TATA CCTV Wastewater Program-Stakeholder Analysis Report

Date: 06/22/2020
Name: Maggie, Hanyun, Linda, Joy, Haijing

Contents

Teamwork distribution table

Name	Responsibilities
Maggie	1.1, 1.2, 3.4
Hanyun	2.1, 2.2, organize the report
Linda	3.1, 3.2, 3.3, organize the report
Joy	4.2，5.2
Haijing	4.1, 5.1

1. Government

1.1 Overview of 3 modes operation

1. Water system can be in charged in three segments in different countries: Government(United States, Canada, Australia, etc.), Completely Prioritized(England, France, etc.), and Half prioritized/half government control(Philippines, Brazil)
2. No matter which segment each country be classified, the regulation of responsible organizations using CCTV to inspect sewage systems is totally legal. The only restriction is that CCTV inspection should not be used in drinking system (United States Environmental Protection Agency, 2020)
3. In the following part, we would like to focus on comparing the regulation restrictions and operation mode in different segments and take one of the countries mentioned in each segment as an example. However, Half prioritized/half government control mode regulation is similar to Completely Prioritized mode. Therefore, it would be shown and declared in the same section.

1.2 Regulation restriction and operation mode

- Government Supply
    - Country: United States
    - Inspection programs are required to determine current sewer conditions and to aid in planning a maintenance strategy. Ideally, sewer line inspections need to take place during low flow conditions. If the flow conditions can potentially overtop the camera, then the inspection should be performed during low flow times between midnight and 5 AM, or the sewer lines can be temporarily plugged to reduce the flow.
    - When cleaning sewer lines, local communities need to be aware of EPA regulations on solid and hazardous waste as defined in 40 CFR 261. In order to

comply with state guidelines on testing and disposal of hazardous waste, check with the local authorities(United States Environmental Protection Agency, 1999).

- The National Pollutant Discharge Elimination System (NPDES) prohibits discharges of pollutants from any point source into the nation's waters except as authorized under an NPDES permit. EPA and state NPDES inspectors evaluate collection systems and treatment plants to determine compliance with permit conditions including proper O&M. Among others, these permit conditions are based on regulation in 40 CFR 122.41(e): "The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with the conditions of this permit."(United States Environmental Protection Agency, 2005)
- Benefits of using CCTV from United States Government side(National Service Center for Environmental Publications (NSCEP), 2009):
  - Detailed view: provides a detailed view of the interior surface of pipes and permits characterization of pipe defects through a systemized coding process
  - Mainly used throughout years: has long been the mainstay of sewer condition assessment and will likely remain a vital part of condition assessment programs
  - Create a permanent video record of sewer pipe conditions

- Prioritized Supply
  - Country: United Kingdom
  - There's no regulation restriction on setting CCTV to do pipeline inspection, however, residents have the obligation to require their prioritized CCTV survey as a routine.
  - Residents are usually responsible for drains inside the boundaries of their property, while the sewerage company is responsible for lateral drains, which are usually outside of property boundaries, and sewers. Although most sewers are now **publicly owned**, there are still some private or unadopted sewers. If the resident's property is served by one of these, they may be responsible for maintaining it(Citizens Advice, 2020).
  - In UK regulation, there's difference between a drain and a sewer:
    i. A **drain** is a pipe that drains water and waste from a building and other buildings which belong with it, for example a garage.
    ii. A **lateral drain** is a length of pipe which carries wastewater away from your property to a sewer. It's usually located outside the resident's property boundary, often under a public pavement or road. A lateral drain might run under their property if they share a sewer with their neighbour.
    iii. A **sewer** collects water and waste from the drains of a number of buildings. Most sewers are **publicly owned** and are maintained by the resident's water company. However, there are still some privately owned sewers. Some people aren't connected to a sewer but to a cesspool, septic tank or treatment plant. If

the resident's aren't connected to a sewer, they won't have to pay sewerage charges to a sewerage company.

