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A Novel Wastewater Pipeline Renewal Engineering Cost Data and Metadata Collection and Reporting Methodology For the WATERiD Project

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Abstract:- Wastewater utilities in the US are faced with the difficult task of managing their pipeline assets with limited resources. Renewal engineering practices are costly and require a great deal of information to guide critical financial decisions concerning their use. This paper summarizes the development of a novel wastewater pipeline Renewal Engineering cost data and metadata collection and reporting methodology as part of the WATERiD project, funded by the USEPA and WERF. The overall objective was to collect large amounts of standardized cost data in an efficient way, i.e. leveraging the power of extract, transform, and load (ETL), a process for collecting, homogenizing, and storing data that is made possible through advanced computing power and the World Wide Web. Over300 examples of pipeline renewal engineering cost data were gathered from over 30 wastewater utilities in the US. Direct costs for popular methods of the work were gathered along with all supplemental direct costs pertaining to the work. Further, the social costs for each project were derived using methods developed in previous research. The results show factors driving the overall project cost and give a monetary estimate of the societal burden involved in wastewater pipeline asset management.

Keywords:- Cost, Renewal Engineering, Wastewater, Pipelines, Automated

I. INTRODUCTION

Infrastructure performance plays a critical role in supporting quality of life. From transportation systems, to power grids, and water pipelines, it is essential to societal welfare. Yet, some aspects, particularly buried wastewater pipeline infrastructure, are currently in dire need of repair or replacement. Current estimates show total investment needs of $255 billion over five years for wastewater infrastructure [1]. While much of this can be attributed to natural disasters and sheer age, a great deal is owed to poor practices in repair and maintenance, lack of enhanced inspection efforts, or misguided investment: in other words, inadequate asset management. While all wastewater infrastructure needs attention, pipelines have become of particular importance as their buried, unseen nature can create a sort of "time bomb" scenario, as large pipelines fail and seriously damage roadways, create significant health issues for the surrounding inhabitants, and eventually cost the utility or municipality millions of dollars above and beyond repairing the pipeline only. This is exacerbated by the fact that wastewater pipeline infrastructure is reaching the end of its lifespan across the country. One key element in effectively managing infrastructure is understanding the true costs of maintaining the assets.

Industry professionals are constantly looking at better ways to capture and understand the true cost of the work, including the burden on the utility itself, as well as society and the environment. A sound knowledge of these parameters can enable managers to make better decisions by including all the pertinent variables related to both time and the impacts of pipeline renewal engineering (RE) in their entirety. Yet, a major hurdle exists in the form of no standard methodology to capture and report this cost data. While some methods such as Engineering News Record or RSMeans collecta great deal of unit cost data that provide guidance at a broad, preliminary level, this data does not give a detailed view of the other direct costs involved in the work, and further leaves the story of the financial impact on society and the environment untold. These parameters are becoming critical components of modern urban planning as officials better understand the symbiosis of infrastructure management, society, and the environment. This vital information that tells the entire story behind the work is termed as "metadata", or information about data. As total cost data is collected in a standard way it will promote understanding at all levels of management, including those approving pipeline renewal budgets. Standardized, verified data in the hands of mid-level managers then becomes invaluable and places the burden upon governing body as the costs of doing the necessary RE work are mutually understood.

This paper summarizes the development of a novel wastewater pipeline RE cost data and metadata collection and reporting methodology as part of the WATERiD project, funded by the USEPA and WERF.The overall goal was to collect large amounts of standardized cost data in an efficient way, i.e. leveraging the power of extract, transform, and load (ETL), a process for collecting, homogenizing, and storing data that is made possible through advanced computing power and the World Wide Web. It will further show the data found and the apparent trends and cost drivers that were brought to light as data was collected in a pilot project of the standard methodology. Also, the research involved the utilization of Google Fusion Tables to query and display cost data in the WATERiD website. Case studies involving the total costs for specific projects were also developed. While this is a major advancement to current practices, the data is still lacking to perform robust trend analyses. The cost data graphs shown in this study are a result of piloting the methodology can only give a high-level view of what is going on in the real world.Industry professionals will have to support this process wholesale to truly collect and report enough cost data to drive advanced modeling and decision making efforts. However, once they begin to see the power of the data standard through this and similar studies, they will readily become involved and drive a real benefit to the industry and nation as a whole.

This research on the use of standards for collecting and homogenizing cost data is to support the future implementation of tools to support asset managementdecisions by:

Justifying renewal decisions made by utility managers to avoid misallocated resources

Offering valuable insights for all parties for enhanced communication and understanding

Conflating disparate cost datasets from scattered sources and enabling enhanced graphical and map-based visualizations

Uncoveringhidden information, relationships, and trendsthrough data mining

Supporting further decision making inrenewal engineering choices and their overall effects on society and the environment

II . LACK OF A COST DATA COLLECTION AND STANDARDIZATION METHODOLOGY

Cost data for buried wastewater pipeline infrastructure is available in inconsistent formats and is collected and stored differently, even within the same utility. Consequently, the need for a cost data standard that can homogenize and sanitize data, and further provide direct comparisons for trend and relationship analysis to drive decision making from project through managerial levels is apparent.This collection and conflation process is shown in Fig. 1. Generally speaking, these standards do not currently exist in a nationally-recognized format, hence limiting managers' ability to extract a great deal of useful information in investment decision-making.

