hence updates are only needed to be made in one system. The integration is a consequence of requirements of the users of GISela and Maximo. The integration works so that Maximo automatically sends information to GISela. The hydro power plant has a cod and the work order has a direct link to Maximo, which means that the technicians do not need to search for work orders in Maximo but can do that directly in the GIS
software, GISela. The integration also simplifies for personnel at the power plant and personnel at other locations to see what is being done at the hydro power plants and follow the maintenance status of them. The ability to visualize the hydro power plant in a much better and clearer way is the advantage with GIS compared to tables in Maximo. The respondent means that a combination of the two systems gives a visual representation of the network, a map and the functionalities for work and resource planning and financial management in Maximo.

**Electrical solutions and distribution**

The GIS software Powergrid from the supplier Tieto is used for documentation and design of the power distribution grid in the division Electrical Solutions and Distribution, ESD. The designers of power grids in Stockholm needs to know the power loads in order to calculate the dimensions of the cables and component of the power grid. In the occurrence of one particularly cold winter in Stockholm in combination with that many estate owners had installed heat pumps resulted in problems since the power grid was not dimensioned for such high power loads since Fortum power and distribution did not know where or how many heat pumps that were installed. To avoid a recurrence of this situation and be able to design the electrical system so that it will keep the demand peaks due to heat pump installations. Fortum power and distribution asked for information from the municipalities about which estates that had applied for permission to dig for geothermal energy. Then all estates with heat pumps could be marked out with symbols in the GIS-map and taken into account when designing and dimensioning new constructions.

**4.2 Heat Finland**

There are four large scale district heating networks in Finland: Espoo, Johensuu and Järvenpää and Nokia, which altogether consist of 1090 km pipe lines. Like the networks in Heat Scandinavia, the networks in Finland (particularly in Espoo) are old and complex. The information has been compiled by interviews with a GIS-expert in during a visit to the Espoo office and by a video meeting with the maintenance manager.

**Documentation and geographic information**

The same systems for documentation and maintenance are being used for all district heating systems in Heat Finland since 2007. The GIS software that is used for Fortum Heat Finland is TeklaNIS and it is based on an oracle database. TeklaNIS is also called Xheat. In addition to documentation, maintenance and sales are TeklaNIS also a tool for analysis of the network and planning of new constructions. For calculations of the network are the software Grades Heating used. All information about the district heating network is documented in TeklaNIS: technical information about the pipes: length, material, dimensions, x, y and z-coordinates, if a pipe are used for heat, cooling or gas, if it has alarm threads, manufacturer, the location of the pipe: in wet land, in a tunnel, in the ground etc. Information about other components of the network: wells and valves etc.

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3 Plastic culvert moisture alarm.
**Maintenance**
Maximo is used for maintenance of the combined heat and power plants in Heat Finland but when it comes to the district heating networks Maximo is only used for purchasing orders. A risk model in TeklaNIS decides the inspection intervals. The module in TeklaNIS for maintenance containing TeklaNIS maintenance basic, mobile inspections and repair is used for maintenance of the district heating networks. The term “work order” is not used here, but a work can be found by clicking on a location in the map. Then the history of works done at that location is shown in a list. It is possible to add material and costs in TeklaNIS, but that function is not being used, it is done in a software called Pipeplan instead. Pipeplan is a tool for planning projects for the district heating network. One chooses what material needed for a pipe and then the costs are calculated. The tool is easy to use and very suitable for projects regarding the district heating network according to the respondent.

**Leak reporting**
One function in TeklaNIS is to mark leakages, when a leakage has been discovered and repaired it is marked out in the map and information about what cause it is added, the mark stays there until the pipe has been replaced by a new construction. The location of leaks has been measured and marked out with good estimation at the map. This method has been used for two years. When a leak occurs, the personnel in the control room get information either from a person that has discover the fault or by alarm. Then the control personnel can search in the map for the location of the address and send a work crew there.

**Mobile device**
For the district heating networks in Finland a mobile devise called Toughbook is used. The Toughbook is a pc without a keyboard with a screen size as a standard laptop. It is designed with a robust water proof cover. Other kind of mobile devices as Ipads and laptops are no good to use according to the respondent because they break more easily. Toughbook works offline but needs to be synchronised with Xheat. The Toughbook do have a GPS-function and can find the closest way to the object that is going to be inspected. Photos can also be taken with Toughbook and directly added to a work. The network is divided into maintenance areas. Not every technician has a Toughbook because it is expensive, but the maintenance mangers and one in every maintenance team has one.

**Sales**
In Finland GIS is also used as a tool for the sales personnel to organize sales activities. Request from people that wants to connect their buildings to the district heating networks are marked in the map. Also when sales personnel call people and ask for interest of connecting to the district heating network a note about the answers are stored in the maps.

**Communicate disruptions to customers**
There is an on-going project for notifications by SMS and by a map at the website to customers at planned or unplanned disruptions. This will be described further at the section 4.3.1 Customer management.
GIS and maintenance in Heat Finland, head functions:

Figure 7 As-is maintenance process in Heat Finland. (Ranta, 2013)
4.3 Heat Poland
The region Heat Poland has three large scale district heating networks Wroclaw (480 km) Płock (130 km) and Częstochowa (185 km). The information has been collected by written questions to persons responsible for the district heating networks in Heat Poland.

Wroclaw

Documentation and geographic information
The GIS software for the district heating network is Mapinfo together with the database Oracle version 8. The background map is a geodetic map that is updated and purchased from the municipality. The current software, Mapinfo needs to be replaced in Poland since the application is not supported. The information that is documented in Mapinfo are technical information about pipes: area, length, material, age, the high position, if pipes are in or above the ground, technical information about other components, drawings of heat chambers, information about assets (network and heat substations). Further information documented in Mapinfo is the heat load of each consumer and additional information about customers, there is an interface from the billing system to Mapinfo. When a new construction has been made, the geographic position of the new construction is updated manually to the GIS-software. Additional functions that the respondent would like to have in a GIS software in the future are operation events as breakdown, shutdowns and interruptions of heat delivery.

Distribution optimization
A model for simulation of the network is not being used in Wroclaw but the functionalities that would be needed is hydraulic calculations, monitoring and steering of district heating and optimization of supply temperature in heating system.

Płock

Documentation and geographic information
No GIS software is used for documentation of the district heating network in Płock. The geographic information is documented in paper maps and in digital maps, only for viewing. Technical data about the district heating network is documented in paper documents and also in excel files. The respondent thinks that a GIS software for the district heating network would be an improvement. Regarding an asset register are also data about the network documented in excel files, access and additional software with assets register but from accounting point of view. There are also technical descriptions, but quite general and not very detailed.