- If the nearest public sewer is more than a hundred feet from the resident's property and their drain runs into an adequate cesspool or septic tank, UK's local authority **can't insist** that you connect to the public sewer.
  However, they can insist if they agree to pay for the additional costs of connection, including construction, maintenance and repairs.

2. Residents

Since in the three models of sewage water treatment, ie, government owned, private company owned and hybrid model, none of them would incur extra money on residents, so there is no direct disadvantage that may be brought about to the residents.

As a result, this part will focus on how using AI to improve detection efficiency can potentially benefit the residents.

One benefit that is obvious is that when the detection efficiency of sewage pipe failures is increased, residents can expect less downtime of water usage. Because even though water supply and wastewater pipes are separated, there will be a downtime if pipes need maintenance. As a result, less water downtime is clearly an expected benefit for residents.

2.1 Benefits: less risk regarding water pollution and public health issues

As it may not be common, a failure in the sewage pipeline can cause flooding of wastewater on the ground, and it is costly to clean the site. Furthermore, wastewater can also carry potentially contagious diseases that may affect the local residents if not properly dealt with[9]. And if residents get sick, it will lead to an increase in public health expenses.

As a result, according to Elmasry, an increased efficiency in detecting failures in sewage pipelines can lead to less money spent on public health, which reduces the burden for residents.

2.2 Potential benefit: help organizations that helps poor countries save money

According to the WHO, safe sanitation systems are fundamental to protect public health[10]. As a result, in developing countries, for example Phillipine, where the sanitation and wastewater management conditions are less developed, if the AI-based approach can help increase the efficiency of detecting failures in sewage pipes, then organizations like WHO, the World Bank and other NGOs can save money in the construction and maintenance of local wastewater treatment systems.

3. Maintainer

3.1 Introduction of Sewer pipeline inspection techniques used by Current Maintainer

It is challenging to inspect the underground infrastructures. Compared to infrastructures like tunnels and road pavement, direct human inspection of sewer pipelines is impractical. It is due to the vast sets of buried pipelines, low visibility, unhealthy environment and small pipelines. Therefore, several sewer inspections techniques are used by current maintainers.

Sewer inspection techniques could be classified into four types according to the classification framework proposed by Moradi, Zayed, and Golkhoo: vision-based technologies, structural and bedding tools, defect specific technologies, and hybrid technologies.

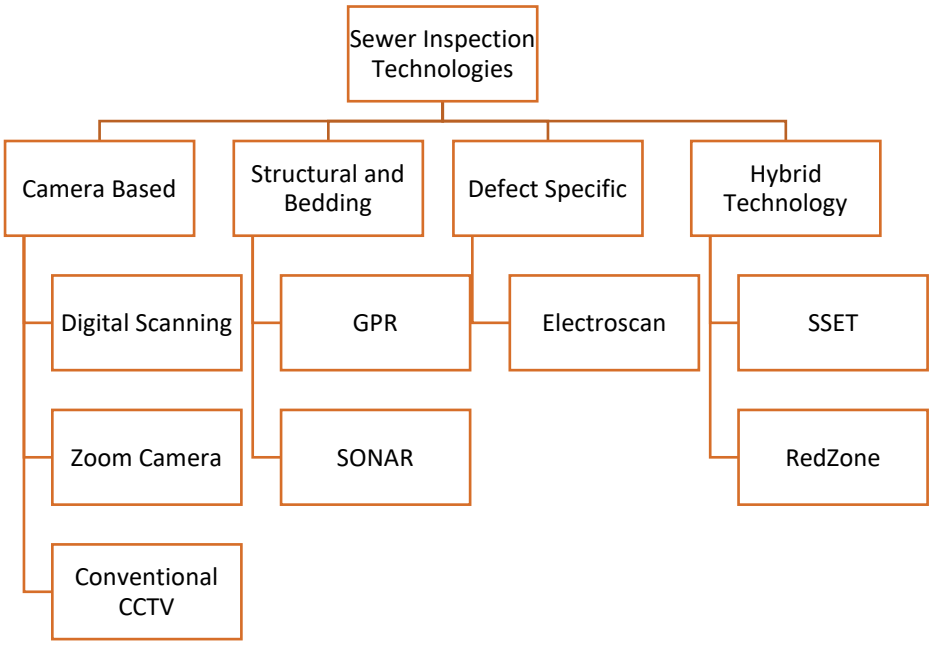


Figure 1 Different sewer pipeline inspection techniques Adopted from Review on Computer Aided Sewer Pipeline Defect (Moradi, Zayed, & Golkhoo, 2019).