Figure 1.Conflation process of disparate Municipal Utility RE Cost Data.

This image explains how the disparate cost data collected from multiple utilities can be collected, standardized, and stored in an automated manner.

III . WATERiD

A national, web based interactive database for water infrastructure systems was developed in order to provide a standard platform through which institutional knowledge on the several fronts could be shared, called

Water Infrastructure Database (WATER*i*D, www.waterid.org). The intent of this national database is to provide a "one-stop-shop" for a utility researching the costs of technologies or products to apply to a specific project or to approve for use within their municipality. WATER*i*D contains information on both drinking water and wastewater infrastructure networks. Information about pipeline condition assessment, pipeline renewal engineering, subsurface utility engineering for locating pipelines, management practices, models and tools, costs, benchmarking, and product qualification is included. This paper focuses on the development of a methodology for collecting and standardizing the costs of renewal engineering work forwastewater pipelines that was performed as part of the project.

IV. RENEWAL ENGINEERING

System renewal includes a wide range of repair/rehabilitation/replacement techniques that bring the pipeline system to acceptable levels of performance within budgets. The decision-making process for the proper balance of repair, rehabilitation, and replacement is a function of the condition of the pipe, the life-cycle cost of the various RE (repair/rehabilitation/replacement) options, and the related risk reductions.

USEPA states that "System Renewal includes a wide range of Repair, Rehabilitation, and Replacement techniques that bring the pipeline system at acceptable levels of performance within budgets" [2]. There are many technologies available and under development for the repair, rehabilitation, or replacement of existing pipelines. Common renewal issues include corrosion, root intrusion, joint separation, tuberculation, and ground settlement. Numerous materials, installation methods, diameters, and construction practices are also in use, creating a challenge for the utility and the designer. Comprehensive system renewal is further complicated by variations in physical, chemical, geographical, technical, and condition of existing and repaired pipe. Ultimately, research in pipeline RE is required because long-term performance data are unavailable, real-world applications are risk-inherent, and large sections of the infrastructure have reached the end of their design lives. The determination of the range of use/limitations of various renewal technologies is complex, and detailed research is needed.

V. PROJECT COSTS

The cost of wastewater pipeline replacement is defined by the authors in this paper as the sum of the direct costs and societal costs. The direct costs are those related to the RE practices paid for directly by the utility such as the pipe work itself, traffic control, bypass pumping, surface restoration, testing and inspection, safety measures, lateral reconnection, and so on. Societal costs in this report will include traffic delay, noise pollution, and lost revenues due to business disruption. Direct and indirect costs are being considered for an analysis of the cost of the RE works being performed by wastewater utilities. While this method does not currently capture all the costs associated with the work due to simplification for utility ease of use, these costs can be added in the future as the industry directs. The costs were collected for a few commonplace practices in the industry. Other methods were considered but those covered in this work had the most readily-available data amongst the participating utilities.

VI . CURED - IN- PLACE PIPE LINERS

Cured-in-Place Pipe (CIPP) liners, in use since the early 1970s, are used to seal and or structurally renew existing pipes. The standard CIPP liner product is a tube treated with a liquid resin that is inserted into a pipeline, typically through a manhole, and cured using hot water, steam, or UV light. \. The tubes can be manufactured from felt or fiber-reinforced materials, and are woven, unwoven, or spirally wrapped. CIPP liners are either inverted, pulled-in-place, or manually inserted inside the host pipe to seat tightly against the host pipe. Various resins are utilized including epoxy, polyester, silicate, and vinylresins. The resins are thermally cured utilizing hot water or steam, or UV cured. Structural capabilities and field performance histories vary significantly across the industry.

VII . PIPE BURSTING

In the pipe bursting process, an existing pipe is cut or broken up and forced into the surrounding soil by a tool, while a new pipe is pulled behind the tool for a replacement. A benefit of pipebursting is that a larger pipe can be inserted where the old one lay.The typical length of pipe replaced by pipebursting is nearing 350 lineal feet, but greater lengths have been accomplished. In addition, depth, soil conditions, and other factors dictate whether pipe bursting is a feasible renewal option [3].