Distribution optimization
As in Wroclaw a model for simulation of the network is not being used in Płock but the functionalities that would be needed are hydraulic calculations, monitoring and steering of district heating and optimization of supply temperature in heating system.
Częstochowa

**Documentation and geographic information and distribution optimization**

In Częstochowa the software for hydraulic calculations, Termis (same as described for distribution optimization in Heat Scandinavia) is being used for documentation and mapping of the district heating network. Since the district heating network can be visualized at a map in Termis and technical data about the district heating network are documented there, technical data is also documented in paper documents. Termis is an on-line optimization system with temperature optimizer, pumping optimizer and production scheduler that is integrated with the TOPI system, a tool for real-time monitoring of the power plant processes. Termis is also used for designing purposes for new networks (dimensioning). When changes in the district heating network has been done the geographic positions of new construction and its technical properties are updated manually to the Termis software. The data in Termis are technical information about pipes: length, dimensions, roughness factor, material, the high position, if pipes are in or above the ground, technical information about other components as heat chambers, Heat load of each heat consumer and other information about customers with an interface from billing system. Although Termis has a map function and also can store information about the district heating system does the respondent think that a GIS would be useful to have in Częstochowa as well. An additional function that the respondent require is an interface with customers contact information available and ready in Termis for text messages and/or e-mail to the customers when disruption in the heat delivery occur.

**Maintenance management in Heat Poland**

Maximo is used for maintenance of the district heating networks in Heat Poland from the beginning of 2013. In Maximo is the district heating network represented by a roughly divided structure from DH Poland down to main group of assets for pipes and components as preinsulated network, channel network, above-ground network, wells, heat substations etc. Hence the asset register in Maximo is not very detailed e.g. equipment of a particular well is not represented as individuals and a work order is assigned to a main groups of assets.

The opinions from Plock and Częstochowa are that the asset register still needs to be more developed. When Maximo was implemented in Heat Poland this roughly divided structure was set and there are plans to go deeper and more detailed in the structure in the future. The geographical information is communicated to the technicians that execute the work by paper maps. Both for the network in Wroclaw where a GIS is used and in Plock and Częstochowa. The maintenance work is described in work orders in Maximo. Functionalities as failure classes and failure codes are not being used. A suggestion from the Częstochowa respondent is that an improvement would be to update existing asset register and then integrate it with Maximo on a deeper level and with prospect GIS. Also the respondent from Wroclaw thinks that an integration of the assets register with Maximo and GIS system is a good idea. The respondents for the district heating networks in Poland thinks that a mobile device would be useful and that it should have the following functions: map of the district heating network, work orders, inventories and camera.
4.4 Heat Estonia
There are two district heating networks in Heat Estonia, which are situated in Pärnu(60km) and Tartu(115 km). The information has been collected by written questions to persons responsible for the district heating networks in Heat Estonia.

Pärnu

Documentation and geographic information
The GIS software used in Pärnu is the CAD based software Microstation V8i from the supplier Bently together with the database management system Microsoft SQL Server 2005. The technical information about the district heating network in the GIS software are technical information about pipes: area, length, material, age, piping types, the high position, ownership and if pipes are in or above ground. Additional data that the respondent think would be useful to have in a GIS is the technical parameter, roughness of the pipes and customer information as contact information. In parallel with the GIS software is technical information about the district heating network also documented in digital CAD format files, .dgn and .dwg. Geographical information about the network is documented in paper maps.

Maintenance and distribution optimization
In Pärnu Excel is used for maintenance management of the district heating network. The information about where a work will be performed is communicated by printing a map of the work area from Microstation and hand it over to the subcontractors. There is no optimization model for the network. When new constructions are planned is manually is schemes made in Microstation and calculations are made in excel.

Tartu

Documentation and geographical information
The data for the district heating system in Tartu is documented in the GIS or NIS, network information system, which the respondents prefer to name it. The GIS software is TeklaNIS 11.1 from the software producer Tekla software AB. TeklaNIS is updated manually and the background map is a vector map provided by the municipality. In addition to that are large wall mounted paper maps, which are updated every five years. From Tekla NIS it is possible to make export data in dwg and pdf files.

Distribution optimization
The system for optimization of the district heating network is the hydraulic calculation tool Heatdisp. It simulates the entire network in different conditions. Heatdisp is also very useful for planning new plant connections or main pipeline constructions to remote areas. Data can be exported from TeklaNIS to HeatDisp. Exporting data from TeklaNIS and import it to Heatdisp takes few clicks but occasionally some faults may come through so some manual fine tuning is in order according to the respondent. The information from TeklaNIS used by Heatdisp is data about the pipes, the location of the pipes, consumer data, heat plants and valves. The respondent does not think there is a need at the moment to fine-tune the model so it can be accurate enough to simulate the district heating network online.
**Maintenance**

Maximo is not used for maintenance of the district heating network in Tartu. A comment from the respondent is the following: “Maximo is a great tool for plant maintenance but that it lacks NIS ability.” The respondent also means that Tekla NIS has excellent maintenance support. The maintenance is not yet implemented/linked with TeklaNIS but they are working on that in Tartu. The first project will be to start rotating valves and document it linked to TeklaNIS. Tekla NIS also has an application for using mobile devices. It is not currently in use in Tartu but there is an on-going project where district heating maintenance data can be inserted and viewed on-site with mobile device (tablets) but the maintenance data do not include a map of the network. The respondent thinks a tablet enabled NIS/GIS system will be very useful.

4.5 Heat Latvia

**Jelgava**

The information has been collected by written questions to persons responsible for the district heating networks in Heat Latvia.

**Documentation and geographical information**

There is no GIS software for the district heating network in Jelgava. The geographic information about the district heating network is documented in paper maps and digital maps just for viewing. The technical data is documented in paper documents. The respondent thinks that an introduction of GIS would be an improvement.

**Maintenance**

Maximo is not used for maintenance of the district heating network in Jelgava. But inspection objects have numbers and each pipe has its own unique number. The respondent for Jelgava also thinks that a mobile device with a map of the district heating network, work orders and inventory would be useful.
5 Potential of utilize GIS for the district heating networks

The potential of using GIS for those two networks that do not have any GIS today are primary documentation. According to one of the respondents is it an advantage to have a GIS even for small networks, but functions needs to be dependent on the size and the complexity of the network. Maybe just the documentation would be enough for smaller networks as a start. The potentials that has been investigated in this study besides the basic use of GIS as a system for geographical and technical documentation are customer management as locating new potential customers, sales activities and customer communication, keep control of the status of the pipes in the district heating networks using a risk model in GIS and maintenance management.

5.1 Customer management

A considerable potential to utilize GIS is for customer management. Both regarding finding marketing “hot spots”, store information about estates in the GIS-map and communicate information to customers when disruptions occur.

