AALBORG UNIVERSITET

Potentials and Limitations of Web GIS in the Utility Industry

Master Thesis

Branko Kuridža

Jun 7, 2019

Aalborg University, Copenhagen

Master of Science(MSc) Programme in Geoinformatics

Title:

Potentials and Limitations of Web GIS in the Utility Industry

Author:

Branko Kuridža

Supervisor:

Carsten Keßler, Associate Professor, AAU Geoinformatics

Project period:

February 2019 – June 2019

ECTS:

30 ECTS

Education:

MSc in Geoinformatics

University: Aalborg University Copenhagen

AAU Master of Science Programme in Geoinformatics

A. C. Meyers Vænge 15

2450 København SV

Denmark

Abstract

With today's emerging technologies, the evolution of the Web and Web applications, the popularity of IoT devices, the concept of Smart Cities and Smart Grid, all the data seems to be connected. Most of the sensors and monitors which are bone to the majority of the modern technologies have "awareness" of its location. One of the industries handling mostly with spatially related data is the utility industry. With population growth and human aspiration for sustainable resources, pressure on utilities grow. It is interesting to perceive how the utility sector can use modern technologies to overcome these problems and how GIS, today's integral part of utilities, merged with Web can help in this process. The principal part of this project will be a focus on GIS technologies related to the utilities. What role GIS merged with Web technologies, play in the utility industry and how it helps it overcoming modern problems. Furthermore, the analysis will be conducted with an observation on the GIS market and software's this market offers for the utility sector.

Table of Contents

Table of Figures

List of Tables

1. Introduction

The Internet is nowadays omnipresent. It is becoming more and more part of ordinary life. People use it for fun, private or professional reasons. Affordable prices of PC's and mobile devices just support spreading this trend globally. By some reports, as today, 56.3 % (InternetWorldStats, 2019) of the world population use the internet regularly. A growing portion of it (Internet of Things) devices, Cloud-based services, progressive web apps, and Web 2.0 technology seems to add a new dimension to all industries and fields. The utility industry is no exception and with concepts of Smart Grid, Smart Cities, big data, SCADA system and trend where renewable energy is in focus support might come from the internet and web technologies for this industry.

"Energy companies and utilities operate in a world with many problems – population growth, climate change, social conflicts, resource shortages, and loss of biodiversity. Additionally, companies must cope with aging infrastructure and workforce. The increasing complexity and severity of these problems portend a challenging future for society, particularly for energy organizations" (Meehan, Brook, Wyland, 2012, p. 888). Dependency on energy in modern societies is one other segment in this chain where utilities need to maintain a constant delivery of power and maintain delivery networks. By the International Energy Outlook, 2016 (2016) released by the U.S. Energy Information Administration world energy consumption will grow by 48% between 2012 and 2040. By the Sioshansi (2016) "There are many who believe that the electric power sector is entering, or has already entered, a new phase in its evolution, requiring significant changes in its operations, business model, culture, and how it is regulated". (p. xxxi.)

With challenges utility industry experience today question is how modern technologies can help to solve or reduce these demands and pressure? We witness Cloud, IoT, Smart Grids and Smart Cities trends emerge nowadays and the question is how these technologies can benefit the utility industry. The fact is that most of the data in utilities have spatial context and “utilities used maps since the beginning of the utility industry” (Meehan, 2013, p. 6). GIS became an integral part of the utilities because of its architecture and functionality. “Regardless of the type of utility services, GIS is essential to determine infrastructure requirements, forecast vulnerabilities using real-time data, prioritize repair-maintenance tasks as per geographic specifications and ensure interoperability of different business components” (Nhede, 2019). GIS is “glue” between databases and IoT, SCADA systems, municipal datasets, and other field data with spatial context.

Web GIS

“Web GIS is a type of distributed information system, comprising at least a server and a client, where the server is a GIS server and the client is a web browser, desktop application, or mobile application. In its simplest form, web GIS can be defined as any GIS that uses web technology to communicate between a server and a client” (“ESRI”, 2019).

Web GIS advantages over Desktop GIS is its scalability, ease of sharing a map, better cross-platform capability, lower cost and ease of performing updates on client-server systems. It is hard to imagine that Web GIS could change Desktop GIS. It seems that Web GIS task is not changing Desktop solution, but expanding the possibilities with a combination of Web technology and GIS. With advantages of the Web, GIS services from one computer (server) can serve multiple users (clients).

Term Web GIS can be confused with Internet GIS. “Web GIS is a close term to Internet GIS. These two words are always used as synonymous with each other” (Hojati, 2014). However, to better understand these differences one must understand the difference between the Internet and the Web. “The World Wide Web, or simply web, is a way of accessing information over the medium of the internet” (Beal, 2018). Internet GIS is a broader term of Web GIS, however, the Web is nowadays the most attractive service on the internet and it is a reason why term Web GIS is much more used than Internet GIS.

How the utility sector uses GIS?

By the Meehan, Brook, and Wyland (2012, p. 889) among problems utility industry faces, GIS is most suited to solve:

- Data management

  Related to managing IoT devices, sensors, smart meters, trucks, and people.

- Analysis

  From the decision-making process of where to locate new wastewater disposal network to the optimal location of the wind farm.

- Mobility

  Fieldwork data collection and integration with office dashboards.

- Operational awareness

  Simply visualizing business spatially for better identification of potential improvements, faults, new customers, etc.

GIS software is standard kit for every sector of the utility industry, dealing with a big amount of data with spatially features, GIS is essential. Whenever data have information about the location of the event or asset it can be incorporated into the GIS. If users report lower quality of services, this customer can be localized and additionally layer with customer satisfaction could be created. With various layers visualized, it is painless to present data to various departments and gain an easier understanding of ongoing processes. This is just one example among many, and the list could go on.

Web mapping and utilities

GIS system benefits for utility sector are well known, but could Web/Cloud GIS provide utility GIS and MIS integration more efficiently, easily scalable systems with the possibility to access it from the field and enable better communication with customers through the maps?

More and more companies in the utility sector are adopting the notion of Software as a Service. It seems that cloud computing is more suitable for management and sharing datasets, cross-platform compatibility, and centralized database. Client-Server technologies in GIS are a trend and it seems it will stay that way for some time now (Meehan, 2013, p. 26). Due complexity of data in the utility sector users will need a client which is capable of capturing and processing detailed data sets. Desktop – client-server model is evolving to incorporate web-based editing and cloud technologies. The complexity of data sets, merging of scientific and engineering fields in the process of designing and maintaining networks in the utility sector are looking forward to more centralized and simpler solutions.

1.1. Problem statement

The fact is that the Internet and Web provide an opportunity for almost every industry to grow and utilize modern applications and available computing power. A utility sector could relate to this fact and its changing with the development of modern technologies. Knowing that the majority of the data related to the utility sector have spatial context and that GIS is present in most of the processes related to this industry consolidation between Web and GIS is inevitable. According to the Meehan (2013) “In order to leverage spatial component of the data, it’s critical that utilities incorporate their GIS with their other major corporate systems, like their financial, material management, network analysis, asset and work management systems, and their smart grid systems such as SCADA, distribution management systems (DMS), and meter data management systems (MDM)” (p. 19). And with all modern systems of communication studies from the United States and the UK implies that utility industry customer satisfaction is among the lowest of all industries (ASCI, UKCSI, 2018). With this in mind, this paper will focus on how GIS vendors follow trends and problems utility industry encounter today and how does GIS merged with the Web has a tendency to become more integrated into utility sector offices and field devices.

1.2. Research questions

Based on the introduction, research questions are:

1. What is the advantage concretely in the utilities from the fact that Web-enable support for a variety of devices and platforms?

   This question will be answered in data analysis and in the discussion/conclusion. At the beginning is a word about problems utility sector faces and how GIS helps to overcome these problems. The final chapters of data analysis are about Web GIS, how it expands the functionality of desktop software and overcome challenges utility industry faces.

2. How software solutions on the GIS market address modern problems that the utility industry encounter?

   Answer to this question is an overview of solutions which GIS suppliers provide today and in which areas GIS evolve.

3. With the premise that companies search for one software which would merge all functionalities required for utilities into one, can Web GIS come as a solution?

   The implication of this question could be seen throughout the whole project. Started by GIS evolution from simple map viewer to the possibility of performing complex analysis. Followed by the mention of merging software's strictly related to utilities with GIS and finally to the cloud and SaaS features.

1.3. Project layout

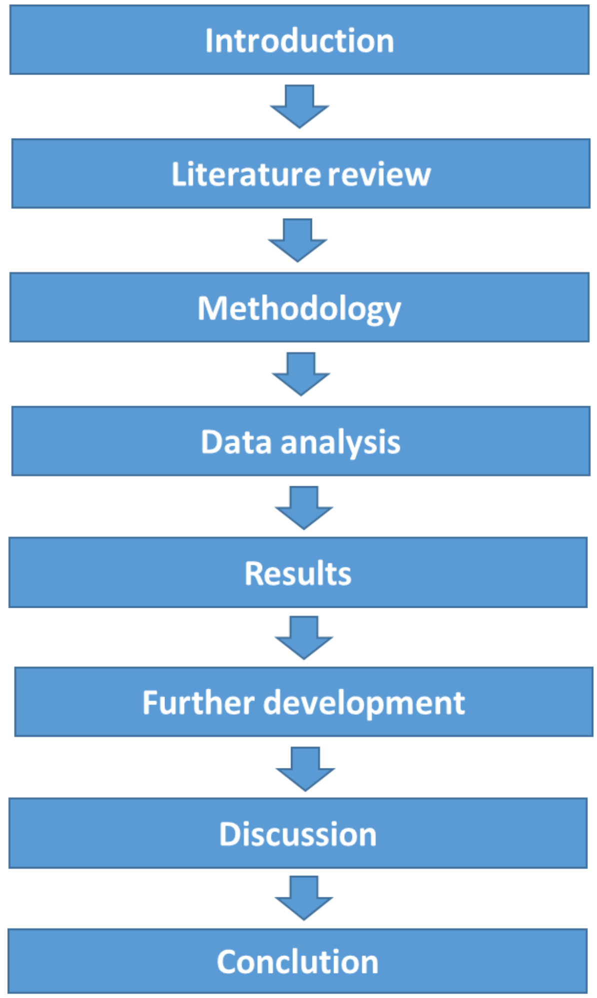

Figure 1 Project layout

In the figure above, the project layout is presented. The logical structure of the project follows the introduction – literature review – analysis – conclusion concept. This was the most logical structure of this project. The reader is introduced to the problem; the literature overview gives understandings of today's trends and state of GIS and utility relation. This is followed by analysis and evaluation on how GIS market follows previously described trends and pointing out characteristics related to the utility sector. Finally, conclusion and discussion provide an answer to most of the research questions. Although, with objective writing, the reader is able to cognizance answer through the project.

1.4. Delimitation

One of the inspirations for this project was ESRI's ArcGIS Pro and package Utility Network. In an attempt to understand complicated relationships between Desktop and Web GIS, and how these definitions evolve led me to this project. Regarding this, in a moment of working with Utility Network, this package provided "out of the box" functions and features specifically for gas, water, wastewater, and electrical utilities. Definition of utility sector is not clear, and boundaries of what industries are included vary. By the online article International labor organization (2019) utilities included water, electricity and gas industry. By Wikipedia (Wikipedia, 2019), the public utility sector is formed of "Coal, electricity, natural gas, water, sewage, telephone, and transportation." Finally, a definition which this project is led by is provided by GICS (Global Industry Classification Standard) and a paper published by MSCI (MSCI, 2019) where it states that "The Utilities Sector comprises utility companies such as electric, gas and water utilities. It also includes independent power producers & energy traders and companies that engage in generation and distribution of electricity using renewable sources." Term utilities and utility sector/industry in this paper are referred to as the GICS definition. Regarding Web GIS, which is one of the most preferred terms in the project, all the technologies related to the Web GIS and Web mapping are embraced for easier understanding. Finally, in the data analysis part, when analyzed features of the software, the name of the software in some cases are related to the company as well. The example does QGIS provide API for users, yes, it does. This confirmation is related to the QGIS project in general. This generalization is made because users with ease can use services from the provider they are using, or, are subscribed already. Additional expenses for the users are not considered.

2. Literature review

The web is evolving with every day and its presence in the modern world affected almost all sectors and industries. By the Netcraft survey (2019) on the web, there are more than 1.5 billion websites (including and Web applications) in the world. This clearly implies that Web technologies are expanding rapidly. Research conducted by "Synergy" (2018) research group states that "The enterprise SaaS market is now generating $20B in quarterly revenues for software vendors, a number that is growing by 32% per year. "On the other side, a considerable amount of literature reporting that IoT, Smart cities and Smart Grids will change our cities, areas we live in, the way we interact with technology, etc. "The first task that cities must address in becoming smart is to create a rich environment of broadband networks that support digital applications" (Schaffers et al., 2011, p. 435). All of these technologies are based on distributed systems and internet technology. Majority of them require location information of the user and/or the device. On the other hand, GIS today is not exclusively available for Desktop but it emerged to the Web and Cloud services. It is hard to predict the future of GIS but by the Jere (Geospatial World) it seems that "There will be opportunities to reduce operating expenses by, among other things, accessing and paying for GIS functionality on an 'as needed' basis through a cable and not having to invest in the technology overkill of boxed desktop products." Interaction between desktop GIS and Web has never been bigger and this evolved into fully functional Web GIS systems. A number of Desktop GIS solutions are growing every year and the majority of utility companies adopted the solution of one GIS vendor or another. Depending on the choice, it is possible to expand, modify and adapt GIS to the needs of their specific company and industry. Distributed systems and client-server architecture enable substantial versatility in architecture and technologies used for building applications. This opens the possibility for Web GIS to be built on various architectures of the software within GIS. In addition, W3C standards (W3C, 2019) allow utilities to adapt and merge GIS more into their management systems and business models. The literature on the subject this project relates is not very broad but overlapping and merging technologies such as Web and GIS provides extensive research material. The literature reviewed during the writing this project could be splinted on four different areas of research: GIS, Web GIS, Web, and the utility sector. In order to properly identify relationships between these four complex variables

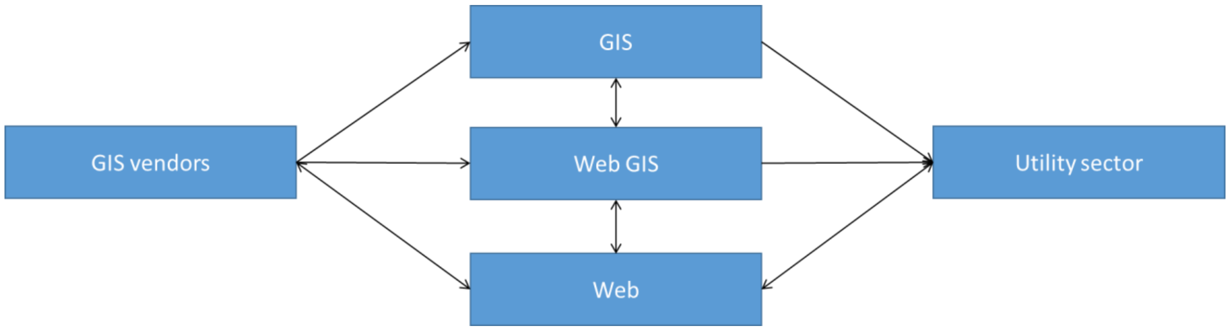

Figure 2 Relationship between GIS, Web, Web GIS and Utility sector

3. Methodology

The methodology chapter is where the theoretical framework, research design, and theoretical background are discussed. Furthermore, methods conducted in the research will be explained with the perspective to address research questions.

3.1 Research design

At the beginning of this project, author decision was to conduct research on to technical component and performance of Web GIS applications and Desktop applications for the utility industry. However, with a lack of standardization in Web GIS features, various solutions and not big popularity for Web GIS in the utility sector, the scope of the project is changed. The general research design can be categorized as a qualitative research design. According to the Denzin and Lincoln in their Handbook of Qualitative Research, they describe qualitative research as "… an interpretive naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings people bring to them." (p. 3) The main accent is description, with an objective approach on demand and offer between utility sector and GIS market. GIS vendors are selected based on multiple criteria and then described. With the objective approach, only features and characteristics of software related technologies are described, without evaluating. The ultimate goal of this research was to gain an in-depth understanding of the relationship between these two variables and with perceived knowledge better understand the reason for today's trends and the situation.

3.2 Data collection

Data collection was necessary in order to provide a base for further analysis. In order to perceive and understand the utility sector and GIS market, this part of the research was invertible. For this research, the most used method was data analysis. However, a survey was conducted for a better understanding of today's trends in enterprises when handling GIS data related to the utility sector. Data analysis refers to a literature overview and content analysis for GIS software and utility sector. In order to perform content analysis, it was required for distinct software suitable for this categorization. For these three tools were used - Capterra, D2 Crowd, and Google Search Engine. For all search engines, two search terms were performed. First was GIS software and second Web GIS software. The first platform, Capterra is online "peer review website" (Wikipedia, 2019) which works based on validated user reviews. "All reviews are manually examined by our team of experts in an effort to ensure published reviews are from verified sources and provide helpful content." (Capterra, 2019). D2 Crowd is based on the same business philosophy as Capterra. By the information from the D2 Crowd (2019) rating of the software or company is affected by the review of the users, the quality of the review, popularity of the software, the age of the reviews and overall customer satisfaction. However, Capterra and D2 Crowd have offers for paid reviews on specific software, on top of that, the ethical concept of paid marketing and promotion of these websites is to be discussed. That is the reason why Google search Engine is added into this category. For the research top results of queries were considered.