VIII . RESEARCH OBJECTIVES AND SCOPE

The objective of this research is to enhance industry understanding of costs to support RE decisions for buried wastewater pipeline infrastructureby developing a framework for collecting and standardizing cost data in an automated manner.Further, it considers how RE cost information,when captured in a standard data structure,can produce better statistical analyses for trends and drivers, and also show the entire picture behind these types of projects in capturing standardized social and environmental costs from a broad range of sources. The key objectives of the research are to:

- Analyze existing research on data management tools available in theindustry to determine the gaps and limitations
- Develop a methodology for collecting and standardizing the costs of renewal engineering work for wastewater pipelines that was performed as part of the WATERiD project
- Collect data from wastewater utilities across the U.S. and conflate it to a standard
- Analyze the collected data to uncover apparent cost trends and drivers in direct costs, and to determine the amount of social and environmental burden accompanying various RE technologies, e.g. Cured-in-place Pipe Liners, Pipe Bursting, etc.
- Develop a platform in WATERiD for utilities to access their data and graph it as desired using Google Fusion Tables
- Develop case studies on cost from various RE projects

The researchers engaged in a comprehensive research review to determine the published research knowledge on the cost of wastewater pipeline RE technologies.The research team performed data mining through soliciting input through a standardized spreadsheet that could be placed in a utility's own FTP site and then accessed via WATERiD's ETL tool, as outlined in Figure 2. Often key data was lacking, wherein utility personnel interviews and public utility records filled in the gaps. Additionally, an expert committee made up of utility managers and consultants with an average of twenty years' experience each provided direction as to the development and implementation of the cost data collection and management methodology. Some limitations included not being able to capture every single type of cost, making some assumptions as to the similarity of projects in grouping them together, and finally assuming that the data received through the collection and interviews was indeed accurate.

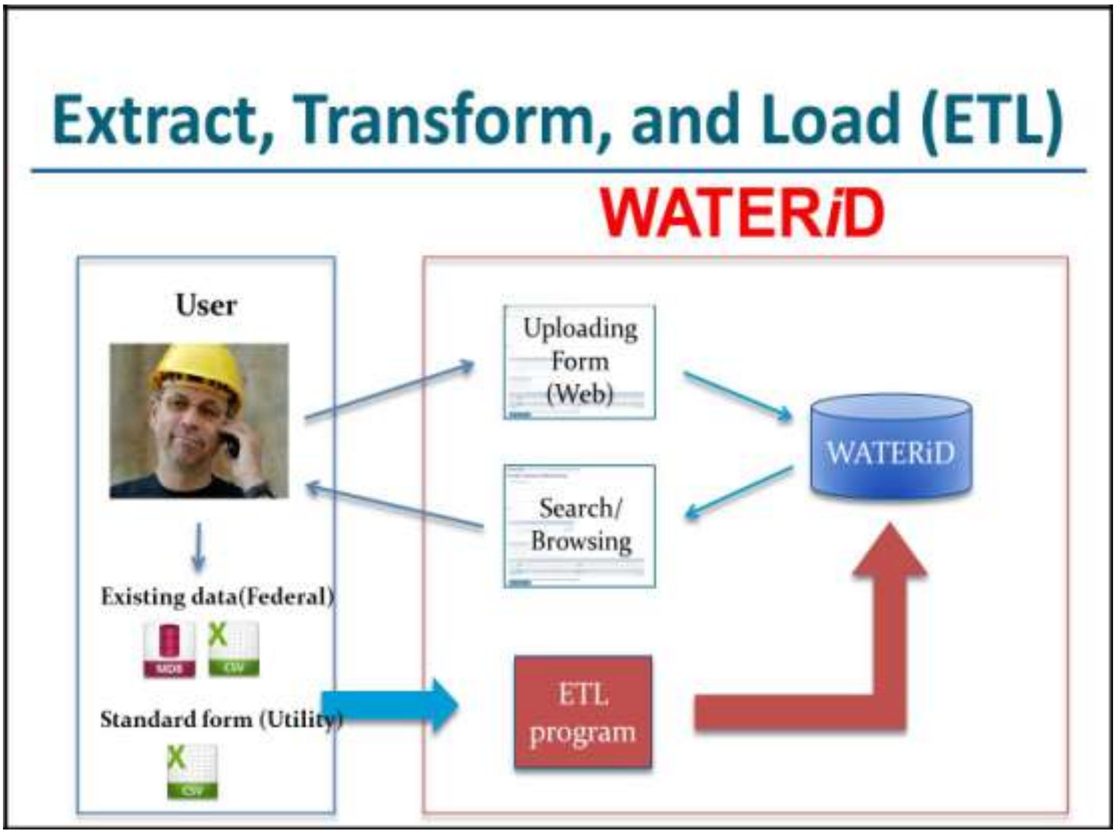

Figure 2. ETL Data Collection and Storage Process

IX. WASTEWATER PIPELINE RENEWAL ENGINEERING COST DATA

USEPA hassupported the need for studies similar to this research to provide benefit to the water industry in the nation, where previous researchers determined that adequate amounts of comprehensive, pipeline RE costs are difficult to capture from the industry; and a centralized cost database is necessary for utilities to better share, analyze, and utilize cost data in decision making [3],[4]. Further, it was determined that the use of a web-accessible tool was useful in helping utilities in decision making for asset management,as well as calculating social costs to assess the indirect costs and societal burden of utility construction projects [5], [6].