1. Vision-based technologies:
   Camera-based inspection techniques can provide direct internal conditions of the pipelines through images, which is one of the most efficient methods for assessing wastewater pipeline conditions. The most common technologies in this category are conventional closed-circuit television (CCTV) inspection, zoom camera inspection, and digital scanning.

Category	**Advantages and Disadvantages**
CCTV	**Advantages:** It provides thorough inspection of pipe interiors. **Disadvantages:** It only provides a view of the pipe surface above the waterline and does not provide any structural pipe

	wall information.
Zoom cameras	**Advantages:** It is an efficient and cost-effective method of inspecting pipelines. By putting a camera at the end of the manhole, the zoom camera can highlight the pipe conditions and help inspection crews make better decisions about whether it is necessary to allocate CCTV resources. **Disadvantages:** This method is only useful for inspecting gravity sewers because force mains and service laterals do not have manholes for placing the Zoom camera. Besides, like CCTV inspection, zoom camera inspection is unable to see the information around pipelines. (It could only provide interior conditions at the end of pipes.)
Digital Scanning	**Advantages:** It produces high-quality images and unfolded views of the pipe. *It is used in Europe for a while and has begun to be used in the U.S. *It ay become a competitive option for condition assessment

2. Structural and bedding tools:
   Visual techniques are not able to evaluate pipe wall integrity and soil conditions around the pipeline, so other technologies have been deployed to explore subsurface features.

Category	**Advantages and Disadvantages**
Ground Penetrating Radar (GPR)	GPR IS known as a non-destructive method for detecting subsurface materials using electromagnetic waves. **Advantages:** GPR reports can produce precise data about pipe walls and condition of soil around pipes. **Disadvantages:** Penetration depth depends on the ground material. Moreover, interpreting GPR data requires high skill operators.
Sonar	Sonar is also able to detect defects of invisible areas. **Advantages:** Sonar can detect defects under the waterline as well

	as pipe geometry, joint displacement, and pipe deflection. (Moradi, Zayed, & Golkhoo, 2019) Moreover, there is no need to shut down the sewer system, if we decide to employ sonar inspection. **Disadvantages:** Different frequencies might be required based on pipe diameter, amount of water sediment, and turbulences in the pipeline. (Moradi, Zayed, & Golkhoo, 2019)

3. Defect-Specific technologies:
   Since visual methods are marginally successful in detecting defects like infiltration and exfiltration, other defect-specific technologies have been introduced.

Category	**Advantages and Disadvantages**
Electrical leak detection systems	**Advantages:** This system can be employed to evaluate the magnitude of infiltration and exfiltration. **Disadvantages:** This system can only be implemented on conductive pipe. *Note: Electro Scan Inc. has developed an improvement tool which can be implemented on non-conductive pipe materials like concrete and brick.

4. Hybrid technologies:
   New inspection methods have emerged in recent years by integrating two or more technologies to detect various types of faults in sewer systems. This approach may offset the limitation of other technologies.

Category	**Advantages and Disadvantages**
Sewer Scanner and Evaluation Technology (SSET)	The components of SSET includes a fisheye camera lens with an optical scanner and gyroscope technology. **Advantages:** Deflections of the horizontal and vertical pipes are measured and graphically illustrated. Moreover, statistical data can be generated on the defects. **Disadvantages:** During the inspection along the pipeline, fogging and staining of the scanner lens may occur, and more light intensity is required for greater diameter of the pipe. (Purdue ECT Team, 2007)

RedZone	RedZone combined laser and CCTV methods. **Advantages:** It can inspect large pipes and provide more accurate and comprehensive information of pipe conditions.
KARO systems PIRAT systems	Multi-sensor inspections system **Advantages:** Both systems can automatically interpret and categorize defects in sewer pipelines. *The KARO system has been conceived primarily for the inspection for concrete and vitrified clay.