For popularity, evaluation has used a website called SimilarWeb. SimilarWeb state (2019), that it "… leverages a growing dataset of hundreds of thousands of websites and apps that share their directly measured data, including Google Analytics, Adobe Analytics, app developer data, and others, to test and calibrate the reliability of the insights produced from other sources." Data for every company is observed and number (if available) of visitors in the last six months is considered for research.

3.3. Survey

By the Jansen, Harrie (2010) "The qualitative type of survey does not aim at establishing frequencies, means or other parameters, but at determining the diversity of some topic of interest within a given population." A survey in this project was conducted for a better understanding of GIS trends and facts. It is carried out through the Email contact of the companies and personal contacts of the writer and employees of the companies contacted. Out of Fifty-six (56) companies in Europe contacted by e-mail, five (5) completed the survey successfully. Because of the low sample size with the successful responses, these results were generalized and presented in the research.

4. Data analysis

Data analysis was required in order to compare, perceive and better understand forms of today's GIS. For a deeper understanding of ongoing processes and trends in today's software technology of GIS in relation to utilities, it was necessary to analyze and research how the utility sector uses GIS and what are the trends today. Furthermore, how much these systems which are still in the phase of evolution are able to integrate into an already established company business model. Followed by this, Desktop and Web GIS solutions were analyzed. In order to compare and perceive how GIS market conforms to the trends in the utility industry, it was necessary to analyze what solutions, packages, and extension vendors offer for the utility sector. GIS software is divided into two groups of software. The first group is software who support and develop Desktop software and Web GIS. The second group was formed out of vendors that support and develop only Web GIS solutions. Reason for this separation comes from the fact that some particular GIS enterprises who supports desktop solutions are many years on the market have mature solutions, most of the GIS users are familiar with one of this software, and big chances are that some of these GIS solution majority of utility companies already use. In the other hand, this is mostly not the case for the enterprises which develop only Web GIS solutions. Web GIS vendors mostly focus on their mobile support, great developer community, and scalability.

GIS vendors and software are selected based on the popularity, years on the market, and provided features for the utility industry in terms of expansions and packages. For the selection of software to be evaluated, in the first place, three platforms were used. The popularity of software is determined by the numbers of visitors in the last six months per the website. This was discussed in the Data collection section of the document. During the research, it turns out that Web-based GIS platforms can be grouped once again. Web-based GIS platforms can be grouped by software which is the end – users oriented or developer – oriented. The first group focuses to replicate the GIS experience in the Web browser. These solutions main advantages are scalability and price. This will be discussed further in the report. The second group also called as an online platform for developers, provide a SaaS cloud solution with orientation for the developers to create an application on top of their services.

4.1 GIS AND COMPUTER TECHNOLOGY

"Computers transformed geography drastically. They enriched the discipline of the geography with the development of the automated geography, GIS, and virtual geography department. Although primitive computers existed in the early 1950s, their existence was not significant for geography at that time. The emergence of GIS software happened in the second half of the 20th century" (Sui, Daniel & Morrill, Richard. , 2004, pp. 82 - 83).

With the appearance of computers, their impact on geography as a field started to change it both as an academic discipline and geography as applied science. Although in the 1950s and 60s computer was slow by today's standards, still, they were able to process large datasets, perform statistical estimation much faster than it was possible before of computer existence. "The history of GIS, as software application began with multiple projects in the 1960s, of which perhaps the best known and influential was the Canada Geographic Information System (CGIS), developed by an IBM team"(Goodchild, 2018, p.2). The first known use of the term "geographic information system" was by Roger Tomlinson in 1968 (By some resources 1963 (Smith, Goodchild, Longley, 2018, p. 1)). "Without wishing to suggest that the next wave of innovation in computing determined the accompanying transformation of—and, ultimately, divisions within—quantitative geography, the growing availability of desktop computers in the 1980s inevitably had a profound effect on how we 'do geography with computers'" (Harris et al. 2017)

With the computer on every geographer's desk, it was likely that geography as a discipline will advance with new ways of using computers for both simple and challenging tasks. This is proven by the increased quality of data with better spatial and temporal resolutions. "With maturing GIS technology and the further convergence among remote sensing, global positioning systems (GPS), and computer cartography visualizing spatial data and map - making has been made much easier" (Sui, Daniel & Morrill, Richard., 2004, p.83).

"First GIS desktop software was released in 1986 by MapInfo and it was the product for Mapping Display and Analysis System (MIDAS)" (Harris et al. 2017). Initially, it was accessible only for the DOS operating system. From 1990s GIS expanded substantially. However, companies were not so keen to adopt GIS software at that time. Gradually, the importance of spatial analysis as a tool for decision - making became recognized. Software's could perform analysis on both vector and raster data and GIS was introduced to classrooms and companies. Furthermore, "after years of development, 24 satellites were into space and the global positioning system was considered fully functional in 1993" (Mai, 2017). Despite its civilian availability GPS was "degraded" for non – military purposes, meaning it was less precise in commercial than in military applications. This changed in 2000 with President of United States signed a policy directive to turn off Selective Availability and provide the same accuracy to civilians that were afforded to the military. This, of course, opened more possibilities, changed the way of how GIS users collect and manage geographic data. GPS today provides a key component in providing high spatial quality of data and enables new methods for gathering and analyzing data.

Today, computers are a part of everyday life. Processor speed is measured in gigahertz and multi-cores, graphics cards are compatible with rendering millions of polygons without problems and GIS data storage is measured in terabytes. It is significant that a vast amount of data is available for storing, processing and analyzing for every field related to the computers these days. According to Cisco Systems (2019), "global IP traffic will reach 4.8 zettabytes (1000^7 bytes) by 2022". Considering all the traffic on the internet and available resources, data is becoming more accessible and with better quality. Development of computational geography and GIS is driven by innovations in computer technology. Interestingly, the number of commercial GIS software's is in constant increase and developers and users are consistent in building GIS software in an open and collaborative way. According to some articles on the web (GISGeography, 2019), currently on the market are available more than a thousand GIS applications, both open source, and commercial. However, the exact number is almost impossible to know because new applications are being developed daily, while, at the same time others stop from being developed and used.

GIS today is a product of many influences and trends which affected it on its path of evolution. It grew with the raised availability of computers, better software and hardware specifications, GPS, cloud computing, internet, machine learning, and many more influences on geography and GIS. It is not only a desktop solution anymore, but accessible today through mobile devices and everywhere where internet is available.

4.2 GIS AND WEB

The internet has matured. A new generation of websites is characterized by name Web 2.0 or also known as Internet 2.0. "The term of Web 2.0 is coined by publisher Tom O'Reilly in 2004" (Lewis et al. 2012). However, it is mentioned the first time by Darcy DiNucci in 1999 by One design. Principle of Web 2.0 application is that application or service runs through a web browser, rather than being a stand-alone application running in the particular operating system. This enables the user to access application despite what operating system or the device they are using. An approach like this has many benefits. It enables developers one cross-platform application with the same functionality regardless of the operating system. On the other side, the user can benefit from the latest version of the service without having to upgrade any software on its device.

Characteristics and features of Web 2.0 is the bone of Web GIS. These characteristics involve much more interactivity between a web page and user than it was possible with its ancestor Web 1.0. It is continually evolving and its technology includes server – software, messaging protocols, standard oriented browsers with plugins and extensions, various client applications and content syndication. All of these features enable Web GIS and many other web applications as we see today. New concepts and technologies being developed constantly. One of the main reasons for this is openness, simplicity, and ubiquity on top which aspects web is found. The concept of the openness is based on the fact that Web follows a set of open standards, certified by a general standardization body - World Wide Web Consortium. The principle of simplicity has two aspects. One is the simplicity of usage and other simplicity of programming. The third principle relates to the aim of the largest possible audience and enables cross-platform accessibility.

All of these factors bring popularity to Web applications and the rapid development of those.

“Internet GIS can be defined as network-based geographic information services that utilize both wired and wireless Internet to access and distribute geographic information, spatial analytical tools, and GIS web services” (Mortez, Shekhar, Xiong, 2008 p.594). The major concept of distributed GIS systems is to move traditional proprietary architectures of applications and data to standard – based components of Web with specialized functions that can interface with other components and service providers. According to Li (2008) “web technologies main implementations were in an application such as spatial data access and dissemination, spatial data visualization and exploration, spatial data processing, analysis and modeling, collaboration and support using public participatory GIS and integration of web-based technologies with mainstream enterprise computing processes and environments”.

“The Web-Based GIS combines the ability of the GIS to make decisions with the accessibility and interactive power of the internet” (Forbes, 2006). Before the internet became widely popular GIS was mainly centralized and reserved for geographers and scientists who had knowledge for effective handling GIS software’s. However, Web GIS started its existence even before the modern Web and internet we know today. GIS was able to use the internet to make its concepts more open, accessible and mobile. “In 1993 the Xerox Corporation developed its Map Viewer as the first experimental tool for interactive spatial data exploration over the Web” (Veenendaal, 2015, p.32). “The Alexandria Digital Library Project funded by the National Science Foundation established the first distributed library service for spatially referenced data” (Dragicevic, 2004, p.80).

Early implementations of Web GIS were characterized by releasing and publishing static maps, followed by interactive maps with enabled pan, zoom and identify features. After this, comes advanced cartographic and Geo-visualization tools. Evolution of Web GIS helped it to evolve and expand into Internet-distributed GIS with the capabilities to interact with multiple and heterogeneous systems, servers and be able to support advanced GIS functions.

3.2.1 Web GIS application architecture

“Web GIS is a type of distributed information system, comprising at least a server and a client, where the server is a GIS server and the client is a web browser, desktop application, or mobile application. In its simplest form, web GIS can be defined as any GIS that uses web technology to communicate between a server and a client” (ESRI, ArcGIS Enterprise, 2019). Today Web GIS represents a fully functional GIS program in a Web browser or other client program, allowing a broad range of functionalities, analysis, access to the spatial databases, etc. Majority of Web GIS applications are based on the client-server model. Characteristic of this model is that the client sends a request to the server and then consume response in the desired way. Within Web GIS this model can be simply explained as a three-tiered system where the web browser represents client, server represents logic and database represents the data.

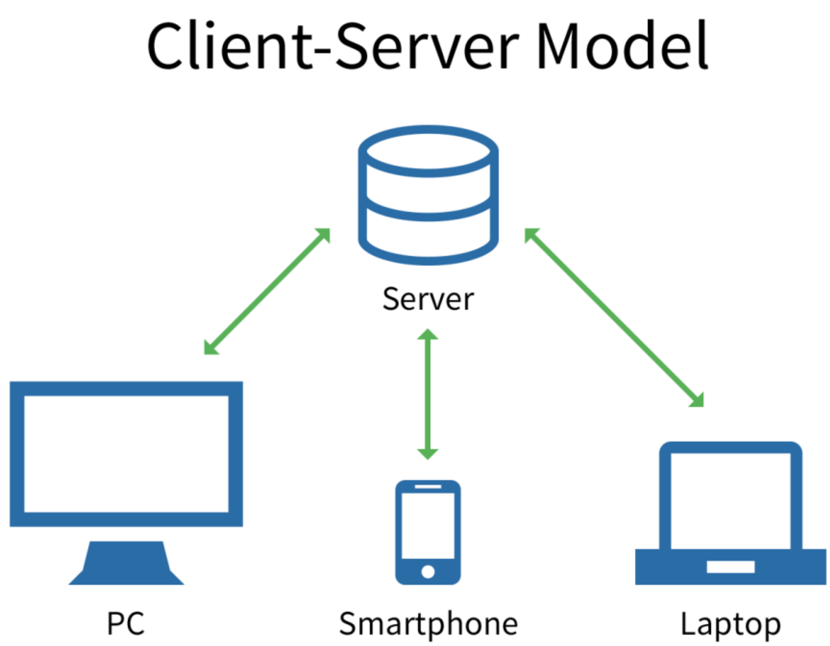

Figure 3 Client - Server Model. Retrieved from techterms.com/definition/client-server_model

The three-tiered structure represents a simplistic structure for understanding components of Web GIS. However, these architectures usually are consisted of multiple layers and tend to be more complex. Capabilities and flexibility of Web GIS can be extended greatly when architectures consist of components that can be on the computer in any part of the world. The application is capable of getting the data without downloading and storing the datasets. Through the API's it is possible to access a different variety of datasets, "real-time" data, geospatial analysis tools and processes that reside within other systems.

Three-tier application elements stand for the clear partition of elements in this model, although in some cases this division is not followed exactly. Any combination of these partition components can and often are implemented in Web GIS applications. This depends on different occasion, complexity, application use and many more factors.

According to the Encyclopedia of GIS (Shekhar, Xiong, 2008) following component, implication frameworks are present within Web GIS:

a) Distributed presentation

This configuration is described as a very thin client where data, logic and even part of the client resides in the server environment. The client is responsible only for presenting a portion of the interface or a mirror of the server environment in manner developer/user needs or requires.

b) Remote presentation

The entire appearance and presentation functionality of the application is on the client side while logic and data are on the server side. One of the examples would be server based GIS that uses CGI to process users requests and then returns feedback to the client. The next step is retrieving content by the client and presented in a suitable manner.

c) Distributed function

This framework splits the logic element between the client and the server and appearance is rendered entirely by the client. Usually in this model "lightweight" processes and functions are executed by the client, while more performance hungry functions are sent to the server for processing. Examples for basic functions performed by clients are zoom, pan on the map, while function such as image analysis or address matching is performed by the server. Logically, results are returned to the client and then presented or used by the client.

d) Remote data access

This framework/architecture is also known as a thick client. Application logic and presentation/appearance of the application are done by the client while it relies on data from the remote database. In this case, the client is responsible for all the logic operations. An example would be the application that uses SQL API's to make calls directly to the relational database.

e) Distributed database

In this framework/architecture, logic and presentation of data are done by the client while the database management function is split between multiple servers.

3.2.2 Web GIS standards

Web GIS opens up a great possibility for geospatial data to be shared, easily accessed and easily integrated into mainstream computing. Challenge many developers and GIS scientist encounter was how to integrate different solutions and create a widespread infrastructure of interoperable geoprocessing software and geodata products. To solve this problem, Open

Geospatial Consortium (OGC) founded in 1994, founded by members of both industry and academia. The aim was to create a framework for software developers in order to enable accessibility and processing of geographical data from various sources within the open information technology information. The framework created by the Open GIS Consortium is called the OpenGIS specification. Standards were necessary to harmonize technical specifications for both users and developers within geospatial science. “The Open GIS specification is based on three conceptual models: The Open Geodata Model (OGM), Open GIS services, and the Information Communities Model” (Mortez, Shekhar, Xiong 2008, p.593).

For compact application and datasets published online, it is necessary to include metadata. This includes history, description, and the findings of the data. There are several variations of metadata standards, but two most commonly used are CSDGM and ISO 19115 standard.

3.3 GIS AND UTILITY SECTOR

The goal of any utility is to plan and manage the use of facilities to deliver a commodity such as gas, electricity or water to its customers. With the start of the 21st-century utility industry and energy companies are facing enormous challenges. Oil, electricity, coal, gas and renewable energies are driving today’s economy. It is clear from both political and scientific standpoints that we cannot sustain the status quo of energy supply. On top of this, privatization of government-owned utilities, though competition between utility industry companies is factors that change today's industry. Smarter and better use of spatial data is one of the key areas of focus for many gas, water, and electrical utilities. With upraise of technology and more sophisticated GIS, utility industry started to notice benefits from this software. “There are two main objectives of GIS application within a GIS: driving down costs and improving customer service” (Mayers, 1999, p.801).

Evolution of technology and GIS trends were followed by the utility sector and its engineers. Considering that some of the utility companies are 120 years old they have been built information system using manual processes. The earliest automation and change from hard copy maps to digital ones became possible during the 1970s and beginning of 1980s. Since GIS systems were too robust and not capable of performing complex analysis most companies used Computer Aided Design/Drafting (CAD) software as the basis for its projects. Therefore, not a vast amount of companies rushed to switch to the GIS systems. By the late 1980s, many utility users of AM/FM (Automated Mapping/Facilities Management) began to adopt the ideas of GIS and its model. “GIS is recognized for its strong role in managing traditional electric and gas transmission and distribution networks, pipelines, production facilities, gathering systems, and wells” (Meehan, Brook, Wyland, 2012).

In this model facility and spatial definitions of land were stored in terms of coordinates and had attributes “attached” to them.

These attributes were stored in the relational database management system (RDBMS) tables.

