INAUGURAL EDITION

BAMI-I 2022

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Cover photo: Quake Wrap's FRP technology (see ad page 46) was applied to the Lake Lure Dam penstock rehabilitation project, extending the life of penstock by 50 years. Dr. Tom Iseley (orange hard hat) & Ms. Wei Liao participated in the second warranty inspection on January 6, 2022.

Buried Asset Management Institute - International

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Message from BAMI-I President

Dr. Tom Iseley
Ph.D., P.E., Dist. M. ASCE, PWAM, BAMI-I President

It has been very rewarding to see how BAMI-I emerged from the City of Atlanta shortly after Mayor Shirley Franklin formed the Department of Watershed Management (DWM) and appointed Mr. Jack Ravan as the Commissioner in 2002. I can clearly remember the conversation I had with Commissioner Ravan in January 2003 regarding what it would take to accomplish the Mayor's vision of moving Atlanta's water program from its current status to achieving the $4 billion federal consent decree to becoming the first-in-class. After discussing the challenges in accomplishing this vision, Commissioner Ravan requested me to serve as his senior advisor to lead the way. Under his leadership, a working group was formed consisting of Troy Norris, John Griffin, Fred Blankenberg and myself, and the learning process began. This working group realized that the major challenge to accomplish Mayor Franklin's vision would be to understand and upgrade the underground conveyance network; so, we wanted to make sure that we stayed focused on the main challenge and everyone we interacted with also knew what our goal was. Therefore, our working group became known as the Buried Asset Management Group reflecting on Mayor Franklin's reference to the underground piping systems as "our buried treasures."

Based on my previous experience with the establishment of the Trenchless Technology Center (TTC) at Louisiana Tech University and being one of 5 founding directors of the North American Society of Trenchless Technology (NASTT), I knew the power of industry/university/government cooperative research initiatives. Of course, to achieve Mayor Franklin's vision would require research in validating the most appropriate technical, administrative and best business practices to achieve what has never been accomplished previously. Academic researchers from 5 leading research universities were invited to spend 2 days with us in Atlanta. The first day was spent allowing them to learn more about the challenge, and the 2nd day was spent off site to discuss what each academic research program could offer. This formed an essential partnership, and working group moved on to become the Buried Asset Management Institute.

We were fortunate in the early days to be introduced to Mr. Steve Allbee at EPA who became the champion of promoting the principles and practices of asset management for water utilities. I had the opportunity to participate in his workshops, meet with him at the EPA headquarters in Washington, DC, and coordinated 2 EPA workshops for the DWM in Atlanta. It became clear that the only to achieve Mayor Franklin's vision was to develop and implement a comprehensive risk-based water asset management program.

The 18 months I served as senior advisor to Commissioner Ravan at DWM in Atlanta was a major milestone in my professional development. It was indeed an honor to serve under such an inspirational leader as Mayor Shirley Franklin who had such a passion for water. She knew that jobs, quality of life, public health and economic development depended on having access to plentiful sources of high quality of water. Her passion for water attracted the interest and support of the international water community. This moved BAMI to the next level in 2004 by forming a non-profit 501-(c)3 organization with the name changing to Buried Asset Management Institute-International (BAMI-I). It is such a joy to reflect back over the past 20 years to know that much of the original industry leaders are still involved and serving together with us.

While BAMI-I is a membership organization, it did not want to be just another membership organization. It wanted to focus on products and services which can help water utilities and especially the smaller water utilities. This BAMI-I mission led to being selected by EPA for a grant program in 2004 which involved developing a pathway for establishing water utility management excellence. This program was completed in 2008. Completion of this program led to the development of the first online water asset management course which was launched in 2010. During the next 5 years, the complete set of 4 Certification of Training in Asset Management (CTAM) online courses were develop for the water industry by industry professional leaders. By 2017, BAMI-I had established a 5 member Certification Board under the Board of Directors to supervise a 2 level water certification program.

There has been so much accomplished over the past 20 years, but there is so much more that must be accomplished. Based on EPA reports, there are at least 70,000 public water utilities in the US with about 93 percent serving communities less than 10,000 population. Even with the resources developed by BAMI-I and other organization, relatively few water utilities have developed and are implementing comprehensive risk-based asset management programs (AMP). It has been encouraging to see how State agencies have realized the importance of AMPs and providing financial incentives to water utilities. This will result in an increased demand for industry professionals who have had formal training in the development of AMPs. BAMI-I has worked hard for 20 years to provide online and classroom training programs to provide the certification needed by these professionals.

BAMI-I

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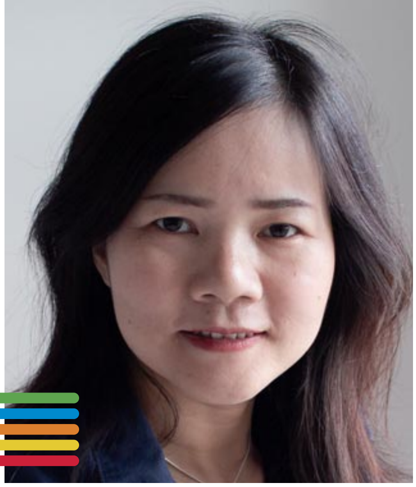
Buried Asset Management Institute (BAMI-I)

Board of Directors 2021-2022



Message from the Journal Editor

Ms. Wei Liao

PWAM

In the past, I often had a sense of fear of the unknown. When I was appointed editor of the first issue of the BAMI-I Journal recently, I had the same fear that I would not be able to do the job. As my understanding of my faith grew, I put aside my fears and did my best to act according to my faith, not my fears. The greatest lesson I have learned from being in the United States for almost three years is that while visible results are important, creative thinking and a persistent pioneering spirit are even more important.

Through the process of receiving this appointment and the following publicity, I became more and more aware of the significance of every minute as an achievement. Behind a thin journal like this, there are many people and many hours of effort. I would like to take this opportunity to express my gratitude to the authors, sponsors, and publishers for their support. I am grateful to be able to work with so many intelligent people. Everyone deserves gratitude for every minute of effort they put in.