5.1.1 Locate new customers

In for example Heat Scandinavia it has earlier not been needed to have a very active and offensive marketing strategy to find new customers. According to sales personnel in Heat Scandinavia, the competition between district heating and other heating forms as heat pumps has increased in recent years. This creates a need to find new customers in a more active way. Analyses can be done with GIS in order to find the most profitable estates to connect to the existing district heating network. The closer an estate is situated in relation to the existing district heating network the less will the cost be for connecting the estate. For example, an analysis have also been made in Heat Scandinavia where length of pipes situated on land owned by Stockholm municipality where calculated. The purpose of the analysis where not to locate new potential customers but to find out how much the municipality should charge Heat Scandinavia for using the land. This analysis has then been used also for sales purposes since it also gave the estates that have pipes underground as output. These estates where then compared to existing customers and owners of estates that where not connected to the network could then be contacted with offers to buy district heating. The above mentioned example is just one possibility to utilize GIS-ability. One could also make analyses where the estates within a certain distance from the existing district heating network can be found and then be matched against existing customers in order to really focus the resources on the right targets instead of contact estate owners in a random way. More targeted marketing would result in using the resources where it gives the best outcome.

A report from the Swedish branch organization for district heating, Svensk fjärrvärme, says that the use of GIS by Swedish district heating companies for initial feasibility studies has become more common. The advantages of GIS systems are that different aspects can be integrated in a map and give the whole picture. Which is why the authors of the report argues that it is likely to assume that GIS system will increase in significance for decision making as more types of data can be linked to the objects at the map. (Helgstedt, 2005) Characteristics of buildings that is of interest for decision making of new connections to the district heating network are:
• Age of the buildings, boilers and heating system. These characteristics gives information about if it is in question for the estate owner to change heating system.
• The size of the building, number of residents and the heat consumption can give an estimation the heat load is. (Persson and Sernhed 2004)

Whether the characteristics of the buildings in the investigated area are collected by telephone interviews or surveys can the information can be stored in a GIS where the information can be linked to each building and thereby easily found. The more knowledge about the estates in an area in consideration of expansion of the district heating network the better decisions can be made. Information about the buildings as if they have waterborne heating system, what the current heating method of the building are i.e. electrical and geothermal heating as heat pump or else. It is for example more difficult to convince the estate owners that district heating is a more attractive economic alternative in a city district or a block where the buildings for the most part are heated by direct electrical heating. The same can be assumed when the estate owner recently has invested in another heating system.

5.1.2 Sales
The GIS-ability gives the possibility to store information related to each estate at a map by using symbols for different properties. For example if a building has electric heating and not waterborne radiation heating. It is better to store information linked to the estates rather than to the customers since the ownership of the estates changes more often than the properties of the buildings on the estate. But there is also a gain to store information about customers and potential customers. For example if there is a symbol system for estate owners that has called and expressed interest in connecting there estate to the district heating network, then one can easily see that directly at the map and one estate owner will then not be contacted twice in a short time interval. In short: GIS gives the ability to organize the sales activities. The use of GIS for sales activities is being used in Heat Finland but not in any the other regions.

5.1.3 Communicate disruptions to customers
Communication to affected customers when disruptions occur at the district heating network is important to keep reliance and good relations with customers. The notifications need to be delivered to the affected customers in advance when the disruption is planned or as soon as possible after an unforeseen occurrence. There is a potential to use GIS as a part of the process for communication to customers. As an example of how this can be done is the communication process in Heat Finland described. There is also a potential for developing a similar solution in Heat Scandinavia and the model in Heat Finland will be followed by the as-is situation in Heat Scandinavia.

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4 Customer here does not mean end customer (if it is not for a small house) but the property owner or property manager. Since district heating is mostly sold to apartment buildings.
Heat Finland

In Heat Finland there is an on-going project for a new customer administration process. The reasons the project was initiated were that a new tool for district heating network interruption planning and support was needed and that customers were complaining because they were not good informed and that the webmap service was poor.

The following application was chosen for the new customer communication process: Tekla Operation management system, OMS, Tekla OMS Internet map service and Tietokoura SMS, which is connected to Tekla OMS via a web service interface. That means that GIS will be used for the customer communication process and the reasons for the choice are that Tekla NIS already is used to handle the district heating network information, the systems can be connected directly into the existing system which makes it easier to integrate and implement and the fact that by integrating interruption message system to Tekla NIS then all client data and location of disruption is obtained from the same place and there will be no need to collect any data manually. Tekla OMS, operation management system, allows monitoring situations at the district heating networks in almost real time. Planned and unplanned interruptions can be registered to OMS and interruption reports for officials and own purposes can be done automatically. The customer service can quickly and easily get more detailed information about the distribution situation and possible interruptions. The three applications in the OMS package are: Operation management system itself, OMS Internet map service and OMS interruption messaging. An application that was left for later decision is the OMS mobile part that would have allowed field workers to use OMS with tablet pc from actual site. With the new internet map can Heat Finland provide customers and media information about current and coming interruptions, work areas, the location of district heating network, measuring distance from house to network for potential customers and address search.

Tekla OMS interruption messaging is a tool for informing planned and unplanned distribution interruptions to customers, but the customers have to report that they want the service by themselves. With this can emails and sms messages about interruptions at the district heating networks be send by three different ways: manually where user generates and sends messages, half automatic where messages are generated automatically when interruptions occur and then send by the user or fully automatic message generation and sending. The main types of messages are: information about schedule of coming planned interruptions, information of start and finish of interruptions and updated information about interruptions. Tietokoura SMS client registering and sms service allows customers to order information service by sms or from the internet page and with that service can end customers in block houses be directly contacted, not only companies. Tietokoura also handles the actual sending of messages to mobile phones and a web service interface was created between Tietokoura and Tekla systems to get the data flowing. The Fortum user has to only use the Tekla system while Tietokoura manages the sending in the background. The Tietokoura messages can also be used for targeted customer messaging and marketing messages. (Kurra, 2013) The new operation management system includes the following functions:
• Registration the status of valves (closed/open) and showing instantly effects to the distribution situation.

• Possibility to analyse the networks by dynamical colouring of pipes.

• Faster and easier to close right valves since system suggests the right valves based on leak location.

• Valves that do not hold can be marked on system so it does not suggest those.

• Tekla OMS allows to monitor and control situation in district heating network almost real time around the clock.

• Interruption planning and handling for both planned interruptions and unplanned failure disruptions.

• Ability to make actions lists for handling district networks interruptions from planning to execution.

• Yearly interruption statistics and reporting for officials and own purposes according to requirements of the energy branch in Finland.
**Heat Scandinavia**

In Heat Scandinavia the process for communication of disruptions to customers is handled by searching for affected substations from the GIS software, dpHeating and then the corresponding contact information to the customers from the billing system and match the data manually as the flowchart below shows.