Today's typical application within the utility sector is built on top of GIS standards and using some form of client/server architecture. One server can serve up to hundreds of users. The modern GIS application within the utility sector is capable of performing analysis based on topological relationships (tracing lines to find customers affected by a power cut) or data relationships (identify pipelines with certain capacity).

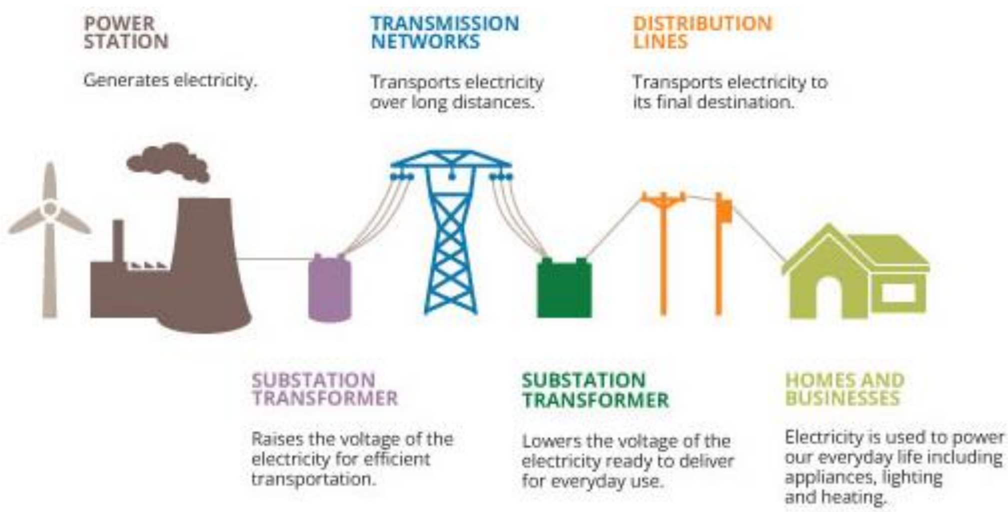

Figure 4 Energy value chain source. Retrieved from seekingalpha.com/article/3077726-duke-energy-the-trough-is-in

While there are many problems, tasks, and requirements for utility and energy companies to solve and undertake, according to Meehan, Brook, Wyland (2012, p.889) in this sector GIS is most suited to solve the following:

a) *Data management*

This includes managing assets such as poles, sensors, switches, smart meters, conduits, and people

b) *Analysis*

Determining the optimal placement for wind farms, transmission lines, etc. based on different multi-criteria analysis

c) *Mobility*

Data collection and processing from the field

d) *Operational awareness*

Visualizing the business spatially, such as identifying overloaded electric cables

“For successful implementation and stable workflow of GIS into the utility sector, it necessary to follow and implement three key aspects” (Mayers, 1999, p.809).

The first aspect is an accurate depiction of the locations of all facilities required to construct the network. It is important to keep data consistent and in synchronization with base maps and other utility company’s data. This step is very important because it represents the base for further analysis.

The second characteristic is the ability to define a model of the utility which would accurately represent the way the network and system operates. In this section, the integrity of the data is critical. This requires the attributes of specific data for information on connectivity with other parts of the system, is pathway open or closed, if the magnitude of flow is changed, etc.

The third aspect represents the ability to integrate spatial information’s within other databases for management, customers or web. This requires consistent data representation and connectivity with other systems.

Well maintained data and consistency is the key for successful implementation of GIS in any industry, so the utility sector is no exception. If not maintained well, data may conflict with each other. With many sources, it is tough to keep every change in data and this can lead to errors, especially where the company stores a significant amount of datasets.

Without GIS, there would be a gap between planning – design – construction. However, if using it, users, management and engineers are able to share data and present it on their machines. The GIS software enables the ability to perform complex spatial queries on infrastructure, maintenance, and present results of the queries visually.

3.3.1 GIS in the water and wastewater distribution and management

"There is no question that water is an essential resource. With population growth, industrial production and climate change, securing enough fresh water for urban and rural areas while keeping it protected from pollution and overuse is a big challenge for humanity. Uses of water include agricultural, industrial, household, recreational and environmental activities" (Wikipedia, 2019).

"GIS today plays an important role in today's water and wastewater management systems, planning, hydraulic modeling and connecting the spatially referenced time series data" (Patel, 2014, p.1). Before performing actual simulation for water resources and distribution modeling, it is required to go through a number of time-consuming processes. This requires collection, compilation, storage, retrieval and manipulation of spatial data. GIS applications save resources in developing water distribution systems with hydraulic models for simulating flows and pressures in the system. For many years GIS is used for generating water supply demand. "Water demands are based on land use maps by a relational database, or geodatabase which incorporates attribute data such as customer ID, land use category, water use records, and per unit planning factors."(Wang, Yang, Ted, 2014, p.142)

For better management of a water distribution network (WDN), it is possible to combine GIS database information for improved efficiency, quality and environmental impacts. According to Abdelbaki et al. (2016, p.1), "the development of a GIS model combined with the generation of information required for effective water services management is time-consuming and expensive. It has become clear that all desired management goals cannot be reached in the application of GIS in water distribution systems without a link to hydraulic simulation models". Hydraulic model EPANET has been recognized as the standard for identifying key parameters.

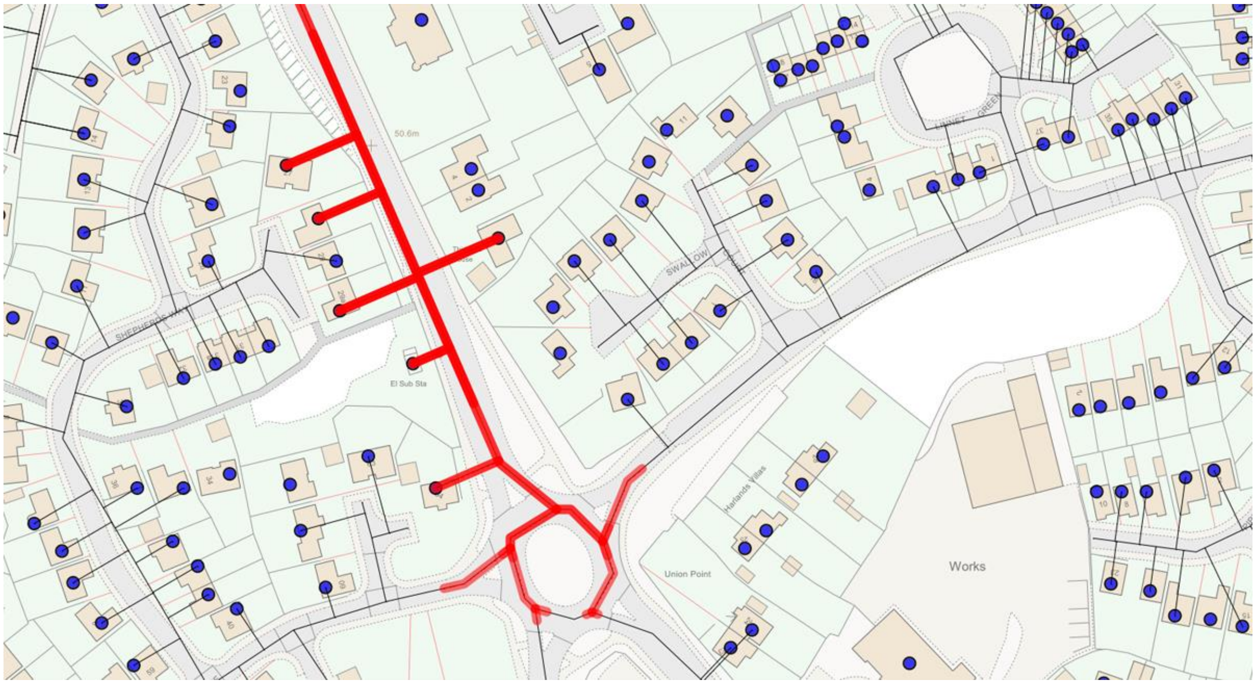

Figure 5 A map of a water distribution system as displayed on ESRI's ArcGIS platform. Retrieved from: www.softwareadvice.com/resources/optimize-utility-asset-management-with-gis/

"For the nowadays sewage and wastewater disposal, it is necessary to build a GIS sewage system. In order to build a GIS sewage system, the actual system information must be entered, that is, there must be a digital model of the system" (Jurisic, Tadic and Dadic, 2015). The whole system is very similar to the water supply system and therefore this paper will not go into a detailed description of this segment. The main difference between these two systems is parameters in location analysis and environmental impact, factors in the location of facilities, etc. However, GIS principles are the same.

Technology keeps evolving and GIS helps greatly with modeling of the water supply systems and water disposal in locating a sufficient exploitation spot for fresh water, reduction of maintenance costs, modernization of the existing systems, helps to protect water resources and nature. It is a great tool for data exchange between different departments in planning – designing – engineering process, with standards which facilitate merging data from different resources and connected databases.

3.3.2 GIS in the Electrical distribution and management

The complexity of the power distribution system and the importance of accurate, up – to – date information about the new network assets requires software that is capable to store, analyze and plan existing and future networks. “GIS comes as perfect software and it helps utilities to reduce the cost of manual maintenance of the maps and allows the simultaneous assessment of technical, financial, and environmental factors” (Rezaei et al., 2009). Electrical energy is a tool of today's socioeconomic development and its impact on the economy and everyday life is tremendous.

“An efficient system for transmitting power cannot be achieved without monitoring of distribution systems. Awareness of the position and type of assets on the network is necessary for engineers in making the right decisions and moves. By using new technology methods and techniques in distribution systems, planning and design problems can be solved more conveniently. As of today, GIS solutions in electrical power transmission and power are well-established”(Hasan, Helwa, 2013).

In the field of the electric utility, GIS is used in all stages, from planning to development, maintenance, optimizing and safety stages of power networks and facilities. It is a vital part of all the processes. The first step in applying GIS in new systems of electrical network and facilities is locating an optimal place for a power plant. Factors which affect land and construction costs, operating and maintenance are all taken into account. Other factors depend on electrical power plant type, location, size of a plant, climate, etc. This stage is followed by planning and design of electrical network considering aspects such as the area of supply, demand, terrain, etc. Latest stage, after the network is built, is a maintenance, monitoring, and management.

Electrical distribution and management main aspects of GIS include optimal route planning of new power lines and networks and optimal location and capacity of new substations and electrical assets. In later stages, these features can be expanded for analyzing the potential market for the future expansion, reduction of the maintenance cost, managing transmission assets and monitoring environment. Power system analysis software is progressively evolving into GIS software and its enrich GIS software with possibilities to perform analysis, such as load flow, short circuit, reliability analysis, load forecast optimization of distribution networks, faultfinding, etc. These analyses are nowadays usually part of the package for GIS, or included in the software, depending on the software. Some companies integrated GIS software with SCADA systems, enabling real-time managing and monitoring in offices.

GIS can be called as a hub of data for electrical power engineers. It enables storing data in databases available constantly for analysis and performance monitoring, integration of real-time data, planning, design, etc. It allows a variety of devices to connect onto one database, share data and perform analysis in the same software. This makes the job of the engineers easier, sharing data between sectors more reliable.

3.3.3 GIS in the natural gas distribution and management

Natural gas is an industry driven by an estimated 80 percent of data with a spatial component. In the gas industry, the spatial component is present from the early stages of planning to the final stages such as maintaining and monitoring gas networks and facilities. GIS applications have found their place in a gas distribution utility network and as GIS popularity and diversity grows so its appliance in a gas distribution utility network. "On the market, there are different solutions for this industry such as an Outage Management System, Engineering Design, Transmission Corridor Management, and Network Asset Management" (Chutkay, 2009). The gas distribution system is very complex and it consists of many segments such as measuring stations, gas control components, various diameter pipes, and facilities. GIS can help companies to manage their gas distribution assets. This includes information such as gas leak location and its impact on the environment in leakage area, information on supply area of one network, etc.

The main trend, as in every utility sector nowadays, in the gas industry is how to best integrate modern technologies. This includes GIS and in-house dedicated systems. GIS should be, and in most cases is, integrated with operational support and service – delivery applications. This integrated system with GIS is called Integrated GIS. According to Chutkay (2009) integrated GIS life cycle of gas distribution consists of the following phases:

- Planning a gas network with regulation stations, mains, services, valves, etc.
- Creating an engineering design for the network, based on
  - Best cost model
  - Available material through enterprise resource planning (ERP) system
- Performing analysis on proposed and existing networks for optimization
- Approving engineering designs
- Procuring material
- Field inspections during network construction
- Energizing the as-built network
- Service provisioning
- Asset management
- Gas outage management
- Operations and maintenance
- Leak analysis
- Cathodic protection

Companies in the utility industry glance on how to integrate GIS and existing systems in the company. As in previously mentioned industries, GIS is present in all processes with the spatial context in this industry. It enables the integration of data from various sources, provides a spatial component to various datasets and its relationships and updates it constantly. This allows companies to make operational and business decisions based only on this software.

4.4 UTILITY INDUSTRY AND WEB GIS

With the advance of the internet and geospatial technologies, various actions were taken to make data publicly open and available as much as possible. "Today in the advancement of Web technology, various management systems, and mobile applications have been developed for utility mapping, power distribution, Earth data, and Planetary data dissemination and archival" (Ajwaliya, 2017, p. 86). The utility industry can benefit greatly from the data on the web, distributed systems, and distributed data. In this industry, the Web enables easier management, using IoT and SCADA systems for monitoring, sharing data with the engineers on the field, publishing the maps, etc.

Based on the appliance of GIS in the utility industry and characteristics of Web it is possible to distinguish three "areas" where Web GIS is most applicable in the utility industry:

- Utility industry management system
- Fieldwork
- Consumer engagement

4.4.1 Utility industry management system

Utility management processes are very complex, multidimensional, and they require modification of traditional approaches. Managers, planners, and engineers experience difficulties in data management and spatial data integration with MIS (Management Information System). On top of this, if organizations and companies implement GIS systems poorly and unorganized it has a tendency to create many problems for future system growth. This reflects in servers and databases contain large numbers of duplicate, not properly named or formatted datasets. The final result is users experiencing slow response time, misunderstanding between planners and engineers and in some cases lost data. Based on the problems utility sector encounters in management systems, the logical answer can be split into two solutions – GIS Cloud and Enterprise GIS.

In relation on integrating GIS and MIS systems, Weng (2001) said: “although many specialists have studied the problem and built some application systems, most have either relatively powerful GIS analysis functions or professional model analysis functions”. However, this integration got a new scope with the appearance of Cloud computing and with Web and Cloud GIS it is interesting to see how GIS and MIS merge up, as collaboration and good communication between departments are crucial for the utility sector.

According to Kouyoumjian (2010) “Cloud computing furnishes technological capabilities—commonly maintained off premises—that are delivered on demand as a service via standard Internet protocols” (p. 3). Regarding Enterprise GIS, by the Wikipedia definition “Enterprise GIS refers to a geographical information system that integrates geographic data across multiple departments and serves the whole organization”(Wikipedia, 2019, Distributed GIS). These solutions can serve utilities for various purposes. The benefits are flexibility and scalability of the systems, available data anytime and anywhere reduced cost and automation. It is important to notify that Enterprise GIS as part of its solution can include GIS Cloud, however, that does not have to be a case.

Based on a company’s needs, resources, and other factors, the company can choose a suitable service to use. In the next section, both solutions will be briefly explained. However, both support scalable systems, integration, and standardization of the data, authorization and the security for the users.

4.4.1.1 GIS Cloud

“Cloud computing can be viewed as a collection of services, which can be presented as a layered cloud computing architecture. The services offered through the cloud usually include services referred to Software-as-a-Service (SaaS), which enable users to run applications remotely. Infrastructure-as-a-service (IaaS) then refers to computing resources as a service. This includes virtualized computers with guaranteed processing power and reserved bandwidth for storage and internet access. Platform-as-a-Service (PaaS) is a concept similar to IaaS, but also includes operating systems and required services. PaaS is IaaS with a custom software stack for the given application" (Furht, B.; Escalante, 2010, pp. 4-5).