3.2 Manual inspection process and skill sets required

1. **Manual inspection process**

    a. **CCTV inspection**

    After verifying the ability of the camera to pass through the pipe, the inspection process starts with putting a closed-circuit television camera at either end of the manhole. The camera will be moved through the line at a moderate rate, stopping when necessary to permit proper documentation of the sewer's condition. If non-remote operated winches are used to pull the CCTV through the line, adequate means of communication shall be provided between the two manholes in the section being inspected to ensure good communication between crew members. If the CCTV camera does not pass through the entire section of the manhole during the inspection operation, the Contractor shall set up its equipment so that the inspection can be carried out from the opposite manhole. If the camera does not pass through the entire section of the manhole again, the inspection shall be considered complete and no further inspection work shall be required until repairs are made.

    b. **Data Review and Reporting for CCTV inspections**

    After recording the interior conditions of the pipes, the contractor is responsible for reviewing collected data, coding observations, and completing a full PACP evaluation of each inspected pipeline. The digital film files shall follow the owner's requirements, such as a minimum of 3000 lines of vertical resolution, and inclusion of an unfolded view of the entire pipeline.

2. **Process of training a proper CCTV operator**

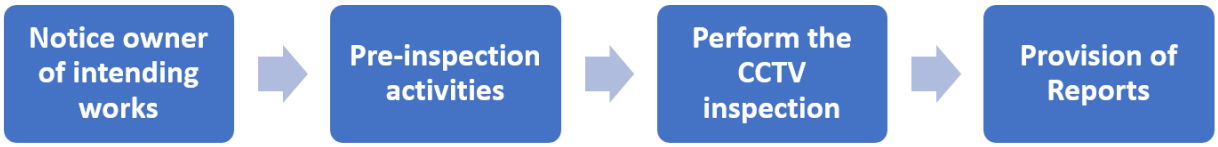
    Ideally, a candidate of CCTV operator will be put in a supporting position to learn the outside of the truck first — six months to a year is ideal. (Aanderud, n.d.)

During this period, this candidate must be given sufficient time to observe and learn the impact they have on traffic, and safety of pedestrians. Then, it is important to send the person to receive NASSCO/PACP training, which provides comprehensive learning tools to help participants understand pipeline inspection technologies.

3. **Skills required for a competent pipeline inspection operator**

    a. Setups and traffic control
    b. Operation of the equipment
    c. Maintenance of equipment
    d. Knowledge of different equipment

3.3 Example timeline of current CCTV pipeline inspection



1. **Notice owner of intending works**: An approximate execution date should be provided in the Contractor's initial inspection plan.
2. **Pre inspection activities**:Pre-cleaning and debris removal are necessary prior to the inspection of existing sewer infrastructure.
3. **Perform the CCTV inspection**: On-site traffic management, flow control and perform the CCTV inspection.
4. **Provision of Reports**: Provide a detailed inspection report certified by the CCTV inspector. Since this is a manual process, it can take 2-3 weeks.

3.4 Traditional method challenges: performance evaluation and cost analysis

- Challenges of using CCTV:
    - large diameter pipes can pose a challenge for CCTV cameras due to lighting and camera resolution issues. In contrast, zoom cameras are known to perform better in larger diameter pipes
    - can only view pipe surfaces above the waterline. Sonar, on the other hand, requires a minimum water level for equipment deployment, and electro-scanning requires a full pipe
    - Time consuming: utilities that have adopted zoom camera technology as part of their sewer inspection strategy have reported inspection rates of 5,000 to 6,000 ft per day, which are roughly three to four times faster than inspections using traditional in-line CCTV
- Things need to be solved:

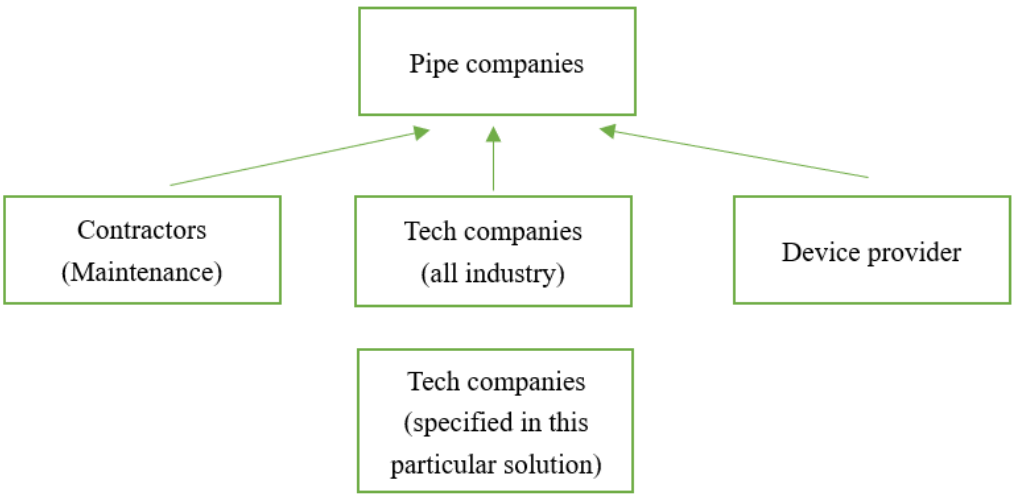
- Ongoing need for evaluations of technology performance
- Comprehensive cost data are not available for all technologies, and where available, they can vary widely:
- CCTV costs vary greatly depending on such factors as local labor rates and size of project.
- Cost/benefit analyses performed in support of a planned sewer inspection and condition assessment program will be affected by local rates for CCTV inspections and for any newer or alternative technologies under consideration. As new technologies mature, the costs tend to decrease.

4. Competitor

4.1 Classification of existing/potential competitors (Names and scope of business for each category)

Different types of developers, also the existing/potential competitors.

- Tech companies specifically target the deep learning solutions of CCTV supervision (vapar, etc.)
- Tech companies that provide AI powered solutions in all industries(Chetu, vGis: https://www.vgis.io/vgis-utilities-use-cases-high-accuracy-survey-grade-augmented-reality-ar-bim-gis/)
- Contractors who have their supervision and maintenance powered by ML technics (city west water, AU)
- Device provider, providing products like deep learning inference cameras(Flir: https://www.flir.com/browse/industrial/deep-learning-inference-cameras/)



4.2 Market Opportunity

- **Old infrastructure.**

Majority of sewers were built a long time ago and are reaching their end-of-service life. The average sewer in the US is 45 years old and they were designed to only last 50-80 years. The demand for sewer maintenance will surge in the near future.

- **New demands from increased runoff.**

Climate change increases frequency and magnitude of rain events. Additionally, urbanization causes more areas to be sealed and higher population density generating higher rain and wastewater runoff to be drained by sewers.

Meanwhile, more than 56 million new users will be connected to centralized treatment systems over the next two decades, and an estimated $271 billion is needed to meet current and future demands.

- **Aging workforce.**

An army of people has been responsible for ensuring that our sewers operate uninterrupted everyday. But large parts of the current workforce will retire in the next decade and with them the knowledge will be lost.

- **Inefficiency of current inspection process**

Currently there are several “defect catalogues” or “standard codes” used to describe defects and features found in CCTV condition assessment, however, the effectiveness of industry standards are limited by human error and the wide variations in quality of the inspection reports produced by different contractors, engineers, and operators in public agencies, not to mention the current workflow of human operators, requiring that every foot and every second of video is viewed in real-time, which contributes to approximately one quarter of the total cost to inspect and assess each foot of pipe.