Over the past several decades, globalization has grown, and humanity has evolved from a small tribe to a large city to a nation, and even globally to an interconnected system. The progress of civilization has always been bumpy, and even today's independent and free America has gone through brutal wars to achieve it. Old ideas always have a strong countervailing force, like the Russian invasion of Ukraine, which is essentially a clash of old and new civilizations. The process of developing a civilized society is unstoppable, and all human beings around the world will continue to pursue individual happiness. Humanity will always work to replace dictatorships with freedom. In spite of the problems of modern society, our world is still full of hope.

Like the development of globalization, our infrastructure is composed of single technologies that function individually but must be developed in a coordinated manner, utilizing integrated management to align resources. It requires more complex thinking and coordination of various factors in order to achieve the best deployment of resources as a whole. This is where the vitally necessary concept of asset management comes in. Happily, asset management has evolved over the past few decades, with individuals, companies, and governmental departments increasingly realizing the importance of asset management and taking more proactive steps. The EPA's document State Asset Management Initiatives (EPA 800-F-19-002, February 2019) survey results show that an increasing number of states are undertaking asset management-related initiatives during 2012 to 2018. The U.S. Infrastructure Investment & Job Act (now Public Law No: 117-58) provides significant funding to upgrade water infrastructure. But from the state regulatory agency level, decisions need to be made to spend these dollars in the right places at the right time on the right projects. Asset management has proven to be a powerful tool for this purpose. In the case of Indiana, Senate Bill 272 mandates that water utilities provide asset management plans in order to receive funding. More training, data sharing, and knowledge&information exchange have never been more urgently needed than it is today. The BAMI-I Journal was launched in this context.

What is needed for the development of asset management? BAMI-I, a non-profit organization founded 20 years ago by Dr. Tom Iseley. Dr. Iseley is a man who has always had a clear grasp of current trends and an extraordinary vision for the future. He has always taught me to think ahead and not be led by problems to address current needs, but never forget that the end result of everything we do is to improve the quality of human life. Thus, all of BAMI-I's efforts are directed toward that vision. We expect this Journal to provide a platform for the exchange of information among water and wastewater utilities, governmental departments, service providers, constructors, material and equipment suppliers, academic institutions, and anyone else concerned with infrastructure management.

This is just the beginning. The wisdom of a group is infinite, and we hope to gain more wisdom through using this platform to develop each other and reap the rewards together. Our goal is to develop BAMI-I as an Internet hub for water infrastructure. I hope readers will receive inspiration from our journal. We invite and especially look forward to your case studies, research, insights, and suggestions here.

2022 is an exciting year for the BAMI-I team as they enter their second year with Purdue University. Purdue's research and innovation platform provide BAMI-I with an even higher level of support capacity. By growing and developing, we are looking forward to an outcome that brings more value to all people. I thank you for this opportunity to serve you as the editor of the BAMI-I Journal.

BAMI-I Will Establish Five New Committees in 2023

2023 will mark BAMI-I's 20th Anniversary and at this important point we plan to launch new initiatives to take BAMI-I to the next level. These include the planned establishment of Five Committees. The asset management program encompasses all aspects from technology to management to finance. It will take everyone involved to understand and embrace the asset management culture in order to work in concert to achieve its ultimate goals. The five new committees will expand BAMI-I's participatory community and help to integrate asset management concepts throughout the infrastructure lifecycle which from the planning stage to the end of the useful life. We believe that the integration of asset management concepts into underground infrastructure products and services and operations will provide long-term advantages. In BAMI-I, companies, organizations and individuals will be able to strengthen their dominant position in the industry and interact with their peers, expand their brand presence, and more.

Listed here are the Five Standing Committees that BAMI-I is considering to establish with a Chair Person for each committee and active members as committee people.

1. **Pipeline Condition Assessment (PCA)**
   SCOPE: Identifying PCA technologies and establishing a protocol for selecting how to develop a PCA program to comply with an asset management plan.

2. **Utility investigation (UI)**
   SCOPE: Establishing a risk-based utility locating program utilizing ASCE 38-22 to develop an accurate inventory and mapping system to comply with an asset management plan.

3. **Financial management (FM)**
   SCOPE: Develop the protocol for establishing the life-cycle-costing criteria and procedures for determining the economic value of buried assets including the remaining useful life required in a risk-based asset management program.

4. **Education & Research (RE)**
   SCOPE: Identify education and training needs including workforce development. This will also include how best to utilize and promote CTAM and the Journal and future initiatives such as a Global Asset Management Congress, etc. This committee will follow ASCE's leadership in preparing the underground construction 2070.

5. **Trenchless Technology (TT)**
   SCOPE: Identify and describe how TT can be utilized to provide the required technical solutions to accomplish the objectives of a utilities operational and management program with a focus on the decision process.

We have received many applications from professionals in industry and government agencies as well as academia to become **committee chairs**. This has been extremely encouraging to us. We believe that with their participation and action, BAMI-I will make significant progress in achieving its vision. These committees and chairs will be approved at the 2022 BAMI-I Board of Directors/Membership Annual Meeting.

2023 BAMI-I 20 Years Anniversary & First Global Water Asset Management Congress

The Global Water Asset Management Congress will bring together regulators, law and regulation makers, owners, contractors, products & service providers, professionals, and researchers from all across the world to discuss the specific issue and learn new techniques, share experiences and discuss technological innovations concerning all aspects of the water infrastructure industry.

We are calling for Sponsorships. For more information, please contact Wei Liao (Email: liao186@purdue.edu)

DATE &TIME & LOCATION: To Be Announced

BAMI-I/UESI 2022 UTILITY INVESTIGATION SCHOOLS

"I'm pleased to announce that Caltrans is sponsoring TWO sessions of the respected Utility Investigation School in California for 2022! Each session is a five day school.

The school is a joint effort with the Buried Asset Management Institute-International (BAMI-I) and ASCE's Utility Engineering and Surveying Institute (UESI). Sessions will be held in San Diego (September) and Sacramento (November). This short course will give utility engineering professionals the knowledge and tools to provide competent utility investigations in accordance with accepted national standards under ASCE 38. Here's looking forward to a successful event for all of us!"