Infrastructure asset management has become of great interest in recent years as many critical components of the built environment reach the end of their useful lives, often with catastrophic consequences. Utility managers are adopting asset management systems to effectively identify, track, and prioritize maintenance on their assets, particularly pipelines. The goal is to minimize the overall cost of owning the assets while maximizing their useful life [7]. Also, while life is lengthened and cost reduced, the asset must maintain a required level of performance [8]. The keys factors of a successful asset management plan include the effective management of asset [7]:

- Design
- Maintenance
- Condition Assessment
- Renewal Engineering
- Investment decisions

The successful outcome of each of the parameters can be attributed to leveraging the right information about the system. This warrants the collection of substantial amounts of data from all departments of the utility that must be maintained and kept current indefinitely to discover long term trends and perform enhanced analyses. Having a large arsenal of standardized data can empower utility managers to make better decisions regarding each of these key components of owning and maintaining this critical infrastructure [7]. A framework to best capture and manage this data from several sources is key to mitigating unnecessary costs and risks, and enables better decisions [9].

X. STANDARD DATA STRUCTURE

Simplicity drove the design of the standard data structure for the collection of cost information.This would in turn help to save time for utility personnel charged with collecting and reporting the data. The standard data structure was built to allow data to be aggregated and analyzed at different management levels for different output needs. TABLE1 shows the desired data in the left column and a description of the data in the right.

TABLE1.Standard Data Structure

Description of Data	Desired Data
EPA Regions 1-10	Region
Utility	Utility
Project Name/Phase	Project Name
Location	Project Location Zip
Date work bid, MM/DD/YYYY	Bid Date
Date work started, MM/DD/YYYY	Work Start Date
Date work ended, MM/DD/YYYY	Work End Date
Hours	Item Duration
Production	(LF/HR)
Continuous or Point Repair	Application Type
VCP AC Cast Iron PVC Orangeburg Steel Manhole Other	Existing Pipeline Type
ID (inches)	Existing Pipeline Size

HDPE PVC Ductile Iron FPVC Steel Other	**New Pipeline Type**
Inner Diameter (inches)	**New Pipeline Size**
Type in Schedule SDR PSI Thickness Other	**Pipeline Rating Class**
Rating in PSI, Size-dimension ratio, Thickness (in, mm, etc.)	**Rating**
Depth	**Depth**
Pipe Age	**Age**
CIPP Lining Pipe bursting Traditional Open Cut Cleaning Other	**Technology Used**
Point Repair Continuous	**Scope of Work**
Lineal Feet Each Hours Other	**Units**
	Quantity
Dollars	**Cost per Unit**
Bid Item Total	**Item Total**
Total Contract	**Total Cost**
Percent of Total	**%**
Planning, Design, or Training Costs: Desc. And % of Total	**Costs ($)**
Mob	**Costs ($)**
Bypass Pumping	**Costs ($)**
Lateral Reconnection Cost	**Costs ($)**
Earthwork	**Costs ($)**
Traffic Control	**Costs ($)**
Testing Inspection	**Costs ($)**
Surface Restoration Costs:	**Costs ($)**
Safety Costs (Shoring, etc.)	**Costs ($)**
Other Direct Costs Related to Piping	**Costs ($)**
Change Orders	**Additional Costs**
Additional Costs due to Crossings: Description and cost Water Highway	**Crossings**
Traffic Costs	**Costs ($)**
Lost Revenue	**Costs ($)**
Environmental Costs	**Costs ($)**
Internal Funds Bonds Grants	**Funding Source**

Loans **Other**	
Cost of Capital	**% of Total Cost**
Total Cost all inclusive	**Total Cost**
Yes **No**	**On Budget**
Yes **No**	**On Schedule**
Primary Drivers for Project: **Demand** **Failure** **New Funding** **Environmental** **Consent Decree**	**Drivers**
Routine **Challenging** **Emergency**	**Circumstances**
Please provide guidance as to what made these costs differ from typical	**Notes**
Other Notes	
Information Link	**File path or web address**