![Flowchart](image)

**Figure 8** Step 1 to 3 in the process for notifications to customers at planned interruptions.

![Flowchart](image)

**Figure 9** Step 4 to 6 in the process for notifications to customers at planned interruptions. (Lorentz, 2011)
In the first step is the pipe isolation or tracking function in GIS used to find out which pipes that is isolated (or switched off) when one or several selected valves is turned off. Then a search function in GIS is used for finding the affected substations where a search area is marked out on the map and then the measure numbers for the substations is selected. The measure numbers of substations for a certain customer group, for example all district heating customers or all district heating customers in a certain city district are exported from Billing, the software containing customer information, and imported to an excel template. In the excel template the measure numbers are matched with the customer information. Then the result from that is controlled by a web service for address search\textsuperscript{5} and after that the software word is used to make letter templates, which are printed out and then sent to the right addresses for notification, either the property owners or the property managers of the estates. The process is perceived as very time consuming and unnecessarily complex by the respondents, who participated in this study and who are working with customer notification in Heat Scandinavia.

Unplanned disruptions
The service for communication of unplanned disruptions to customers in Heat Scandinavia is aimed for large and important customers such as hospitals and estate owners or managers of large apartment buildings, who have registered that they want to have the service. The personnel at the service centre make a manual assessment of which area that is affected by the occasion of an unplanned disruption and then sms are sent out to all customers, who are assumed to be affected. The assessment is based upon which customers that have called and reported absence of heat delivery. A problem is that the predetermined areas for sms sending is divided into too large areas, which means that sms often are being send out to unaffected customers unnecessarily. What would be needed is to know more accurate which customers that are really affected and then send out information only to them. The system used for sending sms to customers is named UMS. Thus, there are two systems with customer information to customers: UMS and Billing, but there is no connection between these systems so contact information is stored in two places and sometimes do the information differ between the systems. Information regarding disruptions is sent out more precisely to district cooling customers than to district heat customers. The reason is that the number of cooling customers is less than heating customers, and that the networks for district cooling is smaller and less spread compared to the district heating network that is large and branched.

Further requests from personnel working with customer disruption are to allow customers to sign up for a notification service and even select how the customer wants to be contacted. Today are planned interruptions communicated by the website, letters two weeks ahead of the disruption and notes in doorways a few days before, while unplanned disruptions are communicated by the website and by sms. If consumers instead was given a choice of either email or letter when they need to be contacted it is likely that many of them would chose to be contacted by email. And if many of customers would be contacted by email instead would the communication with the customers be more cost and time effective. The request is that the customer oneself would sign up for the service and also select how the

\textsuperscript{5} Fastighetskalendern, SFKonline
customer wants to be contacted. Identified areas of improvement within customer communication in Heat Scandinavia are:

- The Ability for users to connect to a communication service, with own responsibility for contact details
- Targeted information to the affected area
- Improve the quality and the content of the interruption communication based on internal and external needs.
- Implementation of a systematic process management
- Measuring and monitoring the effect of the notification process.
- Develop and standardize communication processes during and after major unplanned disruptions

(Rylander, 2013)

**Information about disruptions on the website**
The information posted at the website showing planned and unplanned disruptions is visual and easy to understand as it shows where the work takes place on the map. By clicking at a location on the map, detailed information about that particular disruption is shown to the customer. Another well working service is that the customers can search for their area and then choose to subscribe to the information about the area by using RSS. The webmap is updated manually and not connected to the GIS software, dpHeating.

![Figure 10 Map of Stockholm, where works at the district heating network are marked.](image)
5.2 Risk model

A potential with GIS is to make different kind of analysis. In two of the regions, Heat Scandinavia (Stockholm) and Heat Finland (Espoo) are risk models made in GIS used to keep control at the status of the pipes at the district heating network in order to plan reinvestments and to define inspection intervals for preventive maintenance. Basically, the same risk model is used for the two regions but in Heat Finland the risk model is more fine-tuned. The fine-tuning was initiated by a thesis work made in 2012. (Hokkila, 2012) The aim of a risk model is to determine and visualize the strengths and weaknesses of the network. There is also an on-going implementation of a risk model for the district heating network in Wroclaw, Heat Poland. A risk model is made in GIS and is thereby visualized on a map. The functions of a risk model are:

- Determining the condition of the pipes and component of district heating network
- Visualizing the condition of the district heating network on a map
- Deciding inspection intervals of components and pipes that can be inspected (not in the ground).
- Forming a basis for decisions of reinvestments

Every pipe at the district heating network is given risk points in three different categories. The variables are the following, consequence, which is the loss of heat delivery to customer because of the damage of the pipe section. Probability that damage occur on the pipe and time for correction of the damage, which is the time the customer is without heat delivery because of the damage. The pipes with the highest risk index are the pipes with the largest dimensions, hence the pipes that distributes most heat. Other risk increasing factors are population density and the earth composition. The table below shows the five different risk levels and corresponding inspection intervals between six months and five years and the combination of consequence, probability and time for correction that leads to respective risk index.

<table>
<thead>
<tr>
<th>Risk index</th>
<th>Inspection interval</th>
<th>Combination (C:P:T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5 year</td>
<td>(0,0,0); (0,0,1); (0,1,0)</td>
</tr>
<tr>
<td>2</td>
<td>3 year</td>
<td>(0,1,1); (0,2,0); (1,0,0); (0,0,2)</td>
</tr>
<tr>
<td>3</td>
<td>2 year</td>
<td>(0,2,1); (0,1,2); (1,1,0); (1,0,1)</td>
</tr>
<tr>
<td>4</td>
<td>1 year</td>
<td>(0,2,2); (1,2,0); (1,0,2); (1,1,1); (2,0,0); (1,2,1); (1,1,2); (2,1,0); (2,0,1).</td>
</tr>
<tr>
<td>5</td>
<td>6 months</td>
<td>(1,2,2); (2,1,1); (2,2,0); (2,0,2); (2,2,1); (2,1,2); (2,2,2).</td>
</tr>
</tbody>
</table>

Table 1 Risk index and corresponding inspection intervals. The last column shows the different combinations of (consequence, probability, time) that leads to each risk index. (De Lorenzi, 2006)
As mentioned, the risk model is performed and visualized in GIS. The preventive maintenance intervals for the district heating networks in Heat Scandinavia are in Maximo. The risk model has decided the intervals and then the intervals were inserted to Maximo. This has been done once, about five years ago and there is no continuous update from the maintenance reporting in Maximo to the risk model in GIS. In Finland the risk model is only in use in Espoo at the moment since that is the largest and most complex network. However the risk model is not used so much for maintenance planning in Espoo either since it does not take all aspects into account. But since the risk model and the maintenance planning are both in TeklaNIS the updating of the maintenance intervals based on the risk model not an issue in Heat Finland. For example do a reported leak on a pipe section raise the risk index with one risk point hence the inspection interval for that pipe (if possible to inspect) reduces.