William Owen, PG CEG PGP
Chief, Geophysics and Geology, California
Department of Transportation (Caltrans)

UIS-13

September 19-23, 2022

San Diego, CA

early registration ends August 15

8:00 am – 5:00 pm daily
REGISTRATION FEE: **$1,995**
EARLY REGISTRATION $1,795
Additional 10% discount for 3 or more attendees from same company.

UIS-14

November 14-18, 2022

Sacramento, CA

early registration ends October 14

for more information, contact:

Saleh Behbahani, sbehbaha@purdue.edu or
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The Buried Asset Management Institute – International (BAMI-I) & the **California Department of Transportation** (Caltrans) in conjunction with the **ASCE'S Utility Engineering and Surveying Institute** (UESI) have teamed to conduct the 13th and 14th ASCE UESI / BAMI-I UIS Schools in 2022. These short courses will give practitioners the knowledge and tools to provide competent utility investigations in accordance with accepted national standards (ASCE 38) and to defend against claims through this knowledge and its documentation.

In addition to the classroom lectures, practical sessions will be held where participants will be offered hands-on experience with the GPR, PCL, and etc. These two 5-day schools will be taught by the foremost experts in the geophysics and subsurface utility engineering field.

These 5-day schools have been designed for:

- Engineers and surveyors and project managers providing deliverables that include results and depictions of utility investigations.
- Consulting engineers, Employees of utility companies, state DOTs and local highway agencies, regulatory agencies, local governments, etc.
- Design engineers for infrastructure projects with significant expected utility congestion

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"I/I?

We've Fixed That!"

By: George E. Kurz, P.E., DEE

"I/I? – We've fixed that!' said a Tennessee official responsible for state sewer system grants and loans funding. Really? It is an aphorism that sewer infrastructure is "out of sight – and out of mind." The lack of a national strategy and initiative to correct the problem of I/I (Infiltration and Inflow) seems to be the most neglected of all the issues we face in our industry. However, I am firmly convinced that deteriorated and leaking sewers are the biggest problem hindering effective and economical operation of municipal sewer systems.

The title quotation is an example of the serious gap between people's perceptions and the reality of the magnitude of the I/I problem nationally. (The person assumed that I/I was no longer a significant problem since it was addressed in the original Construction Grants program in 1972.) Another illustration is the gap between I/I as reported by municipal sewer agencies on their NPDES Permit applications, and the amount actually measured. In Tennessee, the aggregate (flow-weighted) annual average I/I reported by all 243 municipal systems was 20 percent. However, this is less than half the annual I/I of 45.3 percent actually measured in the first, statewide study (Kurz, 2014b and 2016). I am not suggesting that municipal sewer operators lied about the amount of I/I in their systems. Instead, I think this is another indication of lack of information, poor understanding about the nature of I/I, and inadequate analytical procedures.

Our understanding about sewer rehabilitation may be "stuck" in the past

The purpose of this article is to highlight some of the reasons why I/I correction has not had a central role in design and operation of sewer systems in my opinion. I think that some of our institutional thinking about I/I and sewer rehabilitation effectiveness may still be "stuck" in the 1970s and 80s and those poor experiences may still be influencing decision making today. I will also present examples where procedures and analytical techniques that hindered widespread development and use of I/I correction 40 years ago, have been improved. Those improvements have resulted in some sewer rehabilitation programs that have had significant success with I/I reduction. I propose that the lessons that can be derived from those documented and verified programs become the new benchmark and impetus for sewer infrastructure rehabilitation.

In the Clean Water Act of 1972, correcting I/I was identified as a critical part of the overall national strategy for building or upgrading sewage treatment (WPCF, Kovalic, 1987). Conklin and Lewis (US EPA, 1981) pointed out that: "Sewer System Evaluation and Rehabilitation has been an important component of the EPA Construction Grants Program since its inception in 1972. The intent of Sewer System Evaluation and Rehabilitation was to eliminate excessive infiltration/inflow from sewer systems. This would allow for the construction of smaller wastewater treatment facilities, thereby saving millions of dollars in funds allocated by Congress for municipal pollution abatement facilities." This strategy is still valid: to save money by decreasing I/I so that new treatment facilities may be smaller (and operated more efficiently) by handling less "clear water."

Low level of confidence in rehabilitation today

So, what has happened to this strategy? Over the past 50 years, Owners and Engineers have designed and implemented many I/I studies, SSES (Sewer System Evaluation Surveys), and sewer rehabilitation projects. However, my impression (in many instances augmented by direct statements) is that there is a low level of confidence that sewer rehabilitation (regardless of the product or process) will achieve a significant (or sufficient) reduction of I/I to avoid or defer upsizing facilities. Instead, I've observed that the designs offered in response to sewer moratoriums or Consent Orders, have mostly focused on upsized piping, pumping stations, expanded treatment facilities, and detention tanks. Sewer rehabilitation projects are often included in Consent Orders but I have not seen where the Order connects those projects with an accountable level of I/I reduction. Unfortunately, sewer deterioration simply gets worse if not rehabilitated and the extraneous flow increases over time.

A commentary in the first edition of the joint Manuals and Reports on Engineering Practice by ASCE and WPCF (1983) identified four main conclusions from EPA's 1981 study:

- "Excessive I/I was not generally eliminated;
- Post-rehabilitation I/I is exceeding treatment plant design for I/I components;
- The major sources of I/I in rehabilitated collection systems are building connections and unrehabilitated pipe joints;
- Major features in the I/I methodology are imprecise."

The first two conclusions answer the questions that prompted the 1981 study. The last two conclusions help to explain why the results from most of the 18 sewer rehabilitation projects studied by EPA were unsatisfactory. I will add three more comments from personal observations and experiences at the Tennessee Division of Water Quality Control during that era (1976-1978) and later research:

Stop migration – not just leaks

Congress required that sewer rehabilitation actions had to be cost-effective to be funded by the Construction Grants Program. The Agency's interpretation of that requirement led to voluminous reports that included each leak observed during tele-video inspection of municipal sewers. The leaks were listed in order of flow rate. The intention was that all leaks observed to have a flow rate greater than a calculated threshold for cost-effective removal would be rehabilitated. Any leaks below that threshold criteria would not be funded for rehabilitation. Implicit in this strategy, each leak was considered to be an independent (and constant) source of groundwater. However, the reality was that a leak that was deemed "not cost-effective" may be occurring one pipe joint (3 to 6 feet) away from a very large leak. In that instance, when the large, cost-effective leak was sealed, then the groundwater simply migrated through the bedding material to other, nearby defects and virtually no infiltration reduction was achieved. Conklin and Lewis observed this problem, but in the case of sewer service laterals, trenchless techniques were not available to rehabilitate connections and laterals. The key point here is that sewer rehabilitation programs must be designed to stop migration – not just to plug the largest leaks.