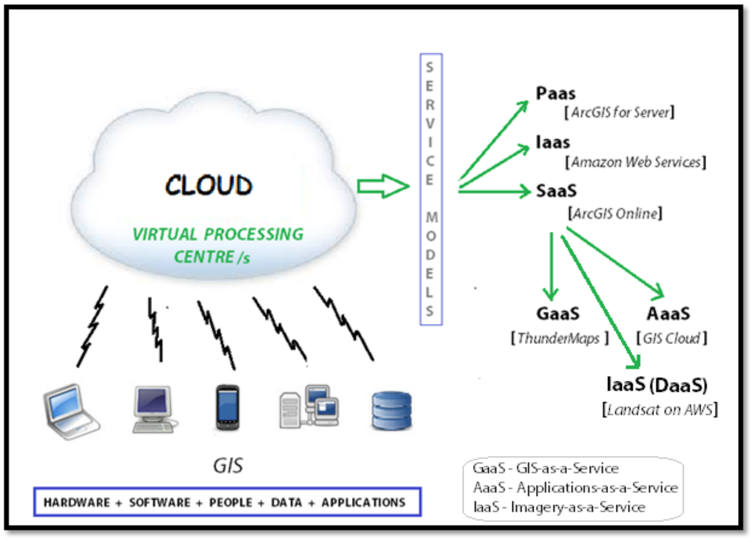

Figure 6 GIS Cloud Service Models. Retrieved from: https://www.gislounge.com/cloud-gis-terms/

"One critical difference between traditional and cloud computing is the scalable and elastic nature cloud computing providers" (Victoria Kouyoumjian, 2010, p. 3). Cloud computing is on-demand availability of computer system resources provided by Cloud vendors. Consumers can use it for data storage or computing power. Regarding utilities, it is up to the company how the services will be used. These possibilities can be just data storage up to providing API's (Cloud API) for its employees and partners. Whatever is the case, this service provides opportunities for organizations to become more flexible, scalable, productive and cost-effective. Moving the data from the computing center of the companies to the cloud reduces the disconnectivity of the datasets and capital spending. This is enabled by the fact that only one server (Cloud) provides storage and, therefore, the possibility of duplicating and losing the data is reduced to a minimum. Hardware and software maintenance is not necessary repeatedly in the case of using Cloud computing services.

Cloud Computing for GIS and the utility industry in terms of architecture is not different from any other Cloud service. However, Cloud services provided by vendors can be adapted from industry to industry. SaaS functions provided by GIS-based industries will be different from those of, for example, the real estate sector. The general structure and architecture of these applications remain the same, but services provided by vendors differ in terms of available resources and scalability. Because this service is very flexible it is impossible to find one 'recipe' that works for everyone. Company varies in sizes and services, so it should adapt services by its needs.

There are different types of deployment scenarios in cloud computing (Victoria Kouyoumjian, 2010, p.10).

- Public Cloud

  A Public Cloud is hosted by a public host provider and its infrastructure is owned by the company which provides the services. When the term Cloud services is used, this is what most people refer to.

- Private Cloud

  This type of Cloud is infrastructure meant to be used exclusively by one company. These services could be managed and operated by the organization who uses the services or by the third – party center. Most of the users opt for this solution because of security concerns. However, this solution is more expensive than others.

- Hybrid Cloud

  Hybrid Clouds provide a combination of Private and Public Clouds. This service can potentially consist of multiple Private and Public Clouds and use many active servers, physical or virtualized.

When a company decides to move its data to the Cloud, it has to be aware that it comes with privacy and security risks. This is the biggest concern for companies when trying to decide onto this solution. Typical examples include data storage and transfer protection reveal and exposure to unauthorized persons. Ryan (2011) in the journal "Communications of the ACM" says regarding Cloud computing "The data could be abused by hiring or promotions committees, funding and award committees, and more generally by researchers choosing collaborators and associates. The mere existence of the data makes the system administrators vulnerable to bribery, coercion, and/or cracking attempts. If the administrators are also researchers, the data potentially put them in situations of conflict of interest" (pp. 36-38). Data stored on the Cloud servers are vulnerable, however, it offers many advantages over the old way of storing and managing data on company systems.

4.4.1.2 Enterprise GIS

Figure 7 Illustration on how Enterprise GIS should look like

Rao and Vinay (2009) define an Enterprise GIS as "Web GIS Solution, which combines the knowledge of complex GIS systems with the standards and best practices of Information Technology to design and implement an end-to-end system that delivers geospatial data services, tools and applications on the web" (p. 1). Utility industry companies are usually very big and it is common that have departments, sectors and other "sister" companies physically allocated from the main management facility. This situation requires a connection between several departments and therefore the internet is very important in these situations. With these problems, companies need one system that would work for everyone. With the exchange of the data, there are various obstacles on the way. Operating systems, applications, experience, etc. Enterprise GIS can help companies where the majority of the data have a spatial context. Utilities are one of these companies and for some this package can be the perfect solution.

Enterprise GIS is very complex. The aim of this project is to implement better coordination and communication between different parties. This includes project teams, IT organizations, users, management and stakeholders. The main focus results of Enterprise GIS are (Jayavarapu, 2007, p.1):

- *System improvement projects*

  This includes the standardization of the data for better integration with other enterprise systems. It requires re-engineering of spatial data, quality and enchased functionality of GIS applications.

- *Process improvement projects*

  These segments consist of standardized processes in the project timeline adopted to a newly implemented system, streamlining and the improvement of business processes associated with utilizing GIS technology.

Architecturally, an Enterprise GIS is a hybrid of tightly and loosely coupled systems(A. R. Dasgupta, 2010). Establishing Enterprise GIS into the company requires complex technologies, but the real challenge is often an organizational one. "All the potential categories of users, their processes, the different kinds of data, functional requirements and software products, and the systems that must be linked have to be known, and corresponding system architecture has to be defined. It is often a balance between having an IT landscape that is homogeneous and satisfying the different requirements of the various user groups”(Reinhardt, W., 2010, pp. 912-913). Technically, this solution is client-server based and, usually, it consists of one database and various clients with external databases connected to the server. With good planning and implementation, Enterprise GIS is scalable and in the long run, it can be a significant plus for companies.

The downside of this solution is that users need appropriate training to use it properly for their needs. For the company, there are things such as the cost of software and hardware. Planning, data standardization, data acquisition, and system deployment will come with an extra cost for a company. GIS vendors have “ready to use” solutions, however, this comes with the cost. One of the main leaders on the market ESRI provides solutions which are highly customizable and with most of the assets every company would need. This is supported by other features provided by ESRI such as ArcGIS Online, and ESRI Cloud services, however, integration with Microsoft or Amazon Cloud services is possible as well. An alternative to commercial vendors is Open source software.

Open source solutions are cheaper in start cost, however, for building enterprise GIS, an IT department or external consultants are required, and support is not included in these solutions.

4.4.2 Fieldwork

Fieldwork for the utility industry is a very broad subject. Utility industry management does not include only desktop computer processing, but also frequent outdoor maintenance and inspection on the field work. ”Previously, field workers needed to hold the maps in their hands to accomplish asset inventory and inspection, to find the locations of the equipment, to get the overview of an incident area, and to drive in the optimal directions” (Fu & Sun, 2010).

The essential part, besides office work, of every utility industry, is maintaining and managing networks and assets on the field. “Fieldwork is considered, in most disciplines and particularly in geography, as a key ‘instrument for understanding our world through direct experience’ and consequently as a fundamental method for geographical education” (Gerber and Chuan, 2000). Mobile GIS comes as a great tool for field workers and engineers within this field. The recent evolutions in Mobile GIS caused the possibility to cost-effectively gather and manage GIS data (Amirian and Alesheikh, 2008). The Mobile GIS is becoming a tool for field inspectors, utility crews, maintenance workers who need to visualize and access the data from the office.

In this section briefly will be covered Mobile GIS as an alternative to existing GPS and geodesic devices, cameras, different variety of sensors and detectors and other related fieldwork devices for utility industry fieldwork. One common advantage of Mobile GIS is a user interface, integrity, and connectivity with existing systems in the company. According to the ESRI (Canadian Utility Goes Real Time with Mobile GIS, 2017) and WaterWorld (Mobile GIS System Streamlines Utility Operations, 2012) online articles, Mobile GIS saves time and resources by replacing paper maps with Mobile GIS. This service enables workers on the field to view, query and access the GIS-based user's current location or search database for needed data. Furthermore, GIS helps workers with its tracing functionality by notifying the workers, which segment of the network should be shut down in case of the repair of leaking.

4.4.2.1Mobile GIS

“Mobile GIS is an integrated software/hardware framework to allow users access to geospatial data and GIS services through mobile devices (e.g., iPhones, pocket PCs [personal computers], Smartphones, notebook computers, and personal digital assistants [PDAs]) via wired or wireless networks”(Ming-Hsiang Tsou, Barney Warf (ed.), 2010, pp. 1919-1921). The mobile GIS contains two types of applications. One of them is field-based GIS and the others are location-based services. Field-based services are primarily interesting for the utility industry and its focus is about validation, updates on the field, data gathering and adding or editing map features on the mobile devices. On the other hand, location-based services mostly focus on the navigation, tracking of the vehicles, routing, etc. Mobile GIS offers application which field workers can use on a daily basis and on the field with constant updates from the office. This comes at low cost, as for some operations standard smartphone or tablet can be of use.

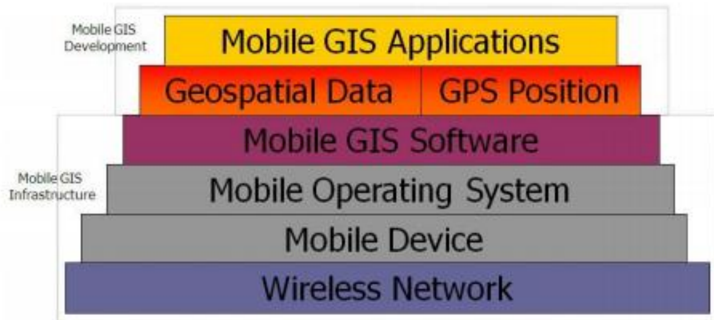

Figure 8 The architecture of the Mobile System. Retrieved from: Eleiche, 2011

The architecture of Mobile GIS is based on server-client architecture. Figure *8* describes the main components of the Mobile GIS. The core of this system is mobile device wireless communication. Jingson, Ge, Wang, Deng(2013) divided key technologies mobile devices use on – "mobile database technology, mobile positioning technology, and wireless network technology".

Mobile database technology

GIS for mobile devices must support multiple users access to the network in various conditions, transaction processing, query the features and display of the map. The server is important in this chain in providing the data for the clients and important for mobile location services, information of the assets on the field, communication, etc. This technology is key in case of interruption of the network where with catching and data replication, mobile users can edit the data in offline mode. Depending on the application, if the user is online again data changed by the user is updated on the server (or vice versa).

Mobile positioning technology

"This technology also referred to as 'geotracking' is crucial for the usage of the mobile device in the utility sector. It uses the wireless communication network to measure some parameters with received radio waves"(Jingson, Ge, Wang, Deng, 2013). Many technologies are capable of performing this task. However, choosing the right one depends on levels of accuracy application actually needs. For the utility sector needs most adequate is the Global Positioning System (GPS) and Assisted GPS localization of the device. "This technology is more precise and does not require an internet connection in order to work. GPS receivers process the signals to compute position in 3D– latitude, longitude, and altitude – with an accuracy of 10 meters or less"(Giaglis et al., 2002).

Wireless network technology

Currently, "on the market, three popular wireless communication systems and they are ad hoc systems, cellular phone systems, and Wi-Fi /WiMAX data network systems"(Ming-Hsiang Tsou and Barney Warf, 2010). For the field workers within the utility industry field most suitable wireless connection is 3G and 4G mobile cellular phone communication. The reason is the coverage of mobile providers in almost all areas of the world. Most of the provider in developed countries covered land by the signal which enables data transmission. This, of course, depends on many factors such as weather, the morphology of the terrain, rural/urban area, etc. However, it is with good coverage, mobile cellular phone communication systems provide decent bandwidth communication and good coverage in most of the habitat areas.

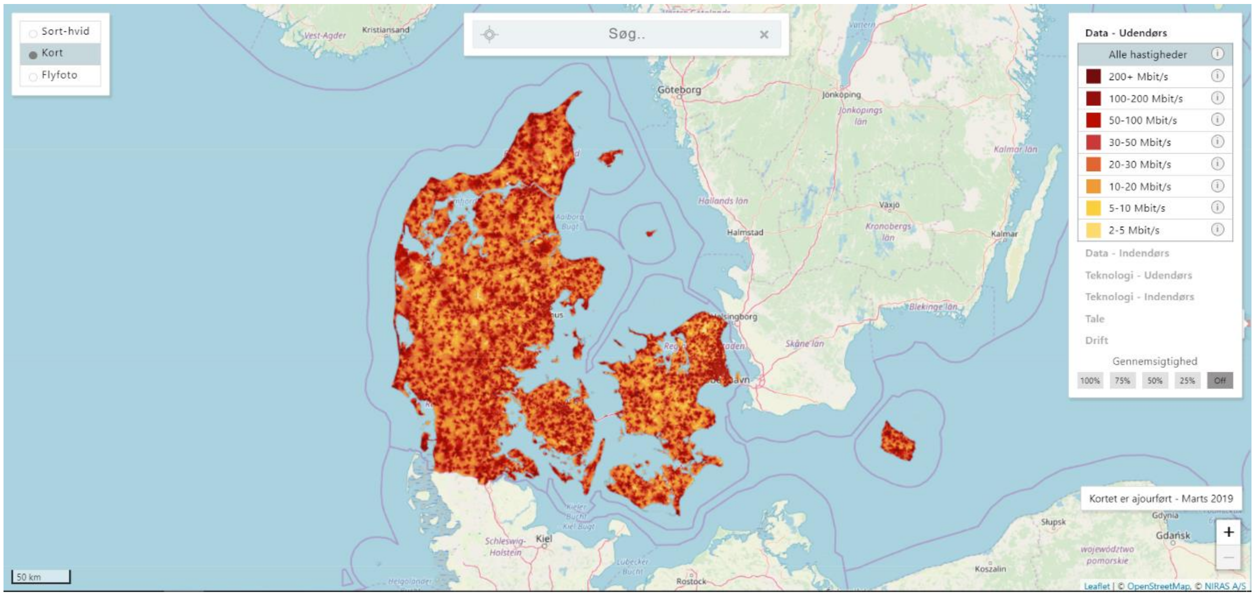

Figure 9 Map of mobile network speed in Denmark by YouSee service provide. Retrieved from; daekning.tdc.dk/tdcnetmap_ext_tile2/

Usually, Mobile GIS applications for the utilities are software developed by experienced programmers and are capable of handling picture input, tracking and most importantly communication with the server. However, on the market, there are considerable commercial applications for Android and iOS devices. On Google Play Store, provider of Android applications for mobile and tablet devices, the result is 1107 applications for search query Mobile GIS/GIS. On the iOS App Store, an official application provider for Apple mobile phones and tablets, this search query resulted in 1183 applications(42matters.com/app-market-explorer). However, for utility industry companies are more suitable applications that can be easily integrated with Desktop versions such as ESRI solutions.

Mobile GIS devices have very limited computing capabilities and limitation with display (user interface). The system architecture is inferior to those of Desktop computers and this inferiority result in less functionality of Mobile GIS. “The preprocessing and post-processing time for spatial analysis and remote-sensing images might prevent the adoption of mobile GIS for real-time response tasks due to the hardware limitations” (Ming-Hsiang Tsou and Barney Warf, 2010). Displays of mobile devices are small and fragile and sometimes inefficient to perform spatial analysis.

To sum up, Mobile GIS has the potential to completely change fieldwork in the future. However, in order to fully change this field, it still requires some further developments. This includes better hardware of the smartphones and integration with the servers. Today smartphones have an impact on this industry, however, in order for this to fully change the way the workers are doing it needs some maturity.

4.4.3 Online maps and citizen engagement

Citizen's engagement in urban planning and, therefore, in utilities is not a new trend. The practice of urban planning is to involve citizens in an area of interest to interact with officials and impact planning of the cities they live in. However, the internet is part of daily life nowadays and it became medium between citizens and planners. Internet of Things, Smart grid and Smart cities are an integral part of the changes that are shaping modern cities. This, as a result, involves utility industry companies in a much smarter and more interactive way of communication with its customers. Dunn (2018) states that "Preparing for smart cities will require utilities to reinvent themselves while continuing to meet their current obligations".

According to the ACSI (American Customer Satisfaction Index) and UKCSI (the United Kingdom Customer Satisfaction Index) research since 2018 overall energy utility sector scores 2.7% lower than the last year and it had a score of 73.2 out of 100-point scale for the United States and 0.7% lower than 2017 and with a score of 74.4 out of 100-point scale for the UK (ASCI, UKCSI, 2018). "These scores are significantly lower than most of the sectors and this outcome is resulted by customer's higher demand, the quality of the services and value' (Ward, 2015). Web GIS is a possible solution for problems with customer support. With the Web, GIS utility companies are able to interactively show planned networks, possible outages and involving citizens in outage detection. With a connected system like these, field workers would be more effective, outages fixed faster and planning would involve citizens more in future decisions.

"Digital embrace will forever alter the utility-customer relationship, leading them increasingly to view customers not as 'captive ratepayers' but as partners who enable more efficient and sustainable operations" (Moreno-Munoz et al., 2016). Web GIS comes handy for the utility industry as GIS vendors enabled the easy publication of the maps on the internet with GIS software and integration with modern Web technologies. Cities are publishing various maps ranging from land use to historical and utility distribution network maps. These Interactive Web maps are useful for citizens, tourists, businessmen's, engineers, etc. Maps regarding utility industry are usually published in cooperation between the municipality and the company.