4.3 Benefit and risk

1. **Benefits of entering automated inspection market**
    - Gain business profits by developing new system that in desire
    - Industry pioneer: stay ahead of competition
    - Help Contractor to save time and scanning cost of anomaly detection - faster data labeling and efficient review
    - Help contractors to improve customer service and safety by reducing the frequency of repairs.
2. **Risks of entering automated inspection market**
    - R&D challenges increase(if the program fails)
    - R&D expenses increase(if the program fails)
    - Take responsibility when problems come up (ex:natural disaster)
    - High video requirement: clean training data without on-screen defect labels to avoid ML “cheating”

5. Solution Provider

5.1 Five forces model

Business perspective, see the ML/DL solution of sewer CCTV supervision as a new product, and check the market response of the entry into the market.

1) Competitive Rivalry (Risk: Medium)

This looks at the number and strength of your competitors. From the summary above we could clearly see there are not many rivals in the industry right now, however, the rivals comes from many different roles in the industry (pipe company/contractor, tech companies, device providers). Since it is a rather new industry, the quality and strength of their product compared to ours are still unknown.

2) Supplier Power (Risk: Low)

This is determined by how easy it is for your suppliers to increase their prices. As a developer in the market, we don't necessarily have suppliers for our product.

3) Buyer Power (Risk: Medium)

We have not many customers, mainly the contractors and pipe companies that are in charge of the inspection and maintenance. These companies are used to manual laborers and are traditional utility industries, it might be hard for the company to embrace a technical change into their operation. Therefore, the buyer has strong bargaining power as of the price of our software.

4) Threat of Substitution (Risk: Medium)

This refers to the likelihood of your customers finding a different way of doing what you do. As we supply a unique software product that automates an important process, people may substitute it by doing the process manually or by outsourcing it. A substitution that is easy and cheap to make can weaken our position and threaten our profitability.

5) Threat of New Entry (Risk: Low)

Our position can be affected by people's ability to enter your market. This industry is very highly regulated and the product we are prospecting takes a lot of brainpower and excellent human resources. The other tech companies are not simply copying what we are doing since the algorithm is unseen to the public.

In a word, it takes too much money and effort to enter the market, and we have much protection of our key technologies. We have strong and durable barriers to entry, and can expect to preserve a favorable position and take fair advantage of it.

5.2 Case study

1) Subterral AI - US

- Product：SewerScout™ + Sewerlytics™

  Compact, light-weight smart device, easy to deploy in hard to access sewers.

  A cloud based platform to upload, review and share inspection data via the web

- Effectiveness：

  30 times faster and at half the cost of current technologies.

2) Hades - Switzerland

- Product:

  Software service (Machine learning to detect defects inspection videos)

- Primary Revenue source:

  charges per distance of sewer analyzed as well as a monthly user fee, with gathered data readily shareable in a web app.

- Main customers:

  public sewer asset managers such as city councils and sewer service providers (e.g. inspection companies and engineering firms).

- Challenges：
    - Difficulties to recruit talented computer scientists experienced in deep learning as they are currently in high demand
    - secure the necessary funds

3) SewerAI - US

- Product: AutoCode™

  SewerAI has developed an Artificial Intelligence-based (AI) tool, AutoCode™ to automatically label defects in sewer pipe inspection videos using existing condition assessment standards for defects and features, which significantly increases the production of condition reports on wastewater, storm, and drinking water assets, while also reducing total inspection costs.

    - Inspection management Saas Platform: Autocode v1 + Cloud Storage + Labeling UI. This platform enables users to directly see the defect Bounding box without rewinding the entire video.
    - Labeling As a Service: AI assisted data labeling for Utilities/Contractors/Engineering firms

- Project: SewerAI with Water Power Sewer
    - Analyzed over 1 million linear feet of lateral inspection video
    - Saved over $750000 and 8800 manual review hours
    - Able to design their algorithm to analyze non-HD videos

  Demo video: https://www.sewerai.com/products

4) Vapar - Australia

Service: Pipe CCTV condition assessment + ML defect Identification + Map embeded Visualization

Challenge: Vapar has collaborated with United Utilities to implement their AI on UK historic dataset. Their current challenge is to adapt to other countries' standards beyond Australia(WSA-05). In this case, to aligned its model outputs with the MSCC.