> "I contend that the most significant hurdle that we face today is: education!"

RDI/I is a linear function of 24-hour rainfall

One of the most common analytical techniques used to project and estimate the quantity of RDI/I (Rainfall Dependent I/I) in the 1970s and 80s was to graph the values for rainfall and associated flow increase on log-log or semi-log paper. This procedure was explained by Nogaj in 1983 as part of EPA's Technology Transfer Seminars. Nogaj also identified several important characteristics of such curves that were often overlooked by analysts of that era. Analyzing data using log-log regression was sometimes used as a preliminary step to interpret various physical and chemical phenomena. (A good example is for estimating radioactive decay, which is widely accepted as a logarithmic function.) One reason it was adopted for estimating RDI/I was that analysts observed that graphs of various rainfall events often exhibited curvature as rainfall values increased and it was convenient to straighten the curve using a log-log plot. However, the author has never found conclusive evidence in the literature that shows (or even proposes) that the rate or quantity of rainfall percolating through a soil column and leaking into a sewer pipe was a logarithmic function (i.e. similar to radioactive decay).

When personal computers became widely available in the 1990s, the author evaluated data from several hundred flow and rainfall monitors, and found (as Nogaj had cautioned) that the observed curvature was primarily related to flow measurements made when the pipe was full. In simple terms, the curvature of the graphical plot of data occurred because the pipe experienced hindered or restricted flow conditions. While RDI/I caused the excess flow that filled the pipe, the conveyance was throttled by physical conditions and the actual flow through the meter did not reflect the upstream quantity of RDI/I resulting from a particular rainfall event that would have flowed past the metering point under free-flow conditions. Therefore, the curve in the graph observed under high and hindered flow conditions was a function of a throttled flow rate, not a pure function of the RDI/I phenomenon. Additionally, the author tested the flow and rainfall data sets using log-log graphs and graphs with simple Cartesian coordinates, and concluded from that study that the relationship between RDI/I and 24-hour rainfall depths (less than 4.5 inches) was a simple linear function with the form of: $y = a(x)+b$. (It is possible that the RDI/I relationship could have been linear for events greater that 4.5 inches, however opportunities to test such situations were too limited for making firm conclusions.) With the addition of 95 percent confidence intervals plotted as boundaries on each side of the regression line, this evolved into the Linear Regression (24-Hour Rainfall) method described by Kurz, et al (2014).

Potential I/I

When hindered flow conditions exist, this leads to an additional problem for estimating the total quantity of I/I and RDI/I in a basin. I refer to this problem as "Potential I/I" and I define it as: the clear water in the pipe bedding material that would enter the pipe through various defects if the pipe had sufficient carriage capacity to accept all the additional water. Typically, when the pipe is full, then the pressure head in the pipe prevents the entry of additional water. When the capacity of the pipe is the limiting factor, then the restricted flow condition becomes easier to understand as illustrated in Figure 1. (Kurz, et al, 2002)

Potential I/I does not enter the pipe during restricted flow conditions, but this extraneous water will reveal itself if additional carriage capacity is provided. Thus, simply upsizing pipes only allows room for this extra load and conveys it downstream to overload more of the system. In this illustration, the RDI/I volumes are plotted from various rainfall events. At the point where the RDI/I flows exceed the remaining capacity of the pipe to carry the flow, the pipe becomes surcharged. In this example, the pipe has a free flow capacity of roughly 8 mgd. RDI/I flows from larger rainfall events may exceed the free-flow capacity of the pipe by some amounts depending on downstream conditions, but the overall flow rate is hindered. The trendline of the RDI/I results begins to flatten and curve. The restricted flow condition may prevent the direct measurement of all the I/I attributable to a system being considered for rehabilitation. Yet, many systems have experienced the frustration of upsizing pipes or conducting sound sewer renewal programs, only to find that the pipes are still overloaded after the project is completed. For estimating the RDI/I resulting from a 5-year storm in Middle Tennessee (4.5 inch event in 24-hours), and which is not directly measured due to restricted flow conditions, the straight portion of the regression line (determined for the rainfall events less than 2 inches) is projected out to the point where it crosses the vertical axis for 4.5 inches. That point is 16 mgd. The actual measured flow for a storm close to the 5-year event measured about 8 mgd. Thus the "Potential I/I" which was not measured – but is present in the bedding material and ready to enter the system – is 8 mgd for the 5-year rainfall event of 4.5 inches.

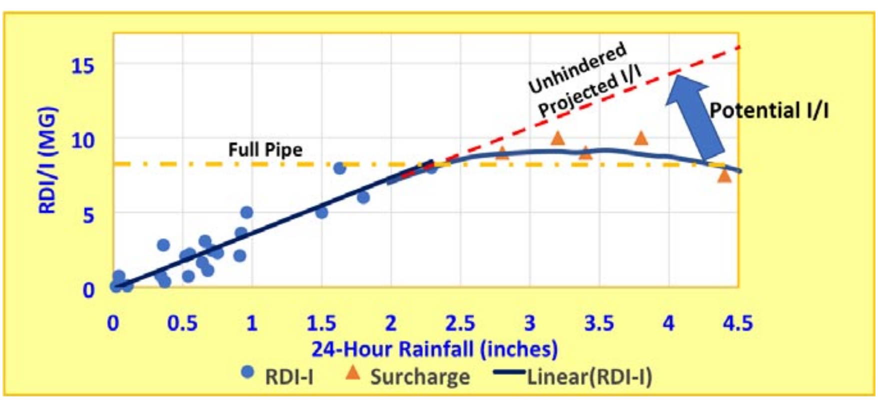

Figure 1. Example RDI/I Regression Curve which I illustrates Potential I/I.