XI . RESULTS

In all, data were gathered from 29 utilities for a total of 271 cases in RE.Utilities were solicited in the gathering of wastewater pipeline RE project costs. Cost practices were sought out from each of the ten EPA regions, taking into account a variation in utility size. Utilities surveyed included the Washington Suburban Sanitary Commission from Maryland, The City of Los Angeles, California, Anchorage Water and Wastewater Utility, Alaska, and a sound mix of mid - to smaller-sized entities as well.The data were then compiled in spreadsheets based on project type and region. The cost data were entered into the spreadsheet from the questionnaires or bid tabs sent by the utilities and an attempt was made to collect all the pertinent data about a project, e.g. pipe size and type, depth, age, exact project location, as well as detailed cost information such as length, unit cost, percent of total project, mobilization, traffic control, bypass pumping, lateral reconnection, and so on. Once the project characteristics and direct cost data were compiled, information was collected from the internet concerning the average annual daily traffic (AADT), approximate number of surrounding businesses near a project that may have been affected by the work, and the average home price in the area. These data were then used to estimate the social and environmental costs of the project, as outlined in a paper by Jung and Sinha [10] on how to best capture societal costs. A comprehensive description of the equations used to develop the cost of increased traffic time can be found in the Jung paper.

The analysis tool developed for the loss of income for local businesses was also taken from the Jung paper[10]. The study assumed an average income of $35,400 or $97/day/business. The cost was increased to $120/day to give a conservative estimate of inflation. The equation then becomes:

$120 x (days) x (work hours/24) x (number of businesses effected) = $(Lost Revenues)

Jung and Sinha also developed a method for calculating the environmental cost of noise pollution caused by pipeline construction. Their methods were developed from a study done by Feitelson et al. in 1996 that surveyed several thousand people to learn their tolerance for noise. From this, a Noise Depreciation Index (NDI) was developed to estimate the possible depreciation of property values based on the aversion to the increase in the decibels. The researchers then applied an equation using the NDI and the increase in noise for a given project, and the equation then became:

0.0017 × K_(additional dBA of effective noise level) x original housing price = $(Noise Cost)

The researchers used an example of a 20 decibel increase brought by an open cut excavation project to an area where the median home price was $118,900. The average noise cost for a year then becomes $121,278=0.0017 x 20 x 118,900 x 30. The article establishes the dBA increase for trenchless technologies such as pipe bursting as only 10, thereby only accounting for half the cost of traditional open cut projects.

The costs discovered in the data analysis mirror other cost study reports from the industry and more or less reflect the average costs experienced in the industry. The data were then analyzed further where all supplemental cost data were compared, namely the other direct costs that could be gathered as well as data to derive the indirect costs, i.e. the social costs.All other direct costs were broken and entered into a spreadsheet. A percentage of the total cost was then calculated for each separate cost. Not all costs were broken out in a similar manner for each project; therefore an average of the percentages was taken to give a flavor of what types of costs were involved in these projects.

1. CIPP

The vast majority of the RE project costs captured was for CIPP pipe rehabilitation. Graphs and tables are provided to better describe the data gathered. First, overall unit costs of projects provided by utilities surveyed were plotted by inner diameter of the host pipeline in Figure 3.

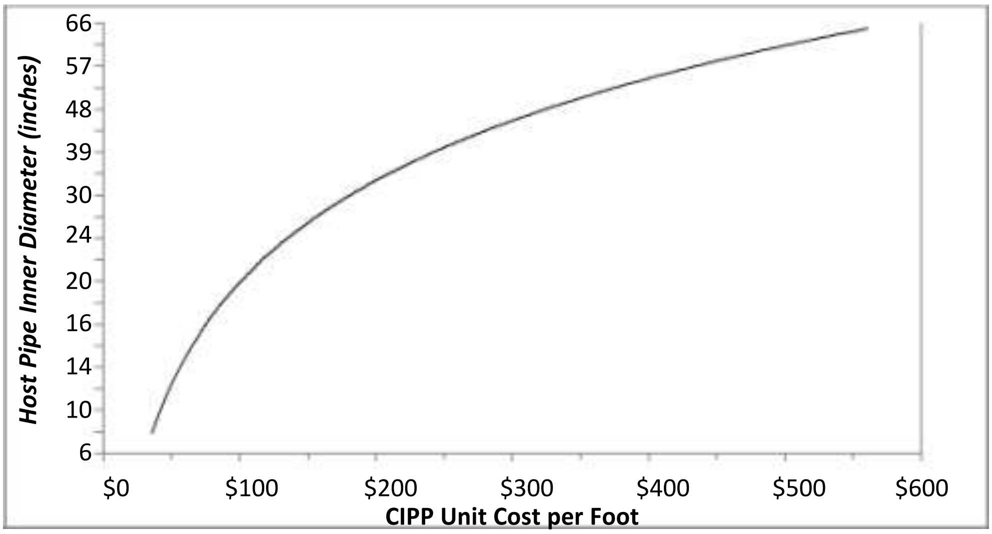

Figure 3. Unit Cost of CIPP Pipeline Renewal by Pipe Diameter.