Plan: They plan to utilize and expand their targeted industry beyond the water and wastewater industry. Oil, gas and electric cable are being considered.

6. References

1. Moradi, S., & Zayed, T. (2019). Review on Computer Aided Sewer Pipeline Defect Detection and Condition Assessment MDPI Journal, Infrastructures 2019, 4(1), 10. https://doi.org/10.3390/infrastructures4010010
2. U.S. Arizona State, City of Sedona, Public Work Department, Wastewater Division. (2013). Pipeline Cleaning and CCTV Inspection Of Sewer Lines Services Contract. Retrieved from http://www.sedonaaz.gov/Home/ShowDocument?id=18846
3. South Australian Water Corporation. (2017). CCTV Inspection of Gravity Sewer Infrastructure. Retrieved from https://www.sawater.com.au/__data/assets/pdf_file/0011/178778/TS-0524-CCTV-Inspection-of-Gravity-Sewer-Infrastructure.pdf
4. United States Environmental Protection Agency (2020). Water and Sewage Utilities Sector (NAICS 2213). Retrieved 2020, from https://www.epa.gov/regulatory-information-sector/water-and-sewage-utilities-sector-naics-2213
5. National Service Center for Environmental Publications (NSCEP). (2009). Report on Condition Assessment Technology of Wastewater Collection Systems. https://nepis.epa.gov/Exe/ZyPDF.cgi/P1008H44.PDF?Dockey=P1008H44.PDF
6. United States Environmental Protection Agency. (1999). Collection Systems O&M Fact Sheet Sewer Cleaning and Inspection. https://nepis.epa.gov/Exe/ZyPDF.cgi/P10053G5.PDF?Dockey=P10053G5.PDF
7. M. Elmasry, A. hawari, T. Zayed (2017), 'Cost benefit analysis for failure of sewer pipelines', MATEC Web of conference.
8. J. Baumert, (2004), 'Private Sector participation in the water and wastewater services industry'
9. K. Medlicott, Sanitation and water, (2020), <https://www.who.int/water_sanitation_health/sanitation-waste/en/>
10. K. Naik, M. Stenstorm, (2012), 'Evidence of the influence of wastewater treatment on improved public health'

11. Federal Regulations. (n.d.). TITLE 40—Protection of Environment Chapter i—Environmental Protection Agency, Subchapter I—Solid Wastes, Part 261—Identification and listing of hazardous waste.. Electronic Code of Federal Regulations. Retrieved June 19, 2020, from https://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr261_main_02.tpl
12. United States Environmental Protection Agency. (1999). Collection Systems O&M Fact Sheet Sewer Cleaning and Inspection. https://nepis.epa.gov/Exe/ZyPDF.cgi/P10053G5.PDF?Dockey=P10053G5.PDF
13. Citizens Advice. (n.d.). Who is responsible for repairing drains and sewers. https://www.citizensadvice.org.uk/consumer/water/water-supply/sewerage/who-is-responsible-for-repairing-drains-and-sewers/
14. Cleaner. (2020). Artificial Intelligence in CCTV Sewer Condition Assessment https://www.cleaner.com/video/webinar/artificial-intelligence-in-cctv-sewer-condition-assessment?rel=related-categories
15. The American Society of Civil Engineers(ASCE). (2017). 2017 Infrastructure Report Card https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Wastewater-Final.pdf
16. SubteraAI. https://www.subterra.ai/products
17. Sewer AI. https://www.sewerai.com/products
18. United Utilities(2019). Meet VAPAR, one of the companies joining the Innovation Lab . https://www.unitedutilities.com/corporate/newsroom/blog/meet-vapar-one-of-the-companies-joining-the-innovation-lab/
19. Jeff Kart. (2020). Hades Startup Uses AI To Explore, Fix The Sewer Underworld. *Forbes* https://www.forbes.com/sites/jeffkart/2020/03/13/hades-startup-uses-ai-to-explore-fix-the-sewer-underworld/#624d1c7b38ab