An example of this problem arose during the planning, design, and installation of the McCabe-Richland Trunk in Nashville in 1994. This trunk sewer replacement was designed with a capacity of 78-mgd using traditional techniques of population projections for design capacity. (Kurz, et al 2002) Flow monitoring at the recently expanded West Park Pumping Station prior to design, showed that system flows peaked at about 32 mgd for rainfall events greater than 1 inch in 24 hours due to inadequate trunk capacity. This rate was even observed during a rainfall event that was close to a 5-year event of 4.5 inches. Construction was initiated using the traditional design approach due to the pressing administrative schedule. However, provision was made in the overall sewer rehabilitation program for addressing various tributaries to this trunk. An additional ten flow monitors were deployed in a long-term network to quantify the true loading. The aggregation of flow results on those upstream tributaries identified 53.5-mgd of I/I. This additional 21.5 mgd represented an estimate of "potential I/I" in this system. Shortly after commissioning, hurricane Opal struck middle Tennessee with 3.5 inches of rainfall, which resulted in a surcharge of the new pipe. Fortunately, extensive sewer rehabilitation work was already underway in the largest tributaries and the peaking factor was significantly reduced over the subsequent 5 years to the extent that the new pumping station could operate reliably.

The national I/I problem today

Congress required that the US-EPA periodically study the needs of wastewater systems nationwide. In its most recent published "Needs Survey" (2012 CWNS – Clean Watersheds Needs Survey), the Agency reported that there were 14,581 wastewater treatment facilities nationwide. 77.9 percent of those systems (about 11,370) had a capacity of 1.0 mgd or less. Previous work with wastewater collection systems in Tennessee (Kurz, 2014b) found that higher rates of I/I and RDI/I were often associated with smaller systems in that plant capacity range. This was corroborated with the data for each state in the CWNS which showed that the vast majority of needs in 42 (of the 50) states were in "small" communities (less than 10,000 people) which roughly generate about 1.0 mgd domestic flow. My experience in Tennessee is that systems in small communities are generally underfunded and may be less likely to seek experienced engineering help to detect, quantify, and correct I/I problems.

Does sewer rehabilitation actually work?

No matter how the measurements of I/I and RDI/I are defined and improved, the real challenge posed by the Conklin report and anecdotal experiences is: "Does sewer rehabilitation really work?" The answer is:

"Yes!" Results are appearing in the literature to verify this statement. However, the following example briefly describes objective, before-after flow monitoring results for a 10-year sewer rehabilitation program in Brentwood, Tennessee. (Kurz, et al, 2012) Brentwood operates a satellite collection system that comprises about 147 miles of pipe in sizes from 8 through 30 inches. The flow is discharged at a pumping station to the Nashville system for conveyance and treatment. Flow monitoring in 2008 showed that this system experienced an annual average of 0.94 billion gallons of I/I. Water consumption in this sewer shed averages about 542 million gallons annually. Therefore, close to half the system flow was typically from I/I. The city initiated an extensive program of flow and rainfall monitoring in late 2007. Sewer rehabilitation was launched in 2008 and continues today. The latest statistics were compiled in 2017 and listed in Table 1. The annual I/I was reduced by 63%.

By 2012, the charges assessed by Nashville for treatment were reduced by more than $1 million annually as a result of I/I reduction. At that point, the City was looking at a return on their investment for their total program cost of about 10 years. The reduction in RDI/I is shown in Figure 2.

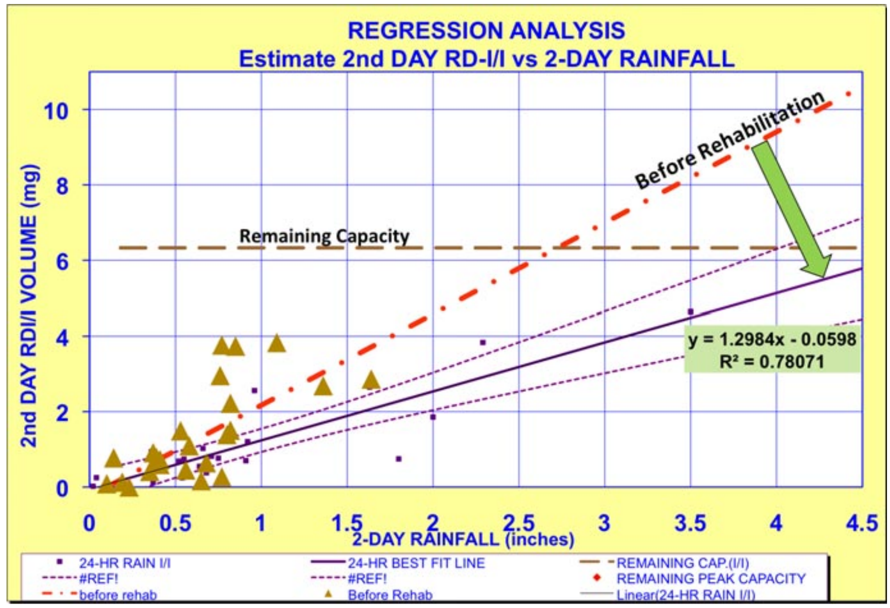

Figure 2. Brentwood RDI/I Regression analysis shows improvement from 2008 to 2017

Table 1. Summary of Long-term Monitoring and Sewer Rehabilitation Effectiveness.

	2008	2016-17	% reduction
Annual rainfall (in)	46.62	52.56	
ADDWF-7 (mgd)	3.048	2.971	3%
Annual I & I (mg)	940	349	63%
5-year projected RDI&I (mg)	10.69	5.78	46%
24-hr rainfall when RDI/I exceeds capacity (in)	2.6	4.9	

Continuing their work, by 2017 sewer rehabilitation was successful in reducing the RDI/I levels so that the system managed to contain flows at the pumping station resulting from typical 5-year rainfall events. The rehabilitation program conducted by Brentwood was based on a system approach – to stop migration. Most of the rehabilitation work used CIPP lining. Additionally, manholes were rehabilitated and (significantly) every sewer service lateral was inspected and they were replaced or rehabilitated when defects were detected.