Figure 11 Example of the risk analysis in dpHeating, Heat Scandinavia
5.3 Maintenance management

Culvert system demands continuously maintenance and inspections since it is important to maintain high availability and reliability to ensure the heat delivery to customers. Importance of maintenance planning increases with increasing age of the district heating network. The key problem with maintenance management of technical distribution systems is to uphold the requested level of service, delivery and reliability to the lowest cost. Requested level of service means that one with adequate security upholds an acceptable heat delivery in terms of time, quantity and quality. (Ekström et al, 1998) Maintenance management is also an area with high potential to utilize GIS for the district heating networks. The reason why GIS is a suitable tool for maintenance management of the networks is that the network at the map is the asset register itself, which means that the network do not have to be represented or structured in another way than it actually is. In opposite to the case when Maximo is used for maintenance of the district heating network as explained in the as-is study for Heat Scandinavia.

Maintenance works are activities that aim to keep pipes and components of the district heating network in good condition in order to maintain supply security. There are two kinds of maintenance: preventive and corrective. Preventive maintenance is inspections or regular small works in order to reduce the risks of damage on pipes and components. It can be initiated by time intervals or by the conditions of pipes and components. Corrective maintenance is unplanned and urgent maintenance and therefore always initiated by conditions. Corrective maintenance consists of urgent operations, which are executed right after damage has occurred, for example when a leak is detected. The urgent operations can therefore not be planned and are normally of temporary character in the first step followed by additional operations that can be planed and consists either of a permanent repair or reinvestment. (Strömwall and Lemmeke, 1989)

Computerized maintenance management systems intend to keep control of assets, works, inspections, resources, spare parts and material. Whether the business is of small or large scale is the maintenance requirement similar. The system should easily be a part of the everyday work and make the management and reporting reliable and effective. A computerized maintenance management system where pipes and components of the district heating network are described and registered in a structured way gives better conditions for effective maintenance work. If the computerized maintenance management system is going to contain information that is already registered in other systems then the information should be easy to import to the maintenance system. The main principle is that data only should be registered once and thereafter be able to transfer other systems, either directly or within a certain frequency. Figure 12 shows a suggestion of communications between different systems (Strömwall and Lemmeke, 1989).
Maximo by IBM is the target system for maintenance management at Fortum. It is a maintenance, material and resources management system, mainly used for production plants at Fortum but also for district heating networks at some regions (www.fortum.com, 2013). The functions of Maximo are reporting, history, data analyses, basic information and equipment management, preventive maintenance templates or masters, stock management and purchasing. (Presentation Fortum Maximo, 2007) The Maximo maintenance system meets the requirements of financial requirements very well. But the asset register is not well adapted to the district heating network. There is difference in the use of the word ”location” between Maximo and GIS. In Maximo is a ”location” en component for example a well. In GIS is a ”location” en geographic point.

Since Fortum already have a target system for maintenance management, it may seem unnecessary to find out which properties a maintenance management system should have. But trough the as-is study it has been found that the Maximo system are not very well adjusted to the maintenance of the district heating network and therefore can a GIS based maintenance management system be an alternative. That or a better adjustment of Maximo to the works at the district heating network.

5.3.2 Requirements of maintenance systems
A maintenance system should fit well into the daily work and facilitate the planning and follow up of inspections and works at the district heating networks. The following required base functionalities of a maintenance management system for district heating networks are formulated on the basis of general requirement from two reports “underhållssystem för fjärrvärmecentraler - kravspecifikation att användas vid upphandling” and “underhållsstrategi för distributionsnät” together with inputs from the written questions and interviews in the as-is study.

Asset register
The asset register represents the district heating network and is the base to which work orders are assigned. All parts of the district heating network should be included here, how they are connected and the properties of each part. The district heating network can be represented in different ways in a maintenance system: in a table, in a tree structure or hierarchy (as in Maximo) or as a spatial asset register in a map (as in GIS). The asset register should include technical information of the district heating network.
Map
Since a district heating network in opposite to a heat plant is spread over a large geographical area is a map of the district heating network necessary for planning and execution of work.

Maintenance planning/work planning
Time intervals for inspection and small regular works are either decided by a risk model or by safety laws for large pipes. Automatic generation of planned preventive maintenance as inspections and regular operations. Work planning of preventive maintenance ensures to keep knowledge of the status of the pipes and the components of the district heating network.

Work order
Every work should have its own unique number so it easily can be followed and referred to in reports, invoices, purchase orders etc. Description of the work and additional documents as photos or drawings, how urgent the fault is, desired date for start and end time for correcting the fault, where the work will be executed, which resources that is needed, staff group, spare parts, tool and material needed. Predefined failure codes and failure categories for frequently occurring failures contribute to easier and faster administration. Work permit planning is needed for some works where the flow in the pipes is needed to be switched off.

Inventory
Inventory of spare parts and materials in stock ensures that one do not buy spare parts and material already in stock and keep control of stock catalogue, material out take and incoming delivery.

Financial management and resource planning
The maintenance management system, or a system linked to the maintenance system should keep control of purchasing and invoice processing as well as resource planning. Time planning and scheduling for both own resources and resources of subcontractors include the skills for different technicians as security, mechanics, welding or other helps to structure the work for the maintenance engineers.

Isolation planning
Function for finding which pipes that get disconnected at valve closure together with calculations of reduction of heat demand at a valve closure and the water volume needed to refill the emptied pipes.

Usability
A maintenance management system should be easy to use and not make the administration to time consuming. As mentioned in the section about “work order”, predefined failure codes and failure categories for frequently occurring failures will contribute to easier and faster administration. Photos should be easy to add when reporting. Work orders, locations and specific components should be easy to find. Therefore is a search function that works well required. So that one is able to search for work orders by components, geographic area, and status of the work order: planned, on-going, executed or postponed. An important aspect is also the availability even offline in case of an emergency.
Follow up and reporting
Reporting and statistics is important to keep control of the district heating network and for planning maintenance and reinvestments. Leak statistic and the cause of the leaks give knowledge of the district heating network. Specific for Scandinavia: reporting leaks statistics to the Swedish branch organization, Svensk fjärrvärme.

Extra functions
Extra functions to facilitate the maintenance work can be to have risk model for planning maintenance inspections and for planning reinvestments. And to have a mobile device with work orders, a map of the district heating network, gps and camera.

5.3.3 Solution cases for maintenance management
One potential of using GIS is to have a module for maintenance management in a GIS software for maintenance management, but that is not the only solution for handling the maintenance works of the district heating network. In this section are three possible solutions presented for maintenance of district heating network. Observe, these cases are only focusing on how the maintenance system support could be configured. It is not a question whether a GIS should be used for the district heating networks or not. A GIS is primarily a documentation system and the maintenance system as Maximo without GIS ability cannot replace the map functionality and the analysis that can be done in a GIS.