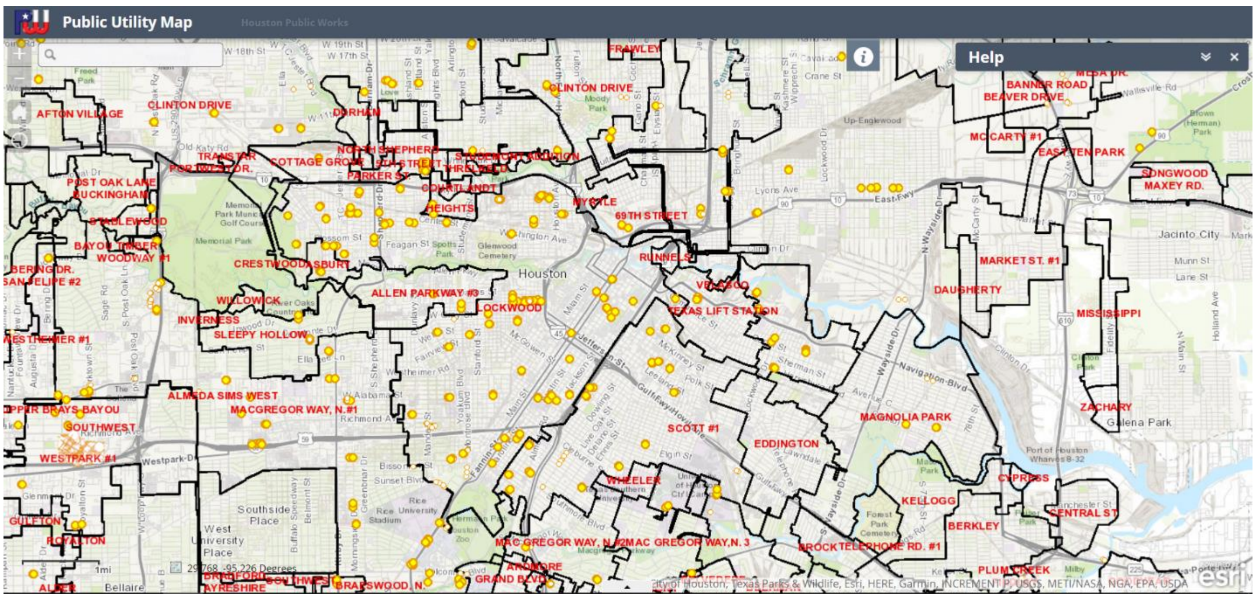

Figure 0 Interactive online map of Houston. Retrieved from: http://www.gims.houstontx.gov/PublicUtilityMap/

Web maps published by the officials enable citizens to better understand their area, urban and regulatory plans of the municipality and similar. Yet, these maps usually allow only basic interaction with the user. In most cases, it is possible to identify features on the map, geocode addresses and zoom-pan options. However, there is no standardization on what these maps should include. Interactive Web maps with basic functionalities do not allow direct impact and contact between municipality/utility company and the citizen/customer.

In recent years' utility companies started shifting towards more automated customer support. This includes web pages, emails, live chat, and mobile applications. Traditional methods of contacting customer service of the utility company by phone have changed. However, according to the Utility Digital Experience Study by J.D. Power and Centric Digital (2018) "utility industry is among the lowest – performing when it comes to the delivery of digital customer experience. This includes websites, mobile applications, emails, social and text functions in 67 largest utility companies in the United States." According to the study, the reason for these results in it that customers with today's technology get used to receiving immediate information on their issues. However, sometimes in the utility industry, this cannot be the case. Measured against other consumer-facing industries, utilities score 571 on a 1,000-point scale. According to the report of this research utility industry in the United States is aware of this problem and put an initiative to address it.

Web GIS comes as very helpful in building applications which enable users to report electric outages, water leakage, and similar issues to the companies. One of the examples where GIS vendor provides a solution "ready to use" is described by Perry (2012) in the online article Customer Engagement Using ArcGIS Online (*Figure 11*). For this application, ArcGIS Online is used as a service. An example map is uploaded on the Cloud services and shared among the target audience with the specified permissions. With provided link users can report broken streetlights by pinpointing their GPS location and with picture for the report. After the problem is submitted by the user, it is automatically updated to the server database of the utility company. After this has been done, the company can access the map with locations of broken street light and proceed to further steps of repair.

Figure 11 Interface of ArcGIS Online application opened on iPhone. Retrieved from https://sspinnovations.com/blog/customer-engagement-using-arcgis-online/

Briefly, citizen engagement is becoming very popular and the utility sector has to follow this trend. Web GIS can help greatly not only in stages of informing citizens on future plans and changes but in actively reporting system outages on the network. On the internet, there are not considerable published work on this subject, but in following years' utilities might see the benefit of this approach to their customers.

3.4 GIS SOFTWARE

In this section will be covered most popular GIS software's which can be and are used in the utility sector. Currently, it is impossible to determine which company uses what software. Usually, this information is protected by the company and not many companies are willing to share in – company information. In this paper, utility industry, GIS consultancy, and consulting companies are contacted to provide information on what GIS software's they use for utility related work. This includes any stage of planning, design, maintain and monitor the process of networks and facilities. However, only 5 companies gave feedback out of 56 contacted companies in the EU (9%). All the companies are from Denmark and the results are presented in the following table:

Table 1 Survey results generalized

Hofor	KortInfo, QGIS, ArcGIS, MapInfo
Aarhusvand	Hexagon G/Technology, OpenLayers, MapInfo
Niras	QGIS, ArcGIS, Rehab – IT, DAS7, DANDASGRAF, DANVANDGRAF
DHI Grass	QGIS, ArcGIS, Google Earth Engine
Ørsted	ArcGIS with Arc-FM

Table blah. Softwares Danish companies use

Even with the tiny amount of data, there is still noticeable that the majority of the companies uses the same three software – ArcGIS, QGIS and MapInfo followed by the rest of the software.

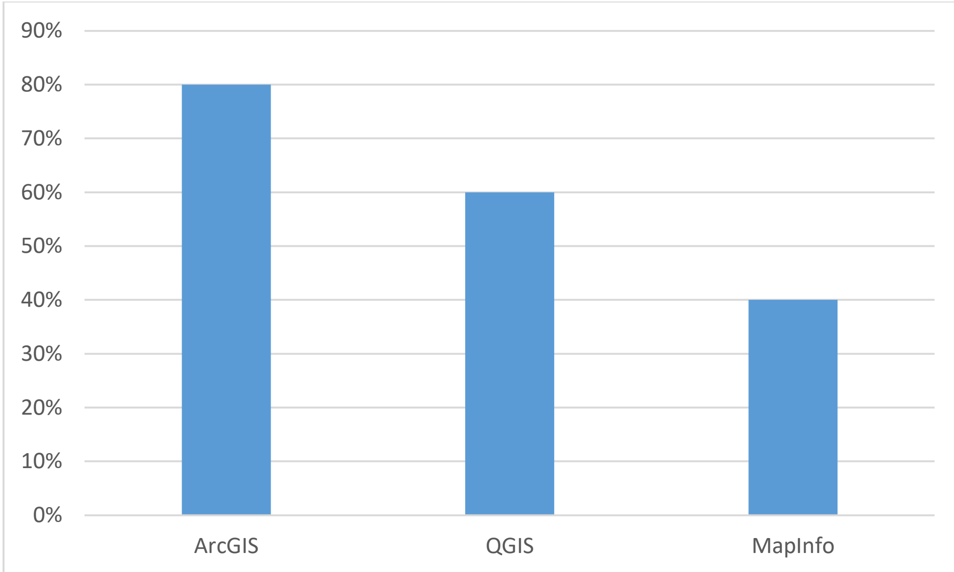

Figure 12 Percentage of survey participants in the usage of GIS software

The number of big companies has departments which built software packages/plugins/add-ons of the existing solutions or exclusively create software for the company. On the market, by the GISGeography (2019) there are more than a thousand GIS applications and it is almost impossible to keep track of all of them. Every day there are new applications while, at the same time, some existing ones are abandoned and not in use anymore.

As from previous chapters, utility companies use GIS software for different management systems, planning, design, analysis, etc. In this section, the decision is in distinct most popular GIS software suitable for the utility industry, which offers a desktop solution with the possibility to publish maps online or store them on the cloud services provided by the same company. These features encourage users to publish their maps with customers, coworkers or use Internet-based services which are provided by software manufacturers. On the other hand, storing data on the cloud simplifies time – consuming process of hardware provisioning, software deployment, backups, etc.

It is impossible for this paper to test features of all available GIS software's, however, classification leads to six applications based on multiple resource's popularity (Capterra, G2, Google Search Engine) and suitability for the utility sector. When creating a list, the author took into consideration years on the market of companies who developed software. This is important to emphasize because it is apparent that many new applications related to utilities are built on top of the mature systems. These new applications on the bottom line use the same logic as providers of the services. This paper will not go into differences and full software features as a whole and will look on software and its extensions as a whole.

Table 2 Selected software based on multiple criteria. Out of all, four will be selected for further analysis

	ArcGIS	QGIS 3	AutoCAD Map 3D	Maptitude	Map Business Online	CartoVista	MapPublisher	MapInfo Pro	Open Utilities Designer
Desktop solution	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Web solution/Cloud	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Utility sector package out of the box	Yes*	Yes**	Yes*	No	No	No	No	No	Yes
First release(First release of sibling software or software under different name by same company)	1999(1982)	2018(2002)	2005(1982)	1995	1996	2016(1993)	1995	1986	1984
Last stable release	2019	2019	2019	2019	2018	2019	2019	2019	2015
Number of visits per Website in last 6 months(estimation) (similarweb, 2019)	12,330,000	1,400,000	35,640,000***	780,150	Not enough data	Not enough data	930,480	1,116,000***	1,160,000

* Not included in the standard package but possible to extend

** Plugin not related to whole utility sector but out of smaller segments such as water management system of flow trace

***For company domain

Based on table 2 author will give feedback on four applications and how their clients can benefit from web services they provide merged with native solutions. These four applications are:

- ArcGIS
- QGIS 3
- AutoCAD Map 3D
- Open Utility Designer by Bentley systems

4.5.1 ESRI- ArcGIS

ESRI is a company founded in 1969 in California by Jack Dangermond and his wife Laura. This company represents one of the pioneers of GIS and their first GIS software was ARC/INFO released in 1982. The power of computers and the popularity of the internet raised and GIS software and its features followed the trend. This lead to ESRI's first desktop release of ArcView GIS which is the ancestor of today's ArcGIS. During the late 1990s, ESRI reengineered ARC/INFO into scalable GIS platform which aims to not only work on desktop computers but across the enterprise. In that time ArcGIS is born. ArcGIS today has two desktop software's – ArcMap and ArcGIS Pro. The current version of ArcMap 10.7 and ArcGIS Pro 2.3.1. However, it is hard to distinguish ArcGIS Desktop as ESRI provides many extensions, packages. In this section, they will be considered as one software - ArcGIS.

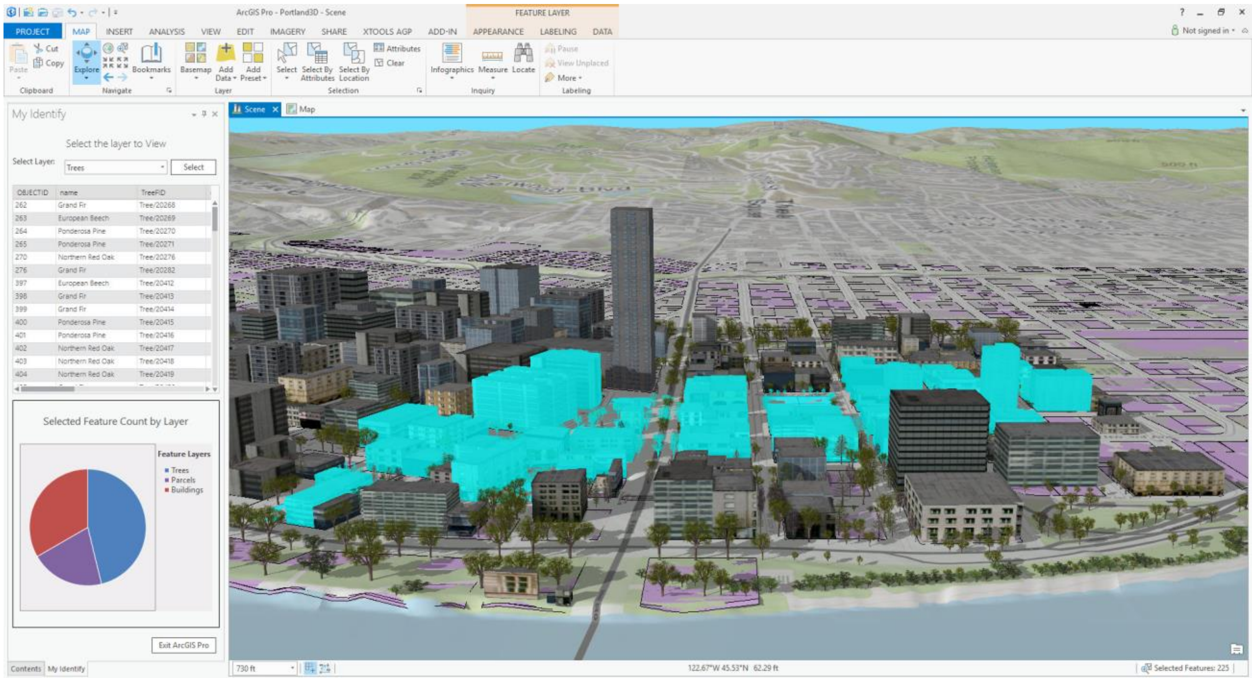

Figure 13 ArcGIS Pro, Retrieved from https://www.esri.com/arcgis-blog/products/3d-gis/3d-gis/arcgis-pro-extensibility-with-add-ins/

ArcGIS has fully matured GIS software with multiple possible extensions which focus on different areas of interest and provide features added on top of basic software capabilities.

<u>ArcGIS and utility sector</u>

ArcGIS offers “ArcGIS Utility Network Management” extension on top of their standard subscription. This extension purpose is to offer additional service regarding the utility sector on top of ArcGIS capabilities. This extension by ESRI documentation enables(ESRI, ArcGIS Enterprise, 2019):

- Extended feature types in the utility network, such as assemblies, devices, and structures. They apply operations such as edits and queries on utility network features
- Utility network services provide tracing capabilities on networks, manage subnetworks and tiers, and validate network topology.

- Network diagram services provide the capability to create, store, edit, and maintain network diagrams.
- Version management services work with branch versioned datasets, exposing capabilities to manage versions with feature services.

On top of these features, ESRI offers users to publish and consume network services online.

ArcGIS in the web

ESRI provides a SaaS model which offers cloud-based mapping and analysis solution. This synchronization of the ArcGIS application and the web give opportunities to make maps, analyze and share data only within a web browser. Data is stored on the servers ESRI provides and it's accessible on the mobile and desktop devices.

ArcGIS Online

ArcGIS Online is an application that enables the user to create web maps, 3D web scenes and simplify the process for creating web applications. On top of this, it is possible to perform analysis in the ArcGIS Online and to use services of ArcGIS Enterprise. For ArcGIS analysis part, this includes basic vector analysis, pattern analysis which would produce interpolated raster layer based on input, network analysis or generate watersheds, and similar.

ArcGIS Enterprise

ArcGIS Enterprise users have access to services such as storing data on the cloud, share maps, scenes, and applications within their organization and adapt these features for their needs. The main goal of making this package was to enable full support for companies and enterprises. This package enables usage of cloud services of other providers with all features from ArcGIS Server and Enterprise package.