Conclusions

Some of the problems identified in the 1981 Conklin report still plague our industry and our communities today. However, I think that we now have the tools (materials, processes, and technology – e.g. sewer lateral connection rehabilitation, longer-life grouts, and reliable lining products) to respond to most of the major areas of deficiencies identified by Conklin and the WPCF. We also have improved monitoring equipment and a better understanding of practical sewer hydraulics. Therefore, I contend that the most significant hurdle that we face today is: education! I believe that the education process must focus on the engineering community – both the designers - and engineers with regulatory responsibilities. When engineers gain knowledge about effective sewer rehabilitation strategies and confidence in the technologies to deliver long-term, cost effective I/I reduction, then we will improve the chances for reducing I/I – not just moving it around. On a nationwide basis, I don't think we will be able to honestly say: "I/I – We've fixed that!" – anytime soon. However, I firmly believe we can make significant progress with education and renewed determination and vision.

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ABOUT THE AUTHOR

George E. Kurz, P.E., DEE is an Independent Researcher & Consulting Engineer with 45 years' experience in working with state and local governments, sewer service contracting, and consulting engineering to improve the effectiveness and efficiency of sewage collection systems nationwide. As a lifelong member of WEF and ASCE, George is recipient of the WEF Arthur Sidney Bedell Award (1999) and the Collection Systems Award (2021). He was also honored with the Underground Construction 2021 MVP Award.

Inspecting Storm Sewer Assets Because

A RIVER RUNS THROUGH IT

City of Loveland

CCTV pipe inspection system gathered more data than anticipated.

By Mark Grabowski, IT Pipes

With the picturesque and environmentally-sensitive Big Thompson River running through its heart, the City of Loveland, Colorado does what they can to protect it. That's why in 2018, the city's Public Works department prioritized storm sewer inspection and maintenance, bringing light to any buried assets.

Currently, the city is undertaking the Gardield Harrison Storm Drainage Improvement Project. This $18MM, four-year project is designed to implement several improvements to infrastructure in the area including replacing and upgrading existing stormwater infrastructure to address existing drainage issues and meet current stormwater standards, installing 18- to 60-inch diameter storm sewer pipes, replacing existing waterlines and valves to address aging infrastructure, and providing stormwater quality treatment measures within the stormwater system.

The monstrous project will occur in four separate phases with approximately one phase completed per year.

"This important work has many benefits to the public. Local street flooding will decrease and we can also better clean the stormwater going into our waterways like the Big Thompson Canyon. The quality of the water distribution system will be improved greatly and lead to fewer leaks," said Eric Lessard, City of Loveland civil engineer. "On the surface, the public will benefit from updated curbs, gutters, resurfaced streets and ADA improvements such as handicap accessible ramps on the sidewalks."

> Loveland knew they had to start at the beginning.

Big investments for big results

A four-year, $18mm project isn't exactly a small undertaking. That's a large amount of money, consumption of city resources, and disruption to residents. But for those in Loveland nine years ago, they won't soon forget the floods of 2013.

"It was a six-month nightmare" said Capt. Pat Mialy, Loveland's Emergency Manager.

In early September, 2013, the Big Thompson River experienced peak flow rates near Loveland of 4,500 CFS before the floodwaters destroyed the gauge. Larimer County, where Loveland is located, had 1,120 square miles affected by flooding, and 1,500 homes and 200 businesses destroyed. Extensive road damage in Big Thompson Canyon cut off-road access to many communities. Damaged sanitary sewer lines dumped raw sewage down the creek and into the Big Thompson River.

And while no storm sewer system could stop a 1,000-year-flood, it did help bring to light some of the system's deficiencies. With the city located at the bottom of a canyon, floods and massive rain will always be a part of life for those living in Loveland and surrounding areas. However, Loveland knew they could do better when it came to handling their regular rains, while protecting the river that makes Loveland what it is – the Big Thompson River.

Adding to Loveland's decision to invest in their storm sewer system assets was that, like a lot of communities, Loveland was experiencing exponential growth. When many of these storm sewers were installed in the 1960s, Loveland's population was under 10,000. Since that time, people have been moving to Loveland in droves, year after year. That same storm sewer infrastructure that supported the roads and surfaces built for 10,000 residents wasn't going to support the roads and surfaces that were now needed for 85,000 residents.

War is 90% information

Loveland knew they had to start at the beginning. To fix the situation, they needed to know what the situation was. The needed confirmation as to what buried storm assets actually exist – not just what a piece of paper said exists. Also, what condition is it in? The city knew they would need to look where they have never looked before – underground. Many of their storm sewers had never been seen since they were installed over half a century ago. Loveland needed to first understand if they had buried assets or buried liabilities.

Working with local outfit Dawson Infrastructure Solutions (North Washington, CO), the city purchased a cargo truck-mounted Ibak CCTV pipe inspection system. The 16-foot box on this truck would become the mobile office and work area for a tenacious crew of two. Outfitted with 1,000 feet of inspection cable, and camera tractor that was capable of inspecting pipes from 8 up to 144 inches, they were soon on their way to gathering more data on their storm sewers than they had anticipated.

With the storm sewer inspection data flowing in, the last thing Loveland wanted was for this vital information to be siloed. The city already utilized Esri ArcGIS and Cityworks Asset Management System and sought a pipe inspection software that integrated with both.

Once again, working with Dawson Infrastructure Solutions, Loveland was introduced to the ITpipes platform. ITpipes consumes Esri Feature Services, having been built on Esri's latest technologies. Also, ITpipes has an automated bi-directional integration with Cityworks, meaning that when data goes into ITpipes, it automatically goes into Cityworks, and vice-versa.

Utilizing ITpipes Mobile, Sync, and Web, they were able to efficiently streamline their workflow. With a whole city of storm sewers to inspect, and only one crew, Loveland knew they had to maximize productivity where they could. With these seamless software integrations, they were off to a great start.