This figure shows the cost trends for the CIPP work done continuously, as opposed to point repairs. The unit costs were presented in a box and whisker plot format to better understand the range of costs observed according to the diameter of the host pipe. As was presented earlier, the boxes in the plot represent the second and third quartiles of the costs, the median of the costs falling below the median being the left edge of the red box, and conversely the median of the costs falling above the median of all the data being the right edge of the green box. The bars extending from both sides represent the costs found in the lowest and highest quartiles. The mean of all the data in each diameter class was plotted as well, and a trend line fit to these values. This method provides an effective way of understanding the range and frequency of the costs observed in a large dataset; i.e. 233 total examples. The graph was limited to $600 on the horizontal axis for clarity. The categories with significant extremes that were cut off in the current view will be discussed in greater detail in the following sections.

Then, the direct costs (not including installation) and indirect costs were compared. The data is shown in the bar graph in Figure 4, where the dark bars represent direct costs and the lighter societal costs.

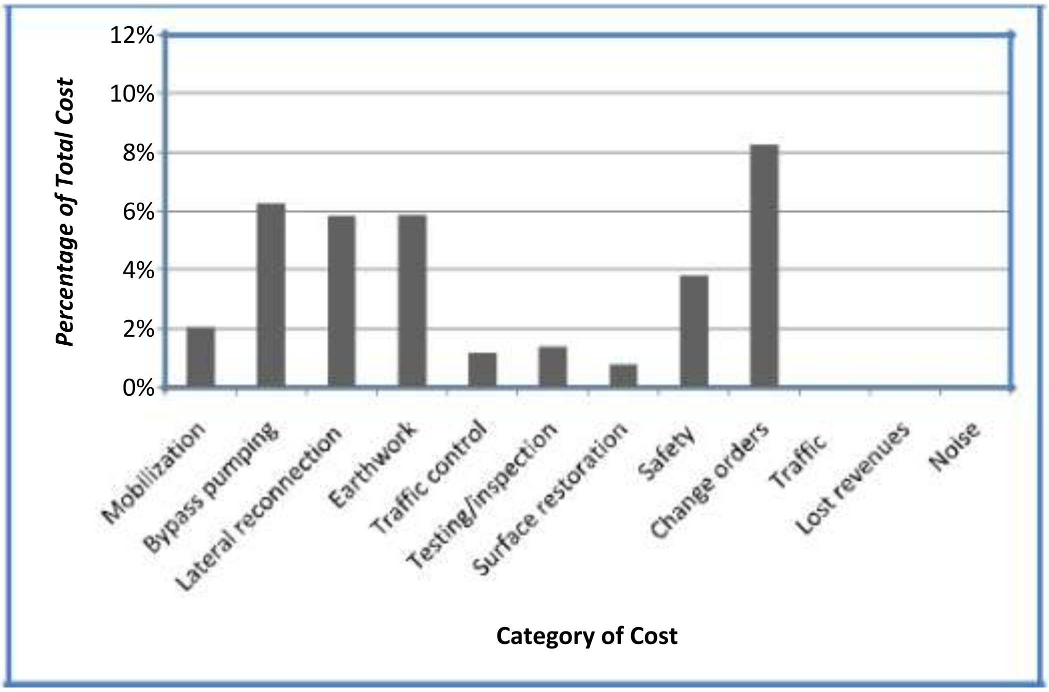

Figure 4. Supplemental Costs of CIPP Work by Percentage of Total Cost.

This figure shows the average of the contribution to the total cost of the work from each type of cost. The lower bars represent the other direct costs of the work, e.g. mobilization and bypass pumping. The top three bars represent the social and environmental costs of the work.

Bypass pumping played the biggest role in the project data gathered. Change orders accounted for a big percentage of the cost, however in the majority of the cases identified in this research, the extra money was to do extra work when the project had been within limits and additional opportunities were seized upon. Next in order of influence were lateral reconnections, earthwork (e.g. excavated test pits and backfilling efforts), and safety measures such as trench boxes and other safety equipment. Mobilization (which frequently includes bonds and insurance, but is also often limited as a percentage of the total contract, e.g. no more than 3%), surface restoration, traffic control and testing did not significantly drive the cost in most cases, though they were often significant amounts of money. Utilities were able to take advantage of economies of scale and to absorb much of these costs into a great deal of rehabilitation work.

The indirect costs were derived as described earlier in the paper and broken out accordingly. A good faith attempt was made to best estimate the AADT on the roadways from the DOT sites on the internet containing historical counts for the specific roadways. If an exact street was not named by the utility, average AADTs, home prices, and the number of surrounding businesses were determined from a brief survey of the area in Google Maps and various real estate websites. In cases where information differed, values were chosen on the more conservative (more costly) side in every case. These percentages are the average percent of the total cost of the work.

2. Pipe bursting

Pipe bursting in wastewater pipe renewal was averaging mostly in the \$130–\$260/meter rangein the project data collected. The unit cost according to project length was plotted in the same fashion as the CIPP data and can be seen inFigure 5.