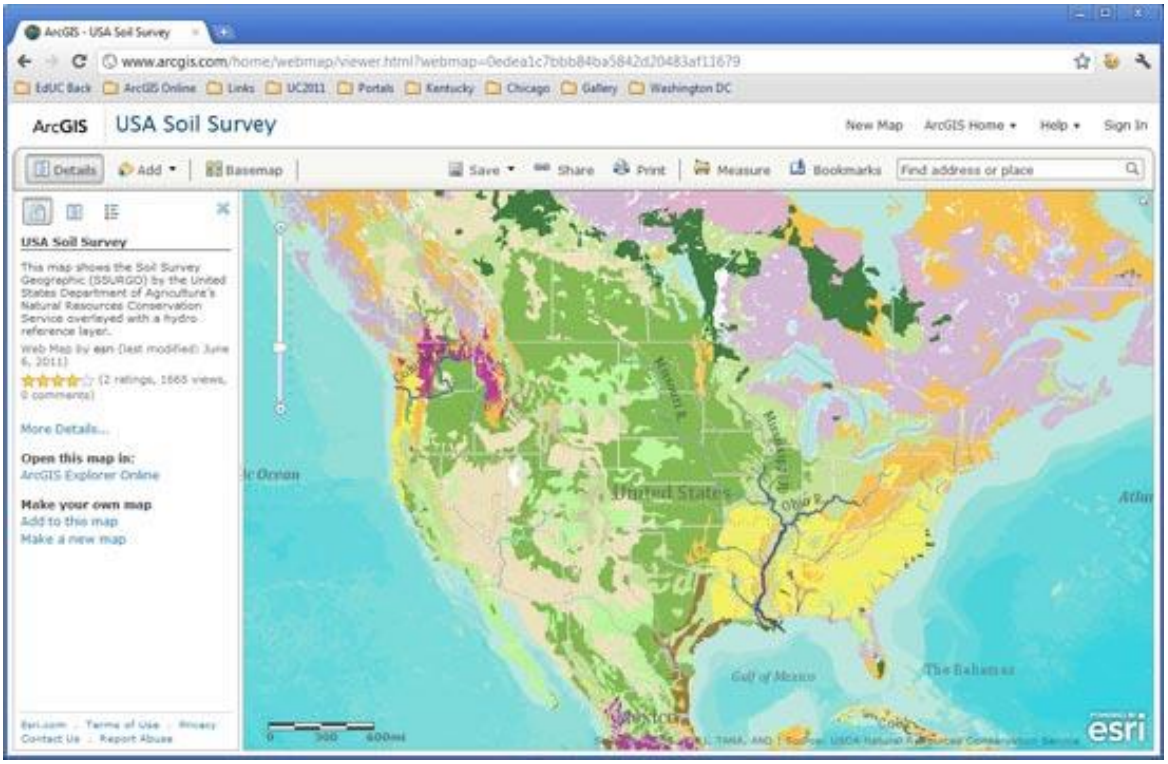

Figure 14 ArcGIS Online. Retrieved from: https://www.esri.com/news/arcwatch/0112/publish-your-custom-applications-via-arcgis-online.html

<u>ArcGIS within the utility sector in the web</u>

All of the previously mentioned features does not exclude the possibility to apply on data related to the utility sector. With a subscription to the utility network, it is possible to perform analysis using ArcGIS Server resources within ArcGIS Enterprise. However, data have to be converted to network topology in order to perform utility network analysis on it. This applies to both desktop and web environment. ESRI has step by step manual on how to convert data and publish utility network feature. Yet, “there are limitations when working with Utility Network Management extension in the web browser” (ESRI, ArcGIS Pro, 2019). By ESRI documentation, these limitations are regarding map layers for published feature service which does not support definition queries and hidden fields checkbox and version management capability is optionally supported.

Table 3 ArcGIS Features

User roles and administration	Supported

3D	Supported
Network analysis	Supported
Cloud storage	Supported
Raster analysis supported	Yes
Vector analysis supported	Yes
Mobile friendly	Yes
SaaS**	Yes
SDK**	Yes
API**	Yes

*Not supported by ArcGIS Online
**Related to ArcGIS suite in general

4.5.2 QGIS

QGIS or previously called Quantum GIS is open source and cross-platform GIS software. The project is born in May of 2002 and an initial goal was to create a GIS data viewer. It is released under the GNU General Public License (GPL) which allows anyone to access the source code and modify it. The current version is 3.6.1 and today QGIS is the most popular open source GIS software. It supports different types of GIS data formats, allow users to analyze, edit, export and create maps and geospatial information. It represents the integration of open – source packages including PostGIS, GRASS GIS, and Map Server. Plugins represent the main features of the software. QGIS has preinstalled core plugins which are part of the standard installation of the software. QGIS supports using external plugins which are available online and easy to integrate into existing software with QGIS Plugin Manager. Plugins are developed by independent organizations and developers and QGIS organization claims it is not responsible for any of the plugins. However, it highly encourages developers with user guides and online tutorials on how to develop a plugin for QGIS.

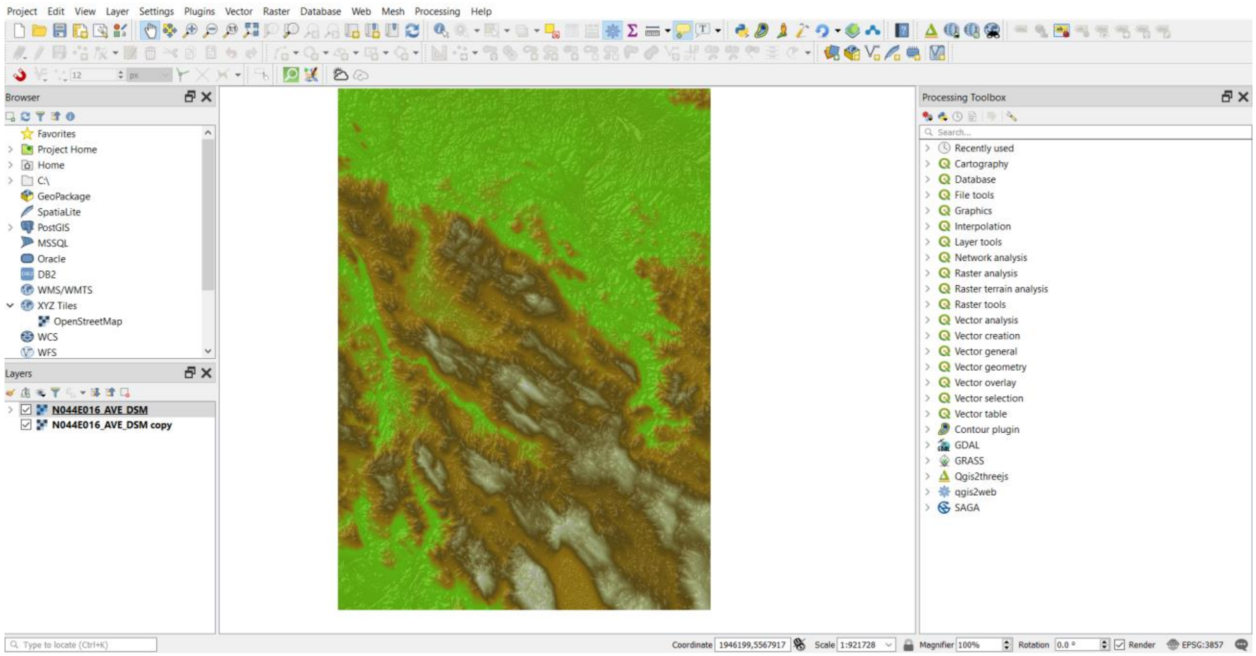

Figure 15 The interface of QGIS 3.6

<u>QGIS and utility sector</u>

As previously said, QGIS offers a combination of PostGIS, GRASS GIS, and Map Server packages which combined makes a great base for various GIS analysis, processes, and features. On top of it, all of the packages are open source and allows modifications and adjustments for the users. Regarding packages and plugins out of the box, the QGIS market lacks in this segment. It offers several plugins for water supply networks and enables flow tracing options for utility sector networks.

Available plugins for the utility sector:

- *GHydraulics*

This plugin allows to design and analyze water supply networks using EPANET

- *Qwater*

Similar to the previous plugin and built on top of it, it allows calculation of economic diameters based on given parameters.

- *WNT Open Source*

It is an application for the documentation and management of water distribution systems.

- *Flow Trace*

This plugin can distinguish all upstream polyline segments from a starting point.

QGIS lack in a package that would provide features for whole utility sector or for other industries than water distribution. The majority of the features that relate to the utility sector in commercial software's are regarding network management, hierarchy, and connectivity. QGIS lacks in supply with packages regarding utility sector. Nevertheless, it offers high customization of its features and basic (shortest path and service area) network analysis.

QGIS in the web

QGSI project offers several applications as the possibility to expand, share and use geoprocessing features in the web environment. These applications are:

QGIS Server

By the QGIS documentation, "WMS 1.3, WFS 1.0.0 and WCS 1 1.1.1 implementation that, in addition, implements advanced cartographic features for thematic mapping" (Documentation QGIS 2.18, 2019). It uses QGIS as a back end for the GIS logic and for map rendering. This application uses the same visualization libraries as a QGIS desktop to ensure that published maps look the same as in the QGIS desktop.

QGIS Web Client

QGIS Web Client represents "WMS based Web GIS client that makes use of QGIS specific WMS extensions (e.g. Highlighting, printing, metadata, etc.). QGIS Web Client reads the configuration from the WMS Get Capabilities to command and builds the layer tree accordingly" (QGIS-Web-Client documentation, GitHub, 2019).

QGIS Cloud

QGIS project offers QGIS cloud as spatial data infrastructure (SDI) on the internet. It enables sharing data without user administration and privacy, with several options as free and paid plans. The paid plan includes user roles and privacy guaranteed.

QGIS Enterprise

This project is developed by Sourcepole and its aim is to represent a “glue” between QGIS Server, Web Client, and desktop and provide support for a user’s.

QGIS within the utility sector on the web

Previously mentioned features and applications which QGIS project offers are possible and intended to merge, however, QGIS is not fully equipped to support the utility sector with its extensions without prior modifications and developments. In theory, it is possible to use all of its features and applications for the utility sector but with many adjustments.

Table 4 QGIS Features

User roles and administration	Supported
3D	Supported
Network analysis	Supported
Cloud storage	Supported
Raster analysis supported	Yes
Vector analysis supported	Yes
Mobile friendly	Yes
SaaS ***	No
SDK ***	No*
API ***	Yes

*It supports Python binding library PyQt
**Related to the QGIS project in general

4.5.3 AutoCAD MAP 3D

"AutoCAD MAP 3D is software for creating maps and performing analysis based on AutoCAD software produced by Autodesk. AutoCAD is a commercial computer-aided design (CAD) and drafting software application" (Wikipedia, 2019). Software is released in 1982 as a desktop application and it is used by architects, engineers, project designers, city planners, and other professionals. CAD is not part of the GIS "ecosystem". It is not compatible with maps and GIS data. It lacks in map creation features, ability to properly calculate and analyze spatial functions and connectivity with databases is not easy as in GIS software. Yet, AutoCAD MAP 3D is part of software "add-ons" developed by Autodesk for discipline-specific enhancements on top of AutoCAD. This software plays a central role in Autodesk product line dedicated to GIS and it integrates with Map Guide Open Source for publication on the web and Raster Design for processing raster maps. The advantage of this software is that many engineers and architects are familiar with AutoCAD and its format and MAP 3D have almost identical interface and commands. This makes easy to integrate projects from one file into another and into smaller scale maps. The last release was AutoCAD MAP 3D 2020.

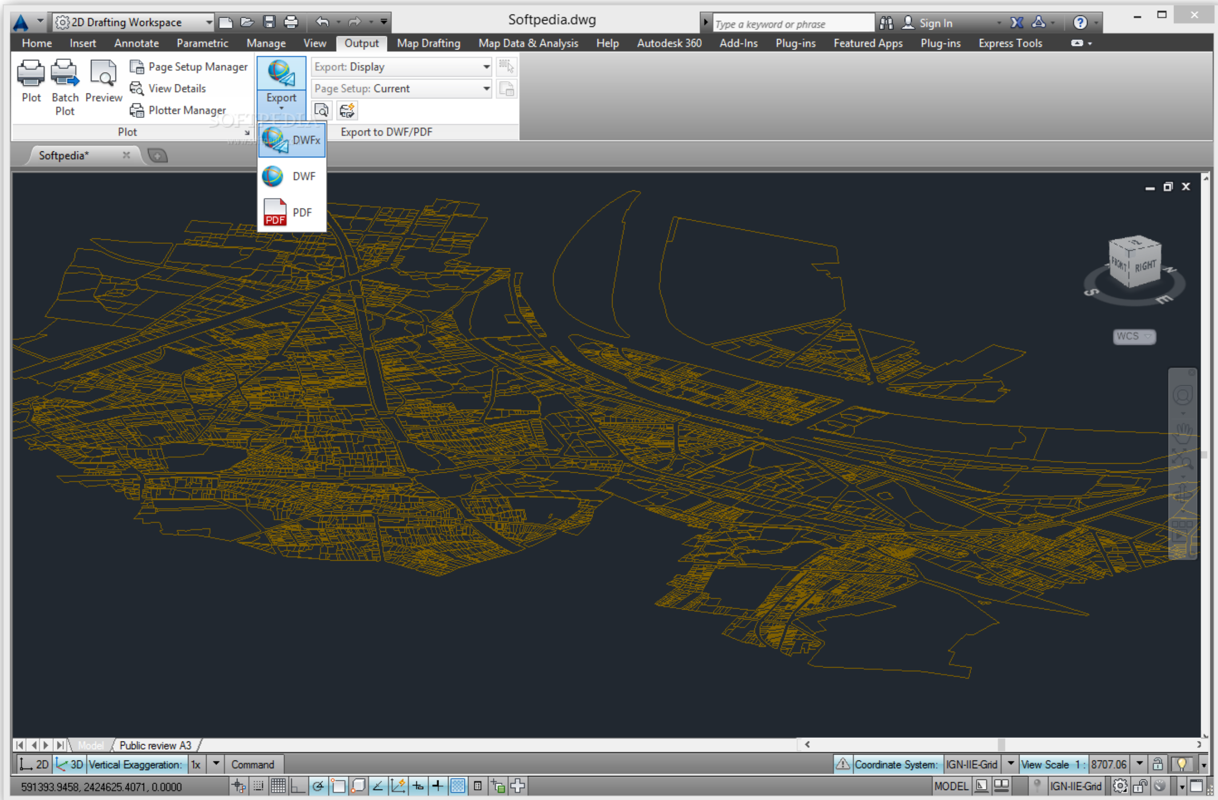

Figure 16 AutoCAD MAP 3D 2019. Retrieved from: https://www.softpedia.com/get/Science-CAD/AutoCAD-Map-3D.shtml

<u>AutoCAD MAP 3D and utility sector</u>

This software offers several modules for the utility sector, which provides easy sketching, analysis, and generating reports for map data. Every module has specific features related to field it is made for and there are Water Module, Wastewater Module, Gas Module, Electric Module. Modules have the ability to establish a comprehensive set of workflows, manage and analyze networks, set materials, topology and generate reports.

<u>AutoCAD MAP 3D and Web</u>

Autodesk offers multiple applications and options for users. This includes their SaaS, cloud or web application. The company also offers the option to publish data and render it in an HTML page with the help of “Web Wizard”. However, many of these web solutions are not related to GIS.

<u>AutoCAD Web App</u>

This application is included with subscription to AutoCAD software. It enables reading, designing and sketching data in a web browser. This solution does not support any of the GIS features except the possibility to open and read datasets. By the Autodesk documentation(Autodesk, 2019) aim of this application is not to recreate the possibilities of AutoCAD, but to allow users to access data out of the desk in the office.

A360

A360 is one of the cloud solutions that Autodesk provides. By the documentation of Autodesk these are features of A360:

- Possibility to create a project
- Add people to project
- Manage and share all project content and information
- View 2D and 3D designs using the A360 viewer on any device
- Review and comment on designs individually or as a group

There are many more options for sharing, consuming and storing data on the web using Autodesk services, but, as there are not related to GIS these services will not be mentioned.

AutoCAD MAP 3D within the utility sector on the web

Beside general options to share and publish the data, this software does not offer any possibility to consume analysis online. It is possible, however, to review and open the datasets through the AutoCAD Web App, but there is no support for the utility sector out of the box.

Table 5 AutoCAD MAP 3D Features

User roles and administration	Supported
3D	Supported
Network analysis	Supported

Cloud storage	Supported
Raster analysis supported	Yes*
Vector analysis supported	Yes
Mobile friendly	Yes
SaaS*	No
SDK*	Yes
API*	Yes

*With Raster Design toolset
**Related to AutoCAD MAP 3D in general

4.5.4 Open Utilities Designer Bentley Systems

Bentley Systems is a software development company from the United States and by their website, this company "supports the professional needs of those responsible for creating and managing the world's infrastructure, including roadways, bridges, airports, skyscrapers, industrial and power plants as well as utility networks". The company is 35 years old and today employs more than 3500 people.

Open Utilities Designer and utility sector

Open Utility Designer is software made for the design and manages electric, gas, water and wastewater networks. This software has the possibility to:

- Analyze and visualize utility networks
- Design district utility sector networks
- Estimate material and work costs
- Maintain utilities network models and maps
- Manage design workflows and approvals
- Synchronize design versions with enterprise GIS

Open Utility Designer and the web

Bentley Systems offer application which adds the possibility to publish and host data on the cloud. This application is called Bentley Cloud Services.

Bentley Cloud Services

The basic premise of these services is to enable its customers shared services between desktop, mobile, server and cloud. To make this possible Bentley Systems utilized Microsoft's Azure cloud service. The service allows user restrictions, available for users to share and interact with projects they share and access it out of office. None of the analysis features aren't available in this cloud service. However, with a subscription to packages such as SACS and STAAD available from this company user is allowed to perform queries, navigate 3D models, generate charts and generate different pallet of visualizations.

Open Utilities Designer within the utility sector on the web

Besides its cloud services where users from utility sector can potentially share their projects and visualize it Bentley Systems currently do not offer much more. This still can be useful, however, regarding strictly the utility sector, there are not many features offered on the web.