"These integrations allow the camera operator to select a pipe on the Esri map, which immediately opens the inspection for that asset in ITpipes, pre-populated with pertinent header data." says Eric Wilson, Senior GIS Analyst with Loveland Public Works. "This prevents the operator from having to enter the data manually on each pipe, as well as greatly reduces the chances for errors. Seemingly little time saving efficiencies become much larger when the crew is inspecting ten or more pipes per day" adds Wilson.

With 1,000 feet of inspection cable, the camera tractor was capable of inspecting pipes from 8 up to 144 inches

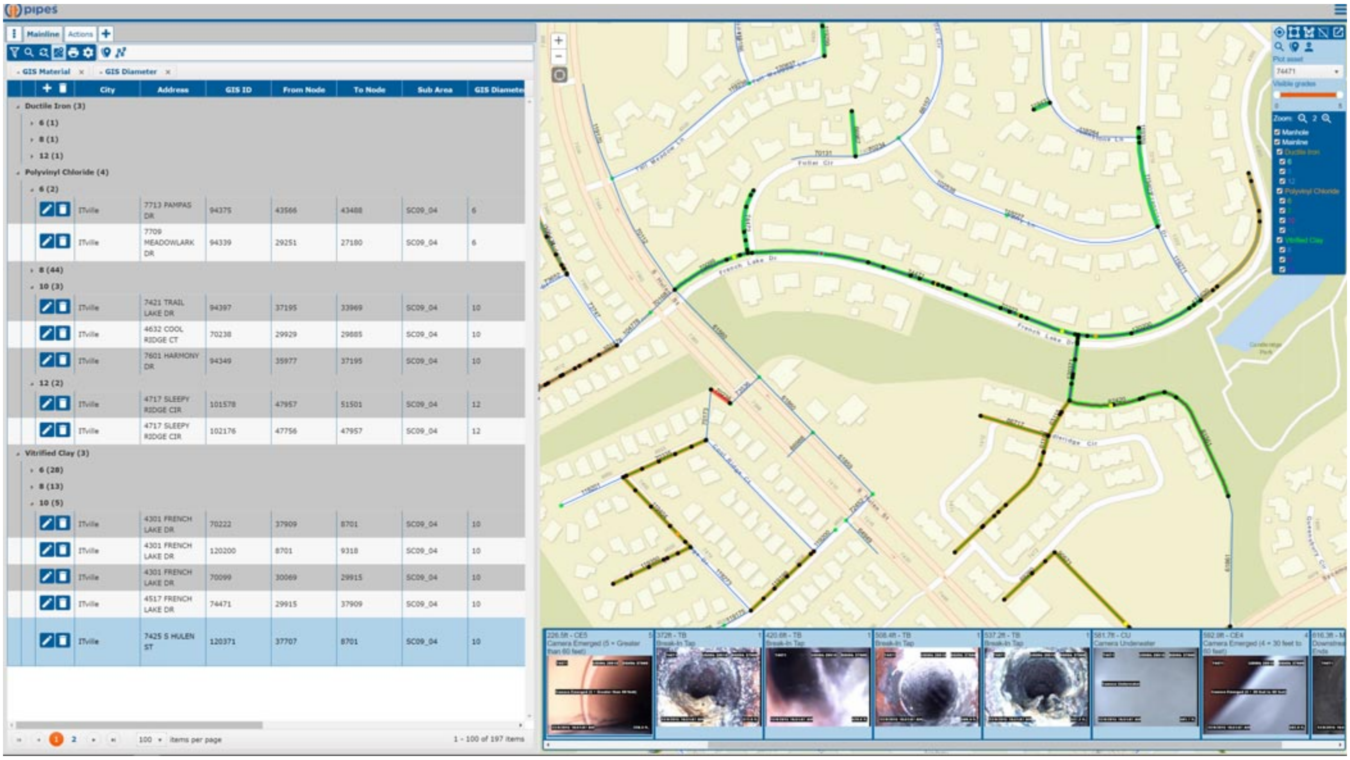
One bite at a time

The journey of a thousand miles (of pipe) begins with a single step, and Loveland decided the first step would be inspecting all pre-1987 storm pipes. These pipes not only had the highest chance of being compromised, but also had the highest likelihood of being hydraulically overloaded in a storm. With the city expanding so rapidly, many of the downstream storm pipes were bottlenecks in the system, and Loveland had to get the data to figure out which ones.

It didn't take long until the inspection team was finding issues – not only with the pipes, but also with the City's existing GIS data. The inspection crew was discovering new buried assets, incorrect pipe diameters, unknown manholes, and different alignments from what was shown on the records. Previously, discrepancies like this often got "lost in the shuffle" and never made it to the GIS team for correction. However, that could no longer happen. This data was vital to Loveland's investigation. That is where ITpipes Sync helped the city.

Each night, the CCTV inspection truck goes back in the shop as the crew leaves for the night. Via an internet connection to the truck's PC, pipe inspection data collected that day automatically uploads throughout the night and syncs to the cloud. This bi-directional sync not only uploads all the pipe inspection data collected during the day, but also downloads any GIS changes or Cityworks workorders. When the day begins, the CCTV inspection crew has the latest updated map and work for the day, and the engineering teams have the latest storm sewer inspection reports and videos. Additionally, the GIS team has the data they need to make the pertinent corrections to the map layer.

"With over 10 inspections per day, there is a lot of data that is coming in every night" adds Eric Wilson. "With this workflow, pertinent data doesn't fall through the cracks."



Justifying the investment

City budgets are scrutinized every year – often by board members who unfortunately may not fully understand the importance of investment in buried infrastructure management. The software, equipment, but mostly the time investment – none of it is cheap. However, Loveland has been able to justify the expenses, with all costs tracked in Cityworks. With ITpipes' automated bi-directional integration, anytime the crew inspects a pipe with ITpipes Mobile, a workorder is made in Cityworks allowing the city to accurately track time and materials. This automated workflow not only tracks costs, but also reduces burdensome paperwork, allowing for Public Works to justify budgets annually. Most importantly, however, it shows the residents of Loveland that their tax money is being wisely reinvested in their infrastructure while helping protect their Big Thompson River. This data also helps rationalize additional investments, like a new jet vac combo truck.