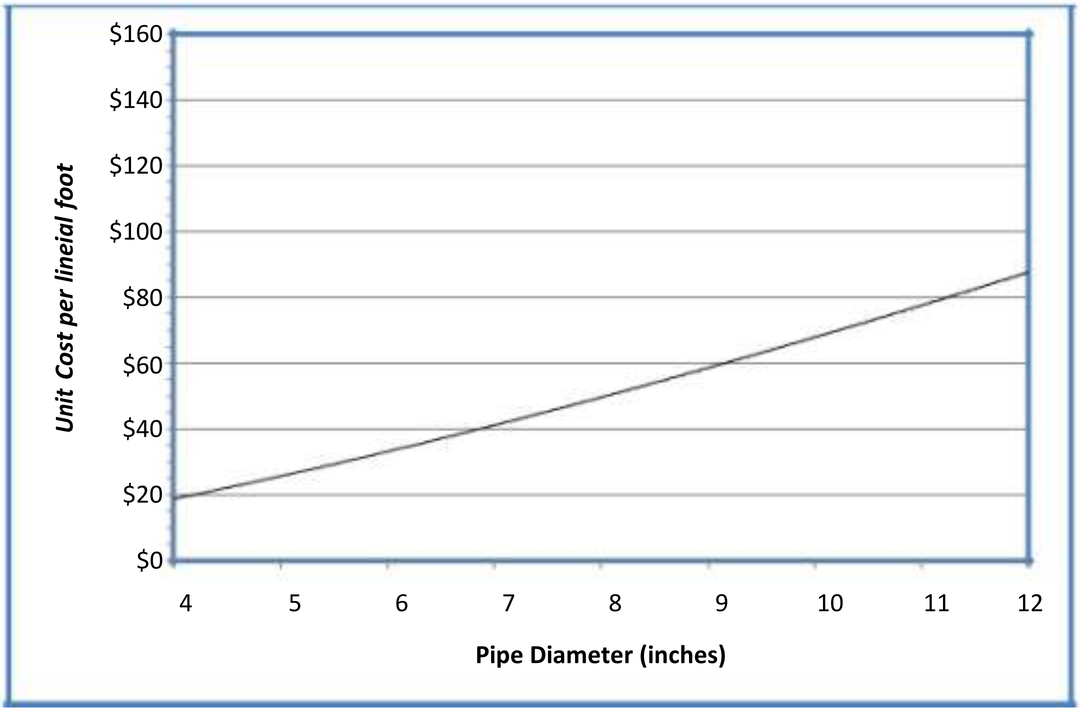

Figure 5.Pipe Bursting Work Unit Cost by Pipeline Diameter.

This figure shows the unit cost of pipe bursting per lineal foot and how it may change according to the inner diameter of the pipeline being renewed. Data was gathered in the range of 4 to 12 inches. A trend line was fit to the data to determine a trend according to the increase in pipeline size and is also shown in the plot.

The supplemental direct costs and social costs were then plotted to see how they were affecting the overall cost of the work in Figure 6.