Maximo spatial management asset – Maximo together with ESRI’s software ArcGIS
Maximo spatial management is an integration between Maximo and the GIS software ArcGIS from ESRI. Maximo spatial asset management visualize the spatial relationships among managed assets and other mapped features and extends the capabilities of assets, location, work order tracking and service requests by adding maps to the functionalities in Maximo. With Maximo spatial management can work be created based on a set of assets and/or locations that have been selected on the map (Data Sheet_Mx_spatial, IBM website).

One feature of the Maximo spatial management is a GIS functionality inside Maximo, which gives the ability to search for an address or assets on a map. This solution improves work planning and analysis while eliminating the need for data duplication. But – since the solution is made for a GIS software, arcGIS that is not used for any of the district heating networks within Fortum today. That means that the whole networks and the documentation needs to be rebuilt in ArcGIS instead of the existing GIS, which would be a major resource and time consuming operation.

Integration between Maximo and current GIS-software
As mentioned would an introduction of Maximo spatial management lead to that the networks would need to be rebuilt in ArcGIS instead of existing GIS, which would be a major resource and time consuming operation. Another possibility would be to develop a brand new solution between Maximo and the current GIS-software. An integration, which would make it possible to for example click at a location at the map and then get the work orders for that location would make the maintenance planning more easy and effective. And the other way around to click on a link at a work order in Maximo and get the GIS-map would be a time-saver. With such an integration updating the asset
register and the documentation about the district heating network would only be needed to do in one of the systems and then the information would be automatically exported to the other system. The clear advantage is that both planning, the map, valve tracking, risk model and financial management would be interconnected and double updates would not be needed. In short: in the best case would an integration combining the two systems would simplify the work and reduce time for administration. An integration of Maximo and existing GIS software would need the developing of a brand new solution. Using Maximo together with ESRI:s software ArcGIS is an already developed solution.

**Maintenance module in a GIS-software**

Planning and documentation of maintenance can be done with GIS as in Heat Finland. GIS was also used for maintenance in Heat Scandinavia earlier and it is used by other district heating companies in Sweden e.g. Eon and Göteborgs energi. These two companies are using the same software from Digpro as Heat Scandinavia (www.digpro.com 2013). The advantage of having the same documentation system as maintenance system is that information about the network does not need to be exported to another system. There is also no need for double updates for information about the networks as the case is in Heat Scandinavia today. The issue with first defining a work that will be done on a component in one system and then to find the location for that component is not an issue when GIS is used for maintenance since the component and its location is chosen at the same time at the map. Work can then be assigned anywhere at the district heating network.

Regarding preventive maintenance, the risk model (if there is one for the district heating network) is documented and visualised in the GIS, which means that it will be easier to create a connection between the risk model and the inspection intervals and by that the risk model, hence the inspection intervals, can be changed in an automatic way. Other advantages are the search ability that makes it possible to search for works based on areas, not only components together with the visualization ability and user-friendliness. The disadvantages on the other hand are that GIS is a system for documentation, visualisation and analysis of technical and geographical information and not a system for financial management as handling costs in a detailed level, purchasing and invoices. Resource and material planning are not functions connected with GIS ability either. If GIS is going to be used for maintenance management as work planning, work descriptions and reporting then one or several systems are needed in addition to the GIS system for handling financial issues, own resources and subcontractors.

**5.3.4 Mobile device – Heat Scandinavia**

There is an on-going project called Fortum Mobile or FoMob in Heat Scandinavia, which aims to implement a mobile application with Maximo that is intended to be used by technicians working with maintenance at heat plants and at district heating networks. The functions of the application will initially be work orders and inventory and the application for work orders can be used both online and offline. If a technician creates a work order when one is offline, the system will be updated as soon as Internet connection is available again, but inventories can only be operated when there is an Internet connection. The idea is that the technicians at the heat plants will have for example three mobile devices per workstation. For distribution would either every technician have its own mobile device or it would be for example two mobile devices at each base station, i.e. the place where a working group is
based. The three different mobile devices that will be used are Iphone 4 or 5, Samsung Galaxy S3 or iPad mini. An idea is that those also can be used for other applications in the future, such as Sharepoint, DM\textsuperscript{6} and possible GIS. According to the written questions and interviews for the as-is study there is an interest of a mobile application with work orders, GIS-functionality and camera in all regions. This information is from an interview with the project manager of FoMob in Heat Scandinavia.

5.4 Export of data to external stakeholders and further potentials

One important aspect is the requirement to report where one’s own pipes are situated to external stakeholders since the pipes needs to be taken into consideration at reconstructions and expansions of other systems as water pipes, electrical cables or other activities such as private persons who are planning to dig at one’s land. In for example Stockholm, one should according to regulations, use the updated version of “Samlingskartan” when digging in public land to avoid damage of underground infrastructure. “Samlingskartan” is a map where all underground structures are drawn. The map is compiled by the Stockholm Vatten (the Stockholm water company) and consists of information from various cable and pipe owners in the city of Stockholm as TeliaSonera, Traffic Office, City Planning, Fortum Distribution, Fortum Heat jointly owned by the City of Stockholm, Stokab, Ports of Stockholm and Stockholm Vatten. (www.stockholmvatten.se/foretag/samlingskartan/)

Other important area of use is the ability of a GIS to visualize the district network or to document different kind of information linked to locations on the map. The ability to create theme-maps for analysing and visualization and ability to show information in a map instead of tables or other forms of categorizing makes GIS-maps a base for decisions regarding reinvestments and marketing. Another useful function in a GIS is the possibility to export statistical data to excel files for different analysis of the district heating network.

![Figure 13](image)

Figure 13 "Length per pipe type" Example of statistical data exported from dpHeating to excel, Heat Scandinavia.

\textsuperscript{6} Sharepoint: a platform for cooperation, DM: the documentation system.
In a GIS one can add maps of the ground and soil conditions such as background maps with geology and the presence of groundwater, which is important when planning to build new lines. In the written questions for the as-is analysis one of the questions was if the respondent thought a geological background map would be useful to have in a GIS. All the respondents answered no to the question but Heat Scandinavia already uses geological maps to get an idea of the work that needs to be done when to dig new ditches for pipes.

6 Discussion
A district heating network is a spatial system spread over a large geographic area. Representing such a system in a map is therefore very suitable. The ability to visualize the networks is one of the main strength of GIS systems. One can choose to highlight exactly the components, pipes or properties one needs to know more about at the moment. The flexibility in how to search for components, special properties of components, and geographic area at any size is also a very useful function, which is not the case in a traditional archive.