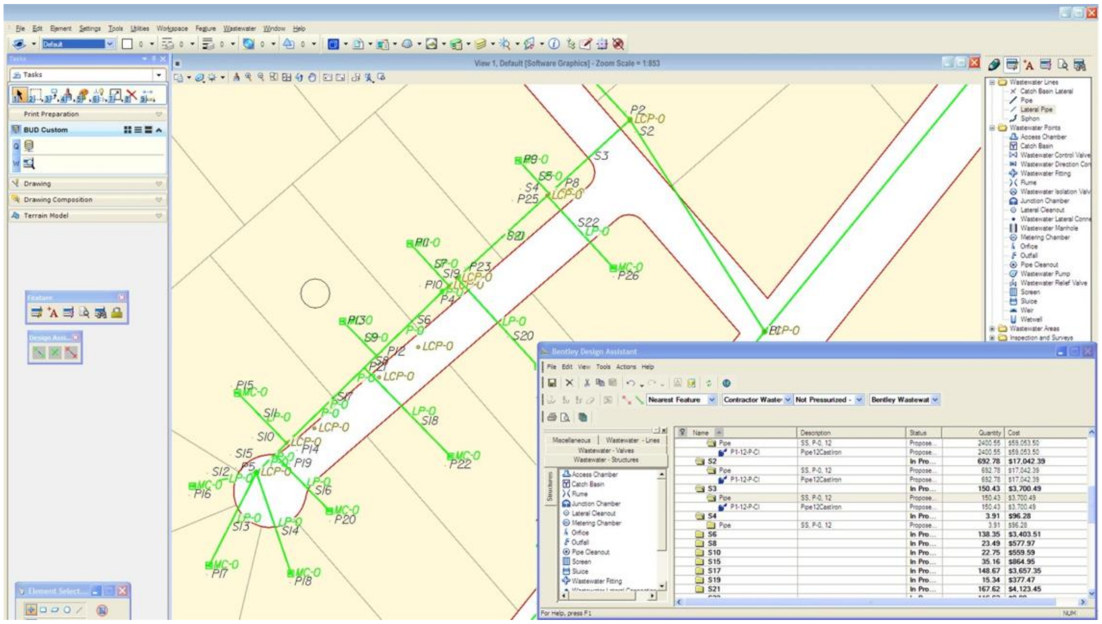

Figure 17 The interface of Open Utility Designer. Retrieved from: https://www.bentley.com/en/products/product-line/utilities-and-communications-networks-software/bentley-openutilities-map

Table 6 Open Utilities Features

User roles and administration	Supported
3D	Supported
Network analysis	Supported
Cloud storage	Supported
Raster analysis supported	Supported
Vector analysis supported	Supported
Mobile friendly	Yes
SaaS	No
SDK*	Yes
API*	Yes

*Related to Bentley all GIS software's

3.5 WEB GIS SOFTWARES

In this category are considered Cloud GIS software and web mapping platforms for developers without the support of the same vendor for desktop and native applications. Advantages of Web GIS/Cloud are cross-platform access, scalability, and the cost. SaaS-enable charging their users "per request" and this comes as a great solution for small companies. Most of the content on the internet is free, so is applied to Web GIS to some extent. This depends on which services and vendors' users intend to use, but some of the API's, SDK's WMS are free of charge while the other companies charge their customers after a certain amount of requests. Cloud/Web GIS vendors and mapping platforms focus on the cloud and mobile devices support. This provides Web maps easily sharable and accessible with an internet connection. Last, but not least, Web GIS enable easy updates. The client-server architecture allows ease of maintenance and one update on the server works for all clients.

Table 7 Web GIS Software features

	eSpatial	**MangoMap**	**GISCloud**
First release	2010	2012	2009
Last stable release	2018	2019	2019
Desktop Solution	No	No	No
SaaS	Yes	Yes	Yes
Cloud storage provided by the vendor	No	No	No
Integration with Databases and Cloud vendors	Yes	Yes	Yes
Utility sector package out of the box	No	No	No
Number of visits per Website in last 6 months(estimation) (Similarweb, 2019)	Not enough data	77,120	77,430
Optimized for mobile devices(smartphones and tablets)	Yes	No	Yes

It is possible to divide web platforms into two categories. Companies which focus is on building platform for the developers (MapBox, CARTO, HERE) while the other vendors focus is mainly on customers as users (MangoMap, eSpatial), however, not excluding developer support.

In this section, the focus is on companies that provide Web GIS software, and platforms for easy building Web GIS applications. Similar to the previous chapter applications are classified by the popularity (Capterra, G2, Google Search Engine) and the suitability of the software to extend its options for the utility sector.

From the table, 7 and 8 can be observed that most of Cloud GIS vendors and mapping platforms for developers which are fully web-enabled are relatively new (around 2010). This is not surprising if the development of web technologies is followed chronologically. Regarding Cloud GIS, none of the solutions don't provide a package for the utility industry, which does not exclude utility companies from using this software. Certain software and platforms support using GIS on mobile phones which extend possible usage in the utility sector. The main focus is on map publishing and basic GIS functionalities. Many users with backgrounds such as marketing, research, various businesses need GIS for elementary purposes and these software seems like a perfect solution. With attractive thematic maps, integration with software such as Google Analytics and Microsoft Excel extend possibilities of this software. Integration with most popular Cloud providers such as Microsoft, Amazon and Google and user's databases allow customers to adjust server administration and architecture for their needs.

Online mapping platforms for developers such as Here, CARTO and MapBox can expand its possibilities integrating other mapping JavaScript libraries such as Turf, Leaflet, OpenLayers and of course, various support on the user server side. This gives the application a great base for the development process and using the service of this provider's development process is much smoother and faster.

Table 8 Web GIS platforms for developers Features

	CARTO	**MapBox**	**HERE**
First release	2011	2013	2011
Last stable release	2019	2019	2019

Desktop Solution	No	No	No
SaaS	Yes	Yes	Yes
Integration with Databases and Cloud vendors	Yes	Yes	Yes
Utility sector package out of the box	No	No	No
Number of visits per Website in last 6 months(estimation) (Similarweb, 2019)	458,730	2,590,000	13,850,000
WMS	No	No	Yes

Table 9 Web-based Vendors Features

	eSpatial	CARTO	Mango Map	MapBox	GISCloud	HERE
Support user roles and administration	Yes	Yes*	Yes	Yes*	Yes	Yes*
3D	No	No	No	Yes	Yes	Yes
Network analysis	No	No	No	Yes**	No	Yes
Raster analysis supported	No	No	No	Yes***	Yes*	Yes***
Vector analysis supported	Yes	Yes	Yes	Yes	Yes	Yes
SDK	No	Yes	No	Yes	No	Yes
API	Yes	Yes	No	Yes	Yes	Yes
Enterprise package	Yes	Yes	Yes	Yes	No	No

**Related to developers, request count and included features of the various subscriptions*

***Integrating other libraries which company highly supports*
****This is related to basic raster analysis*

In the next section brief description of the previously mentioned platforms and solutions.

4.6.1 eSpatial

eSpatial is GIS vendor which business philosophy is mainly based on customers which need basic GIS analysis, map publication, and marketing business analysis. Main company aspect is focused on the scalability of the software and low price. However, this software provides mobile support which can help field workers greatly. Running the analysis tools, queries and selecting data on the map using a smartphone or tablet can be very beneficial for the specific fields such as utilities. With the Enterprise subscription, a user is able to use CRM software system, API, mobile GIS and enjoy the support of this provider. Integration with the popular Cloud solutions and user's databases expand the possibilities of the software and add new perspective and possibilities for what this software is capable of.

4.6.2 Mango Map

Mango Map philosophy is very similar to eSpatial. They provide simple software for users, which does not need advanced functionalities and spatial analysis. This software goal is to provide an intuitive interface and with ease create maps. This solution offers integration with the Desktop GIS and with "data Portal" users are able to grant other users permissions, store that on the Cloud and perform more organization. One more advantage of this software is easy integration with Google Analytics and Maptiks.

4.6.3 GISCloud

GISCloud is one of the first cloud GIS solutions on the market, presented in 2009. This company provides software for mobile data collection, map editor, map portal for publication of maps and connection with other cloud-based services or user databases, API for developers and even publisher for ArcMap. Compared to its competitors, it supports 3D and raster data basic editing. As previous Cloud GIS vendors, this company is very similar, it focuses on simplicity and low price for users.

4.6.4 CARTO

"CARTO, previously known as CartoDB is a SaaS cloud computing platform which provides web GIS functionalities in a web browser. The company is positioned as a Location Intelligence platform due to tools with an aptitude for data analysis and visualization that do not require previous GIS or development experience. CARTO is an open source software built on PostGIS and PostgreSQL. The tool uses JavaScript extensively in the front end web application, back end Node.js based APIs, and for client libraries. CARTO consists of two primary offerings. CARTO Builder and CARTO Engine" (Wikipedia, 2019).

CARTO builder is a similar application to the ArcGIS App Builder. This platform aims to enable customers without coding skills to customize and build their application based on their needs. CARTO Engine is a set of tools and API's which empower users to perform operations and functionalities such as data analysis and management and visualization.

Simply said, this company aim is to enable easier application, dashboard builder and interactive maps for researches, data scientists, marketing companies and all mappings related industries. With a subscription, the user gets access to a set of API's and SDK's which would enable easy integration with the database, routing, geocoding, etc.

4.6.5 MapBox

This is one of the largest fully Web GIS platforms for the developers on the market currently. MapBox is the provider of online maps for Facebook, Foursquare, the Weather Channel, Snapchat, etc.” Mapbox is the creator of, or a significant contributor to some open source mapping libraries and applications, including the MBTiles specification, the TileMill cartography IDE, the Leaflet JavaScript library, and the CartoCSS map styling language and parser” (Wikipedia,2019).

“MapBox is location data platform for mobile and web applications. They provide the building blocks to add location features like maps, search, and navigation into any experience you create.” (MapBox, 2019). This is a development platform which helps developers to create spatially related applications. The main focus of this company is the support of web and mobile – data making process. By the MapBox documentation you are able to (MapBox, 2019):

- Work within Mapbox's robust data.
- Style map down to the smallest details.
- Upload or create custom data.
- Develop full-featured web and mobile applications.
- Extend your app's functionality with web services for geocoding, directions, spatial analysis, and more.
- Create static maps programmatically.

This SaaS cloud computing platform is providing base maps, geocoding services, routing, styling libraries, spatial analysis and APIs and SDKs for easier creation of web and mobile applications. One of the only web mapping platforms that provide SDK for Unity.

4.6.6 HERE

HERE maps are the online mapping platform which provides location data and related services to the other individuals and customers." It is majority-owned by a consortium of German automotive companies (namely Audi, BMW, and Daimler), whilst other companies also own minority stakes. Its roots date back to U.S.-based Navteq in 1985, which was acquired by Finland-based Nokia in 2007. HERE is currently based in Amsterdam" (Wikipedia, 2019).

Interesting history of Here technologies starts in 1985 in Chicago when company Naviteq started with development electronic navigable maps. This company was acquired by Nokia in 2007. Under Nokia Naviteq rebrand to Here in 2012 and in 2015 was bought by German carmakers Audi, BMW, and Mercedes. This interesting history gives a brief insight into what HERE maps are today and why its focus on navigation and mobile technologies.

Today the company provides location-based, automotive, mapping, traffic, indoor mapping products. The list is long and HERE maps are one of the leaders in this sector. The company promotes its support for the utility industry, however, functionalities and features explicitly for the utility industry are not available. As in other industries, the customer is able to extend the possibilities and adjust application build on top of Here technology for utilities, however, there is no exclusive support for the utility sector.

5 Results

Results from data analysis are presented in a tabular manner in the previous chapter. However, a table with final data, merged with both Desktop/Web and only Web software will be presented. It is important to emphasize that it is impracticable to compare all of this software based on one criterion. In the data analysis section, they were separated into different groups. In this section, they will be shown together for a better overview and with all the characteristics related to the utilities and possible adjustment for the utility sector.

As mentioned in delimitation, when considering components of the software, all of the services provided by the vendor who developed software were considered. Regarding features of the software, several criteria is checked. In the following section, they are explained for a better understanding of the results. For utilities concretely, 3D data is becoming a standard, although not necessary. By the Al-Rawabdeh “3D GIS model expresses terrain features in an intuitive way which enhances the management and analysis of a proposed project through 3D visualization” (2014, p 19.). Network analysis are an important factor as most of the packages, add-ons and plugins for utilities run these analysis in order to perform functions such as load flow, service area, short circuit, etc. Even if GIS vendor does not offer package “out of the box” for the utility sector, to develop a solution on top of the system which already have network analysis functions is much smoother and easier for utility companies. Reason for this are analysis usually conducted by the utilities, which mostly include networks and network related topology. Raster and vector analysis are an integral part of GIS softwares. Preferably, all GIS software used in the utility industry have the possibility to perform these analysis. SDK and API were considered because of the possibility of the company to adapt the software to its needs. As different companies have different standards and ways of performing the work, it is preferred for the software to offer this feature. Last three features can be addressed as a whole. They are meant to be used by the big companies. Enterprise GIS is a set of software where company have the ability to adapt this model by its requirements. The cloud solution is one of the most popular today and mainly consists of the company storing the data on the cloud, while it can also offer cloud services such as SaaS to its employees or customers.

	eSpatial	CARTO	Mango Map	MapBox	GISCloud	HERE	Open Utilities Designer	AutoCAD MAP 3D	QGIS	ArcGIS
Support user roles and administration	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Support 3D	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Support Network analysis	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Raster analysis supported	No	No	No	Yes	Yes*	Yes	Yes	Yes	Yes	Yes
Vector analysis supported	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Have SDK	No	Yes	No	Yes	No	Yes	Yes	Yes	No	Yes
Have API	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Provides Enterprise package	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Supports Integration with Cloud solutions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SaaS	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes

Table 10 Result table with all software in this project and their features

6 Discussion

Utility industry can benefit from the fact that Web GIS support multiple platforms and this can be applied to both office systems and fieldwork. With a system based on client-server architecture, company can have one data center which would be accessible from multiple locations. Server with good standardization would greatly reduce the multiplication of the data and allow access to company datasets from all the locations where internet is available. It seems that GIS vendors realize this and are trying to integrate their systems with Web technologies as much as possible. This is cognized through GIS Enterprise and Mobile support various vendors include for their users. Out of four vendors who provide both Desktop and Web GIS, all of them are mobile friendly and offer Enterprise solutions. With these subscriptions, or without, users are able to integrate their systems into the Cloud environment. In this case, it seems that vendors who support both Desktop and Web GIS can offer more and their Web solutions do not lack in functionality compared to fully Web supported GIS. The benefit of the Web for utilities is ensured in connectivity between various systems.

GIS market looks like it follows up problems and emerging technologies in the utility sector. Most problems related to management and handling spatial data, GIS vendors seem to have a solution for that. ESRI and AutoCAD have package exclusively for utilities, while Bentley software is made just for handling data within the utility sector. All software provided by the same company seems as greatly connected. In the other, hand fully Web GIS vendors tested in this project does not have software specifically made for utilities. These companies rely on their API's and SDK' which would provide an opportunity for developers and companies to create their own applications allowing them freedom and adoption for their requirements.

GIS expands its possibilities greatly with the Web, however, that does not seem to make GIS primarily management system in enterprises. Even though GIS supports data management, enterprises need a much more complex system for handling various of the data. In the other hand, GIS integration with existing systems can be facilitated with Web. Data with spatial context could be easily visualized in Web browsers, permissions and authorizations would be held with much fewer resources and integration into one system would make handling data much easier.

7 Conclusion

It seems that GIS is not yet ready to be fully transmitted from Desktop to the Web. Web GIS does add great versatility and new ways of utility industry can use GIS. However, it seems that it is a long way from full evolution from Desktop GIS to the Web environment. However, trend among all software's is moving to cloud computing, as it is gaining more and more popularity. With different architectures and features among Web GIS applications, there is a vast amount of the opportunities for utility enterprise to choose from, and on top of that, it is possible to expand these opportunities with software tools, libraries, etc. provided by GIS vendors and communities. GIS definitely cannot solve all of the problems utility industry encounter but can come as a tool which would help greatly in the organization, fieldwork, and better user support.