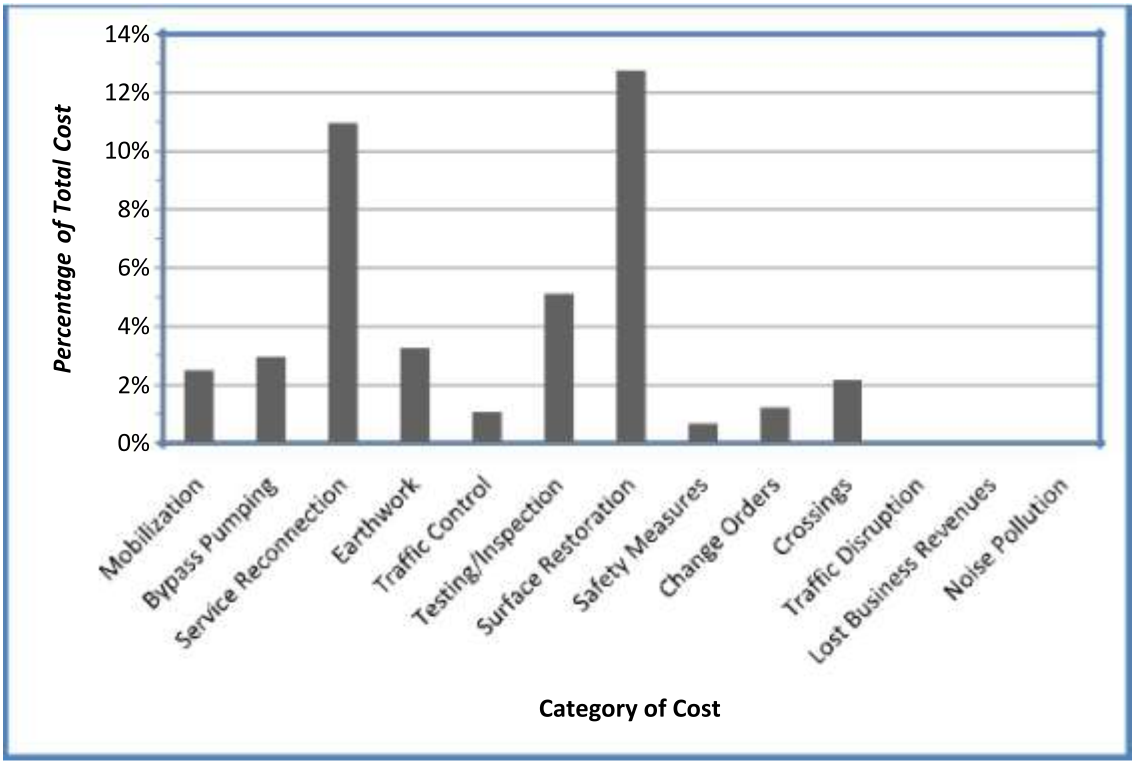

Figure 6.Supplemental Costs of Pipe Bursting Work by Percentage of Total Cost.

This figure shows the average of the contribution to the total cost of the work from each type of cost related to pipe bursting work. The lower bars represent the other direct costs of the work, e.g. mobilization and bypass pumping. The top three bars represent the social and environmental costs of the work; the top being the environmental cost, i.e. noise pollution, and the second and third bars representing the social costs, i.e. traffic disruption and lost business revenues as they relate to pipe bursting.

The various costs supplemental to pipe bursting work are shown by percentage of the total work in Fig.6. Service reconnection and surface restoration were big parts of the total cost in these projects, as numerous access pits were dug in improved areas. Service reconnections pose a greater problem than in CIPP work as they must typically be done as in traditional work, requiring full excavation. This also adds to the surface restoration costs as more excavation is required to make these connections. Of the remaining direct costs related to the work, testing and inspection accounted for the third largest percentage of the cost, followed by earthwork to create entry and exit pits, followed by bypass pumping and mobilization. The remaining supplemental direct costs were not found to be a major factor in the overall cost of the work. The social and environmental costs, while not as apparent as those related to the CIPP projects surveyed, are still worth noting. The pipe bursting did not take place in areas that were considered as very busy urban ones, therefore the traffic and lost revenue costs were not a significant as they were in the CIPP projects, yet should still be weighed in considering the total cost of the work to society. At roughly 6% and 7% of the total cost, these items can add up quickly as the size of the project increases, and particularly in a heavily urbanized setting. It appears that large cities are not as fond of pipe bursting projects for this reason, as well as the risk of damaging adjacent utilities.

XII . Utility Hub Pages

Utility Hub Pages were created in the WATERiD website to provide information to users as to what technologies and practices were being employed with regards to managing their buried pipeline assets. The Hub Pages were also found to be useful to the utilities themselves by accessing their own data in a simple, single location. The hub page for the Town of Blacksburg, Virginia is show in Figure 7.

Figure 7. Hub Page for the Town of Blacksburg, Virginia as found in the WATERiD website.

While data was collected on many facets from these utilities in concert with the objectives of the WATERiD project, the goal of this paper is to show the functionality of the site with regards to the cost data. Sample graphs were created from the data to show how it can be used, as shown in Figure 8.

Figure 8. Sample Graphs related to Cost in the Hub Page

These graphs were not created to show comprehensive trends or drivers, yet to provide an example of what can be done with the standardized data. The users themselves can come to the site and create any plot they desire from the data, only limited by the options within Google's Fusion Tables. Several participants found this to be a useful tool with great possibilities going forward.

XIII . CONCLUSION

This paper summarizes the development of a novel wastewater pipeline RE cost data and metadata collection and reporting methodology as part of the WATERiD project, funded by the USEPA and WERF. The overall goal was to collect large amounts of standardized cost data in an efficient way, i.e. leveraging the power of extract, transform, and load (ETL), a process for collecting, homogenizing, and storing data that is made possible through advanced computing power and the World Wide Web. It further showed the data found from nearly 300 examples of cost data gathered from over 30 wastewater utilities in the U.S. and the apparent trends and cost drivers that were brought to light as data was collected in a pilot project of the standard methodology. Also, the research was shown that involved the utilization of Google Fusion Tables to query and display cost data in the WATERiD website. Case studies involving the total costs for specific projects were also discussed. While this is a major advancement to current practices, the data is still lacking to perform robust trend analyses. The cost data graphs shown in this study were a result of piloting the methodology can only give a high-level view of what is going on in the real world. Industry professionals will have to support this process wholesale to truly collect and report enough cost data to drive advanced modeling and decision making efforts. However, once they begin to see the power of the data standard through this and similar studies, they will readily become involved and drive a real benefit to the industry and nation as a whole.

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