As mentioned in the section about the as-is analysis is the descriptions more detailed for the regions where there has been interviews and less detailed where there has been written questions. The information quality also differ between the different networks depending on how the respondents have experienced the questions and how detailed the answers from the respondents have been. Some respondents answered very detailed and some more briefly. One should keep in mind that the result can be affected on the personal experiences and opinions of the respondents. The personal opinion of a particular system or process may therefore affect the answers in the as-is analysis. Since the scope for this project is large, each potential area could have been a thesis work itself are the recommendations quite wide and not very detailed. The result for Heat Scandinavia is more detailed than the other regions since the thesis work is made in Stockholm and thereby has the availability to get information been easier for Heat Scandinavia. That is the reason why Heat Scandinavia has its own section in chapter 7 Conclusions and recommendations. A comment on the different as-is flowchart for the maintenance processes in Heat Scandinavia and in Heat Finland is that the process in Heat Finland seams more simple and has fewer steps. This may be due to the as-is processes are made by two different persons, whom may have divided the process in different ways.

For the networks that are utilizing GIS can the ability of finding marketing “hot spots”, document information for sales activity and connect the maintenance system be very useful. The main rule should be to only document data once and then export the data to other systems when needed. Duplication of data only leads to more manual work and administration and also more resources and costs. Many suppliers of GIS systems promote the ability of having all documentation and almost all functions as maintenance, sales and customer data in the same system as a benefit itself. But to have all functions in one system is not a goal in itself. If there is a well working system for maintenance, then it may not be a benefit to change it right away. One security aspect to take in consideration when creating an eventual integration between Maximo is that there is confidential information about the district heating network
in GIS as locations of secret tunnels, while that Maximo do not have the same level of confidentiality in Heat Scandinavia today.

Suggestions for further studies are to investigate how an eventual integration should be constructed, outline a strategy for how the regions could use the same systems and benefit from each other and a careful comparison of the GIS software used for the different networks to find out which system that works best for the district heating networks.

7 Conclusions and recommendations

7.1 General conclusions
The potential of utilizing GIS (or NIS) for the district heating networks are:

- Geographic and technical documentation
- Visualization
- Maintenance management
- Locate new customers
- Sales
- Customer communication
- Risk analysis and other analysis

The district heating networks within Fortum Heat differ in size, heat delivery and complexity and the situation regarding documentation, maintenance management and customer management differs a lot between the district heating networks within Fortum Heat. However, the basic documentation is similar. And since district heating networks has a technical life length of fifty years is it important not to lose the documentation for them. The main principle is that data only should be registered once and thereafter be able to transfer to other systems, either directly or with a certain frequency. It is important to make sure that data in GIS are accurate since this data form the basis for calculations, risk models etc. To those networks, which uses paper maps that is updated with an interval of a few years, is a documentation of the network in a GIS a huge potential that would open doors to other opportunities and applications. The networks could really benefit from changing documentation from for example paper documents and excel files to geographic information systems. Those networks are: Płock, Częstochowa and Jelgava.

A recommendation is to have one GIS target system for all district heating networks within Fortum Heat, which would mean that integrations made between the GIS target system and other target systems will benefit all regions. The advantages with using the same systems in the whole heat division are also that there would be many users with knowledge of the GIS system and that could collaborate with each other. Despite the regions have individual conditions and abilities can knowledge exchange and cooperation lead to progress and each region can assimilate the information that favours its own operations. Although one GIS target system has many advantages it may not be possible to establish this solution since it would require an evaluation of the most suitable GIS system for all the networks.
And it would also involve an extensive operation for those networks that already has their documentation in one particular GIS system to chance their documentation process entirely. The benefits of having one target system would most likely not compensate for the costs of chancing documentation system for each of the networks that have their documentation in GIS today. This argues against implementing one target system in the short term, but in the long term when a GIS system in one region is going to be replaced or introduced it would be preferable to choose one that is already implemented by another region and eventually one target system in all regions can be achieved.

### 7.2 Maintenance management

A maintenance management system for a district heating system should include an asset register where the district heating network is well defined and where all parts of the district heating network is included. A map of the district heating network is necessary since work that will be executed needs to be connected to a location at the network. A distinct and standardized way to exchange information leads to efficiency and contributes to avoid mistakes, which is why a maintenance management system include automatic generation of planned preventive maintenance, as inspections and regular operations based on laws or risk index for the pipes. The system should also include predefined failure codes and failure categories for fast and standardized reporting. Predefined failure classes and failure codes that corresponds to common fault on the district heating networks would decrease administration time and give higher search ability since all maintenance engineers and technicians would use the same template and explanations in free text would decrease.

Inventory, resource planning and financial management should be included in the maintenance system as well as reporting, usability and a search function that works well and where maintenance engineers and technicians is able to search for work orders by components, geographic area or status of the work order. A function for finding which pipes that get disconnected at valve closure is also important in order to find which customers that are being affected by a valve closure. A mobile device with maintenance and map functions is also needed for the district heating networks. These functions are required in a maintenance management system for a district heating network, but may not necessarily be in the same system. If the functions are in multiple systems then it should be able to transfer data between the systems to avoid duplication of administration and updates.

A maintenance management system with GIS ability is very suitable for district heating networks.

The recommendations use a maintenance module in a GIS system or to integrate Maximo with a GIS system. One very useful function if there was an integration would be the ability to search for work orders directly from the map by marking out an area and also the ability to go from a work order to the position of the map. In the best case would integration combine the two systems in order to simplify the work and reduce time for administration. The conclusions are that a GIS-based maintenance system meets the requirements of an asset register very well since the asset register is the network itself and a work can be assign to any location at the map and thereby get the exact locations of where work will be executed. On the other hand is GIS software not systems for financial management, while the Maximo software very well handles resources and financial management. To meet the requirements of
maintenance management of district heating networks system Maximo needs to be complemented with GIS-ability and the functions in Maximo needs to be more fine-tuned and adjusted to the conditions of the district heating networks.

A mobile device for map viewing and maintenance is used only in Finland. A project for implementing a mobile device for Maximo is on-going in Heat Scandinavia but not yet with a GIS application. In Heat Finland a mobile device called Toughbook with the GIS software TeklaNIS is used for execution of maintenance work.

7.3 Risk models
The risk models needs to be updated and fine-tuned in Heat Scandinavia and Heat Finland. The risk index should be modified continuously as the pipes ages, the status of pipes are controlled, leaks occur and the result from inspections is reported. This should be operated automatically in order to decrease administration and ensure that the risk model always is updated. Figure 14 illustrates the suggested continuous process.

Figure 14 Flowchart showing how the risk model and preventive maintenance should be connected to keep the risk model updated, and the inspection intervals at an adequate level in relation to the status of the network.