REFERENCES

1. Enterprise GIS, Best practices, (2007). Retrieved from: www.esri.com/library/bestpractices/enterprise-gis.pdf (May 2019)
2. Daniel Sui and Richard Morrill (2004). Computers and Geography: From Automated Geography to Digital Earth, pp 81 – 83.
3. Michael F. Goodchild (2018) Reimagining the history of GIS, Annals of GIS, 24:1, 1-8, DOI: 10.1080/19475683.2018.1424737
4. Michael J, de Smith Michael, F Goodchild, Paul A Longley (2018). Geospatial Analysis: A Comprehensive Guide (6th edition), pp 1 – 3.
5. Denzin & Llncoln (2005). Handbook of Qualitative Research. Pp. 3 – 7.
6. International Labor Organization (2019), Retrieved from: www.ilo.org/global/industries-and-sectors/utilities-water-gas-electricity/lang--en/index.htm (May 2019)
7. MSCI(2019), Retrieved from www.msci.com/documents/1296102/1339060/GICSSectorDefinitions.pdf/fd3a7bc2-c733-4308-8b27-9880dd0a766f
8. Capterra (2019). Retrieved from www.capterra.com/reviews/faqs-verification
9. G2 Crowd (2019). Retrieved from www.g2.com
10. SimilarWeb (2019). Retrieved from www.similarweb.com
11. Jansen, Harrie (2010). The Logic of Qualitative Survey Research and its Position in the Field of Social Research Methods [63 paragraphs]. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *11*(2), Art. 11, http://nbn-resolving.de/urn:nbn:de:0114-fqs1002110.
12. Synergy research group (2019). Retrieved from www.srgresearch.com/
13. Jere, The future of internet GIS – An opportunity all the way. Retrieved from www.geospatialworld.net/article/the-future-of-internet-gis-an-opportunity-all-the-way
14. Schaffers, Hans & Komninos, Nicos & Pallot, Marc & Trousse, B & Nilsson, Michael & Oliveira, Alvaro. (2011). Smart Cities and the Future Internet: Towards Cooperation

Frameworks for Open Innovation. Future Internet Lect. Notes Comput. Sci.. 6656. 431-446. 10.1007/978-3-642-20898-0_31. pp. 435

15. Al-Rawabdeh, Abdulla & Al-Ansari, Nadhir & Attya, Hussein & Knutsson, Sven. (2014). GIS Applications for Building 3D Campus, Utilities and Implementation Mapping Aspects for University Planning Purposes. Journal of Civil Engineering and Architecture. 8. pp. 19-22. 10.17265/1934-7359/2014.01.003.
16. Daniel Arribas-Bel, Alex Singleton (2019). Geographic Data Science. Department of Geography and Planning, University of Liverpool, Liverpool, L69 7ZT, U.K. pp. 1-8.
17. Borko Furht, Armando Escalante (Ed.) (2010). Handbook of Cloud Computing. Doi:10.1007/978-1-4419-6524-0, pp. 3-9.
18. History of GIS (2018 January). GISGeography. Retrieved from gisgeography.com/history-of-gis
19. Mai T (2012 Oct). Global Positioning System History. Retrieved from www.nasa.gov/directorates/heo/scan/communications/policy/GPS_History.html
20. Howell E (2018 Apr). Navstar: GPS Satellite Network. Retrieved from www.space.com/19794-navstar.html
21. Selective Availability(n.d.). Retrieved from www.gps.gov/systems/gps/modernization/sa
22. Leick A (2009 Mar). Using GIS with GPS. pp 1 – 8.
23. Jayavarapu A.(2007). Enterprise GIS Projects: Challenges and Solutions. pp.1-2
24. Reinhardt, W. (2010). Enterprise gis. In B. Warf (Ed.), Encyclopedia of geography (pp. 912-913). Thousand Oaks, CA: SAGE Publications, Inc. doi:10.4135/9781412939591.n351
25. Lewis, J. (2012). Web 2.0. In H. K. Anheier & M. Juergensmeyer (Eds.), Encyclopedia of global studies (Vol. 1, pp. 1782-1782). Thousand Oaks, CA: SAGE Publications, Inc. doi: 10.4135/9781452218557.n561
26. Purnima K Sharma, Dinesh Sharma, R.K. Singh(2017). Development of Field Propagation Model for Urban Area. Hamburg. Anchor Academic Publishing. Pp.1 - 8
27. Rao S and Vinay S. (2009). Choosing the right GIS framework for an informed Enterprise Web GIS Solution. New York, USA. CIESIN, Columbia University & NASA
28. DiNucci D. (1999) Fragmented Future. Design and New Media p.220

29. Stefan Jablonski, Ilia Petrov, Christian Meiler, Udo Mayer(2004). Guide to Web Application and Platform Architectures. Erlangen, Germany. Springer; 2004 edition pp.31 -33
30. Dasgupta A (2010, Jun). An introduction to Enterprise GIS. Retreived from www.geospatialworld.net/article/an-introduction-to-enterprise-gis/
31. GIS Standards(n.d.) Retreived from www.gistandards.eu/gis-standards
32. OSGEO (n.d.) Retreived from wiki.osgeo.org/wiki/Main_Page
33. Wikipedia (n.d.) Retreived from en.wikipedia.org/wiki/Distributed_GIS
34. Meyers J.GIS in the utilities (2005). P A Longley, M F Goodchild, D J Maguire, and D W Rhind(Eds). Geographical Information Systems: Principles, Techniques, Management and Applications, 2nd Edition, Abridged. Second edition(2005) 978-0-471-73545-8
35. 1000 GIS Applications & Uses – How GIS Is Changing the World (2019).GISGeography. Retreived from: gisgeography.com/gis-applications-uses/
36. Liang Zhao, Sherif Sakr, Anna Liu, Athman Bouguettaya(2014), Springer; 2014 edition pp. 3 – 10
37. Kouyoumjian V (2010). GIS in the Cloud. The New Age of Cloud Computing and Geographic Information Systems. ESRI pp 3-10
38. Sourcepole(n.d.) Retrieved from qgisenterprise.com/ueber-uns/Sourcepole
39. Werner Kuhn (2012) Core concepts of spatial information for transdisciplinary research, International Journal of Geographical Information Science, 26:12, 2267-2276, DOI: 10.1080/13658816.2012.722637
40. Lawrence K. Wang, Chih Ted Yang(Ed.)(2014) Modern Water Resources Engineering .Publisher Humana p.2 & p.142
41. Private vs. Public vs. Hybrid Cloud – When to choose what? (2017, Jan), Retreived from www.thinksys.com/cloud/private-vs-public-vs-hybrid-cloud
42. State of Green(2019) Retreived from stateofgreen.com/en/sectors/water/water-resource-management
43. YouSee interactive map(2019) Retreived from daekning.tdc.dk/tdcnetmap_ext_tile2

44. Abdelbaki, C., Benchaib, M.M., Benziada, S. et al. Appl Water Sci (2017) 7: 1561. doi.org/10.1007/s13201-016-0416-1
45. Chandresh G. Patel (2010) Role of Geographical Information System in Water Resources And Management-An Overview. Ganpat University 1U.V.Patel College of Engineering, India. Pp. 1 -2
46. Lateş, I., Luca, M., Ilie, G., & Iurist, N. (2016). Studies on the Implementation of GIS Model in Water Supply Systems, Present Environment and Sustainable Development, 10(2), 153-160. doi: doi.org/10.1515/pesd-2016-0033
47. Martin Lněnička, Jitka Komárková(2013). Cloud solutions for GIS and Cloud – based testing of Web – Based applications. Pardubice. University of Pardubice, Faculty of Economics and Administration, Institute of System Engineering and Informatics
48. Rezaei, Najmeh & Nayeripour, Majid & Roosta, A & Niknam, Taher. (2009). Role of GIS in Distribution Power Systems. World Academy of Science, Engineering and Technology. 36.
49. GitHub (2019) Retreived from github.com/qgis/qgis-web-client
50. M. A. Hassan and S. R. Abu Helwa,(2013) "GIS university course for senior electrical engineering students," 12th International Conference on Environment and Electrical Engineering, Wroclaw, 2013, pp. 277-281.
doi: 10.1109/EEEIC.2013.6549631
51. Fu, P., & Sun, J. (2010). Web GIS: principles and applications. Esri Press.
52. 42matters (2019) Retreived from 42matters.com/app-market-explorer
53. ESRI(2019) Utility Network Serivces. Retreived from enterprise.arcgis.com/en/server/latest/publish-services/windows/utility-network-services.htm
54. QGIS Documentation (2019) Retreived from docs.qgis.org/2.8/en/docs/user_manual/working_with_ogc/ogc_server_support.html
55. WaterWorld(2017). Use of GIS Growing in the Municipal Water, Wastewater Business Retreived from www.waterworld.com/home/article/16197217/use-of-gis-growing-in-the-municipal-water-wastewater-business

56. Chutkay S. (2009 Jan). Integrated GIS for Gas Distribution System. Retreived from www.geospatialworld.net/article/integrated-gis-for-gas-distribution-system/
57. Meehan W, Brook R. , Wyland J. (2012). GIS in Energy and Utilities. Kresse, Danko (Eds.). Springer Handbook of Geographic Information (2012). 10.1007/978-3-540-72680-7
58. Moretz D. (2008) Internet GIS. In: Shekhar S., Xiong H. (eds) Encyclopedia of GIS. Springer, Boston, MA
59. Client-Server Model(2016 June) Retreived from techterms.com/definition/client-server_model
60. Veenendaal B.(2015). Developing a Map model for Web mapping and GIS. Department of Spatial Sciences, Curtin University, GPO Box U1987, Perth, Australia pp.31-34
61. Dragicevic (2004) The potential of Web-based GIS. Spatial Analysis and Modeling Laboratory, Department of Geography, Simon Fraser University, 8888 University Drive, Burnaby, BC, V5A 1S6, Canada
62. Deogawanka S. (2015, Dec) GIS in Oil and Gas. Retreived from: www.gislounge.com/gis-in-oil-and-gas/
63. Ge power(2019) Retreived from www.ge.com/power
64. Dadić T, Jurišić M. Jurišić L(2015) Application of GIS in the wastewater management. Tehnički vjesnik 21, 5(2014), 1159-1163
65. Dragićević, S. J Geograph Syst (2004) 6: 79. doi.org/10.1007/s10109-004-0133-4
66. Peterson, M. (2008). Web gis. In K. K. Kemp (Ed.), Encyclopedia of geographic information science (pp. 511-513). Thousand Oaks, CA: SAGE Publications, Inc. doi: 10.4135/9781412953962.n230
67. ESRI (2017) Canadian Utility Goes Real Time with Mobile GIS. Retreived from www.esri.com/about/newsroom/arcnews/canadian-utility-goes-real-time-with-mobile-gis/?rmedium=arcnews&rsource=www.esri.com/esri-news/arcnews/winter17articles/canadian-utility-goes-real-time-with-mobile-gis
68. Song J, Song Q (2014). Analysis of mobile database technology and its application. School of Information Technology, Kunming University, Kunming, China. Mechatronics Engineering, Computing and Information Technology(2014)

69. ArcGIS Server(2019). About web GIS. Retreived from enterprise.arcgis.com/en/server/latest/create-web-apps/windows/about-web-gis.htm
70. Forbes, A. (2006) Issues involved in the development of Internet based GIS applications. A Thesis submitted for the degree of Bachelor of Applied Science. Dunedin, New Zealand: University of Otago
71. Perry S(2012). Customer Engagement Using ArcGIS Online. Retreived from sspinnovations.com/blog/customer-engagement-using-arcgis-online
72. Fouskas, Kostas & Giaglis, George & Kourouthanassis, Panos & Pateli, Adamantia & Tsamakos, Argiris. (2002). On the Potential Use of Mobile Positioning Technologies in Indoor Environments.
73. Ming-Hsiang Tsou, Barney Warf(Ed)(2019) Mobile GIS, Encyclopedia of Geogpraphy. Doi: http://dx.doi.org/10.4135/9781412939591.n775
74. Dunn P (2018). Utilities Can Use Digitalization And IoT To Power Smart Cities. Retreived from www.digitalistmag.com/cio-knowledge/2018/12/17/utilities-can-use-digitalization-and-iot-to-power-smart-cities-06195186
75. Simmhan, Y, Ravindra, P, Chaturvedi, S, Hegde, M, Ballamajalu, R. Towards a data-driven IoT software architecture for smart city utilities. Softw Pract Exper. 2018; 48: 1390–1416. doi-org.zorac.aub.aau.dk/10.1002/spe.2580
76. S Geertman, J Ferreira, Jr.R Goodspeed, J Stillwell(2015). Planning Support Systems and Smart Cities. Switzerland 2015. Springer, Cham. **DOI**doi-org.zorac.aub.aau.dk/10.1007/978-3-319-18368-8 pp 1 - 9
77. Gerber, R., and G.K Chuan, 2000. Fieldwork in Geography: Reflections, Perspectives and Actions, Kluwer Academic Publishers, The Netherlands, 284 p.
78. Chen , Y. B., Zhong , E. S., et al. (2002) A seamless integratio n research metho d o f GI S an d O A syste m based o n ComGI S technology . Remote Sensing for Land & Resources 2 , 56-60 .
79. Weng , Q. IT. & Haute , T. (2001) Modelin g urba n growt h effect s o n surfac e runof f wit h th e integratio n o f remot e sensin g a n d G1S. Environmental Manage. 28 (6) , 737-748 .

80. Guonian Lü, Michael Batty, Josef Strobl, Hui Lin, A-Xing Zhu, Min Chen. (2019) Reflections and speculations on the progress in Geographic Information Systems (GIS): a geographic perspective. International Journal of Geographical Information Science 33:2, pages 346-367.
81. Harris, R., O'Sullivan, D., Gahegan, M., Charlton, M., Comber, L., Longley, P., … Arribas-Bel, D. (2017). More bark than bytes
82. Reflections on 21+ years of geocomputation. Environment and Planning B: Urban Analytics and City Science, 44(4),
83. Meehan, B. (2013)GIS for Enhanced Electric Utility Performance, Artech House,. ProQuest Ebook Central, ebookcentral.proquest.com/lib/aalborguniv-ebooks/detail.action?docID=1455539.
84. F. Goodchild, Michael. (2018). Reimagining the history of GIS. Annals of GIS. 24. 1-8. 10.1080/19475683.2018.1424737.
85. Hristian O, A Boso, J Espluga, A Prades(2013),A qualitative study of users' engagement with real-time feedback from in-house energy consumption displays,Energy Policy, Volume 6
86. Jansen H (2010). The Logic of Qualitative Survey Research and its Position in the Field of Social Research Methods
87. Fereidoon P. Sioshansi(Ed.)(2016). Future of Utilities - Utilities of the Future: How Technological Innovations in Distributed Energy Resources Will Reshape the Electric Power Sector
88. J.D.Power(2019) J.D.Power. Retrieved from www.jdpower.com/business/press-releases/jd-power-2018-utility-digital-experience-study
89. Rezaei, Najmeh & Nayeripour, Majid & Roosta, A & Niknam, Taher. (2009). Role of GIS in Distribution Power Systems. World Academy of Science, Engineering and Technology. 36.
90. A.T. Kearney(2017) Technology and Innovation for the Future of Production: Accelerating Value Creation.Geneva. World Economic Forum

91. Abdelbaki, C., Benchaib, M.M., Benziada, S. et al. Appl Water Sci (2017) 7: 1561. doi.org/10.1007/s13201-016-0416-1
92. ArcNews(2012) The 50th Anniversary of GIS. Retreived from www.esri.com/news/arcnews/fall12articles/the-fiftieth-anniversary-of-gis.html
93. E. Poorazizi, A.A. Alesheikh and S. Behzadi, 2008. Developing a Mobile GIS for Field Geospatial Data Acquisition. Journal of Applied Sciences, 8: 3279-3283.
94. ASCI(2018) American satisfaction customer index. Retreived from www.theacsi.org/
95. UKSCI(2018) UK satisfaction customer index. Retreived from www.instituteofcustomerservice.com/uk-customer-satisfaction-index
96. Amirian, P. and A. Alesheikh, 2008. A hybrid architecture for implementing efficient geospatial web services: Integrating NET Remoting and web services technologies. J. Applied Sci., 8: 730-742.
97. Bovaird, T. (2007), Beyond Engagement and Participation: User and Community Coproduction of Public Services. Public Administration Review, 67: 846-860. doi:10.1111/j.1540-6210.2007.00773.x
98. InternetWorldStats(2019) Retrieved from www.internetworldstats.com/stats.htm
99. TechnoPedia(n.d.) Retreived from www.techopedia.com/definition/26002/web-based-application
100. Doman L. (2016) Eia. EIA projects 48% increase in world energy consumption by 2040. Retreived from www.eia.gov/todayinenergy/detail.php?id=26212
101. Simmhan, Y, Ravindra, P, Chaturvedi, S, Hegde, M, Ballamajalu, R. Towards a data-driven IoT software architecture for smart city utilities. Softw Pract Exper. 2018; 48: 1390– 1416. https://doi-org.zorac.aub.aau.dk/10.1002/spe.2580
102. D. Ryan(2011) Cloud Computing Privacy Concerns on Our Doorstep. Communications of the ACM, January 2011, Vol. 54 No. 1, Pages 36-38 10.1145/1866739.1866751. Retreived from cacm.acm.org/magazines/2011/1/103200-cloud-computing-privacy-concerns-on-our-doorstep/fulltext
103. Autodesk (2019) Retreived from www.autodesk.com
104. Bentley (2019) Retreived from www.bentley.com/en

105. Mango Map (2019) Retreived from mangomap.com
106. Here (2019) Retreived from www.here.com
107. MapBox (2019) Retreived from www.mapbox.com/
108. CARTO (2019) Retreived from carto.com

Appendix

In appendix are questions that were in e-mail related to survey. Intention was not to have a lot of question for easier understanding.

Dear Ms/Mrs,

Please read this email if you have 5 minutes. It will benefit me greatly.

I am a student at Aalborg University. Currently, I am in the process of writing a master thesis. In short, the thesis is about comparing web/cloud GIS with desktop applications within the utility industry. More precise, how they behave and respond on different occasions.

I am kindly asking if you can provide me information which GIS software for work related to utility sector company is using?

This question is aiming for GIS software included in any stage of planning, design, maintain and monitor the process of networks and facilities?

What software company uses for Web GIS?

This will be used just in research purposes.

For any more information contact me: bkurid17@student.aau.dk

Thank you in advance,
Branko Kuridza