7.4 Locate new customers and using GIS documentation for sales activates
There is a large potential of utilizing GIS for documentation about customers and estates, which can lead to more targeted marketing and sales. The more knowledge about the estates in an area in consideration of expansion of the district heating network the better decisions can be made. In GIS can analysis be made in order to find estates close to existing pipes, which mean estates that are profitable to connect to the district heating network can be found. By matching these addresses with current customers new potential customer can be obtained. More active use of GIS when locating new customers and analysis of where non-connected buildings near existing district heating networks are situated would result in more targeted marketing. GIS gives the ability to organize the sales activities and personnel working with sales would benefit in be learning more about how to use GIS and get training of the functions available in GIS e.g. find estate owners through the search function in GIS.
7.5 Customer communication
The customer communication process should be more coordinated and automatized to reduce the risk of faults and minimize administration time, resources and thereby reduce costs. The largest requirement however would be to know more accurate which customers that are affected by interruptions and communicate to them in an efficient way. One possibility would be to use a system for distribution optimization as Termis to calculate heat delivery to customers in a disruption scenario and by that find out which customers that are affected by the disruption and contact these.

7.6 Heat Scandinavia
Maximo is an almost complete system for maintenance management for the district heating network in Heat Scandinavia today. The functions that needs to be added from GIS to maintain the network are:

- Isolation planning, tracking which buildings that is going to be without heat supply when valve closes. This needs to be known for works, which can only be done when pipes are emptied.
- The locations of “stop-jobs”
- Leak reporting
- The geographical location of pipes and components
- The risk model, which determines the maintenance intervals are in dpHeating and not in Maximo.

Regarding customer communication in Heat Scandinavia is it important to find out which customers that are affected by an interruption and send notification only to these. A problem is that the predetermined areas for sms sending is divided into too large areas, which means that sms often are being send out to unaffected customers unnecessarily. What would be needed is to know more accurate which customers that are really affected and then send out information only to them. The situation in Heat Scandinavia is that to many messages is being send out because it is not possible to know exactly which customers that will be affected by a disturbance today.

The requirement from personnel working with customer notifications is to make the communication process both for planned and unplanned works more automatic in order to save resources and time. A large timesaving action would be if the process was simplified so that marking the area in GIS and then have an application that automatically connects to Billing and automatically generates letters for the customers by a template. If consumers instead of letters were given a choice of being contacted by either email or letter is it likely that many of them would chose to be contacted by email. And if many of customers would be contacted by email instead would the communication with the customers be more cost and time effective. A recommendation is that the customer oneself would sign up for the service and also select how the customer wants to be contacted. The general issue regarding customer communication in Heat Scandinavia today is that much work is done manually, which means that it takes much time and that the risk of errors is larger than if the work was done automatically. Since it is humanly to forget something or make a mistake. The RRS service is really good and there should be marketing to customers so that they know that it exist and can register for it.
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**Interviews**

*Heat Scandinavia:*

GIS system manager – 12/4 2013

GIS expert - 16/4, 27/5 and 2/7 2013

Maintenance engineer – 8/5, 19/6 and 3/7 2013

Maintenance technician – 8/5 2013

Project manager, Fortum mobile – 11/6 2013

Three persons working with sales and customer management - 3/6, 24/6 and 26/6 2013

*Other divisions in Scandinavia:*

GIS user at renewables – 6/5 2013

GIS developer renewables – 21/5 2013

GIS user Electric solutions and distribution – 2/5 2013
Heat Finland

GIS expert – 15/5 2013

Maintenance manager – 22/5 2013

Respondents for written questions in Heat Poland, Heat Estonia and Heat Latvia

People responsible for GIS, documentation and maintenance in each region.
9 Appendix – written questionnaires

9.1 Written questionnaire: GIS Potential

1. General questions
1.1 How is geographic information about the district heating network documented and presented?

1.2 How is technical information about the district heating network documented? E.g. dimensions and material of the pipes.

1.3 Describe the method for updating geographic and technical information when changes in the district heating network has been done?

1.4 Are you using geological data (information about the kind of earth deposit e.g. soil or solid rock) to investigate an area before decisions about how to build new constructions is taken? If yes, is a GIS involved in that process? If no, do you think it would be useful?

1.5 Is a mobile application for digital maps used today? If yes please describe it briefly. If no, do you think it would be useful?

1.6 What tool or tools are used for planning of new constructions, new pipes in the district heating network?

1.7 If a GIS is used for the district heating network, please give the name of the software and the software supplier. If no, skip questions 1.8-1.10 and continue to question nr 1.11.

1.8 What information is stored in the GIS?

1.9 What background maps are used in the GIS?

1.10 What additional kind of information or functions do you think would be useful to have in the GIS?

1.11 If a GIS is not used for the district heating network, do you think it would be useful to implement a GIS for documentation of geographical and technical information at your district heating network?

2. Distribution optimization

2.1 Do you use a model for simulations of the district heating network? If yes, please give the name of the software and the software supplier. If no, skip questions 2.2-2.6 and continue to question nr 2.7.

2.2 What is the main function or functions of the simulation model?

2.3 What additional functionality would be useful in order to improve the optimization of the district heating network.
2.4 Please describe the method for updating the model when changes in the district heating network has been done?

2.5 Is there a connection between the model and a GIS? If yes, how does the connection work? If no, would it improve the optimization?

2.6 What information from the GIS is used by the simulation model? Whether there is a manual transmission of information or an integration between the programs.

2.7 If no, do you think a model for simulations of the district heating network would be useful? What functionality should the model have in order to improve the optimization of the district heating network?

3. Maintenance

3.1 Is Maximo used for maintenance? If not, please write the name of the software (and the software supplier) that is used instead.

3.2 When a work order is made for the district heating network, does the work order describe exactly where the work is going to be done (which component and the geographic position of it)? If not, how is that information communicated?

3.3 Do you use a risk classification system for the pipes and components in the district heating network? If yes, is that risk classification documented in GIS, Maximo or other?

9.2 Written questionnaire: Maintenance systems

1. Work orders

1.1 What geographical information would be needed to be defined in a work order for a work at district heating network?

1.2 When a work is defined, how is the geographic information about where the work is going to be executed described and communicated to the personnel that is going to execute the work?

1.3 Do failure classes and failure codes in the maintenance system fit well to faults that occurs on the district heating network? If no, what could be improved?

1.4 What functions regarding maintenance of district heating networks do you think is missing in Maximo? (If your not familiar with Maximo you can just skip this question)

1.5 Can an overview of locations where planned and on-going works at the district heating network be displayed in the currently used maintenance system? If yes, how is that displayed?
1.6 What information from the maintenance system needs to be in the GIS? (If a GIS is not used for the DH network you can just skip this question)

1.7 What information from the GIS needs to be in the maintenance system in order to make the maintenance system complete for the district heating network? (If a GIS is not used for the DH network you can just skip this question)

1. **Asset register**

1.1 How is the asset register defined?

2.2 Is a work order assigned to a group of assets or for a specific asset? Please describe the asset hierarchy in detail.

2.3 Does the current asset register work well for the network? Why or why not?

2.4 How do you think the asset register can be improved?

3. **Mobile device**

3.1 If a mobile device would be used for the district heating network, what information would be needed to have in the mobile device?