"Thanks to our storm pipe inspection program, we were able to justify the investment in a new combo truck. With that truck and our inspection program, we have cleaned more storm pipe in the last five years than in the city's history. These targeted cleanings not only drastically improve flow, but capture debris before entering the Big Thompson. It also recovers vital capacity within the pipe" says Eric Wilson.

we have cleaned more storm pipe in the last five years than in the city's history.

Looking forward

The 4-year Gardield Harrison Storm Drainage Improvement Project is just the start for Loveland. Owing to their considerable investments in equipment and software, information is efficiently disseminated across the city's public works department. Anyone in the city with access and a connected device can access pipe inspection data, anywhere, at any time via ITpipes Web. This provides stakeholders quick and easy access to pipe inspection data. This means operators in the field can easily pull up pipe inspection videos on their phone to see where a blockage is, just as easily as an engineer in the office can formulate a prioritized capital improvement plan.

Decades of old buried infrastructure can't be fixed overnight. Nor can it be done cheaply. Loveland's investment in efficient data-gathering tools and systems will help them assure that when the shovels begin moving dirt, their residents are getting the best bang for their buck when it comes to flood reduction and storm sewer improvements. And the biggest winner of it all is the Big Thompson River.

About the author

Mark Grabowski is an almost 20-year veteran of the water & wastewater industry, specializing in the inspection and rehabilitation of collection and distribution systems. His career has included contracting, equipment design, and software for the underground utility industry. Mark holds a BS in Mechanical Engineering from UCF and is active in multiple state and national industry associations.

Asset Management for Waterworks in South Korea: Trends and Case Study

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1. Introduction

Problems caused by aging water supply facilities are increasing worldwide. In countries that built water supply facilities relatively early, the problem was recognized, and appropriate solutions have been in place for more than 20 years. Although there have been several methods to solve the problems, the most effective of these has proved to be the application of an asset management (AM) paradigm.

Water supply facility problems became evident in Korea after year 2000. As the age of the facilities increased, the frequency of failures began to gradually increase, thus the cost of maintenance and repair also began to increase rapidly. Concurrently, consumers began to demand improvements in service quality as their income levels rose. The Korean government also has a price stabilization policy where the water rate is set lower than the production cost, resulting in Korean water service providers not having the resources to maintain water supply facilities with a large amount of non-revenue water exacerbating the situation. In other words, it can be said that the water service providers in Korea have reached their limit in maintaining water supply facilities.

Investigation into a waterworks AM were underway, considering examples from developed countries. One such country was Japan, which has a water supply system similar to that of Korea, AM started there for the purpose of giving the system a longer lifespan. New systems related to AM were also established and introduced in Australia, the United States, and the European Union, all of which were studied as a references.

This article describes the progress made in introducing AM in Korea, the mindset around AM, and the application effects of the AM system on an actual city. The object of this article is to provide a reference for other countries and industries seeking to implement an AM solution for their water supply facilities.

2. AM for waterworks in Korea

1) Definition

The definition of AM for infrastructure is widely established; using this definition, Korean researchers generated new definition specific to waterworks sector:

"A management system to identify and manage risk factors throughout the life of waterworks facility assets in order to achieve safe water quality, sufficient quantity, and appropriate water pressure, which are the original goals of waterworks, and at the same time provide the services required by consumers at the lowest cost"

2) *7 STEP AM procedure (for Korean style waterworks)*

In Korea, a 7-STEP AM execution procedure, shown in Fig. 1, was developed from a combination of the 10 STEP AM procedure suggested by U.S. Environmental Protection Agency (2012), the Macro/Micro concept of Japan Ministry of Health, Labor and Welfare (2009), and the key elements of AM discussed in the International Infrastructure Management Manual (IIMM) (2015) by the Institute of Public Works Engineering Australasia in Australia.

3) *INSAM (INtegrated System for Asset Management of waterworks)*

Fig. 2. shows a schematic of INSAM, an AM system developed in Korea. The word INSAM

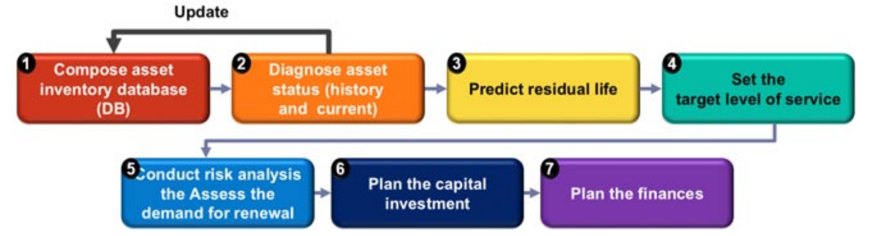


Figure. 1. 7 STEP AM execution procedure in Korea.

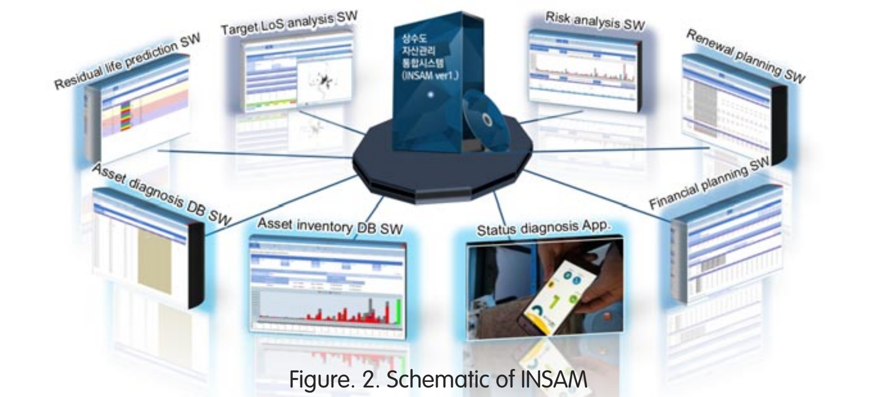


Figure. 2. Schematic of INSAM

in Korean has the same pronunciation as ginseng, a Korean specialty. The system was named INSAM in the hope that it would become Korea's unique AM system. The system integrates seven sub-software packages ranging from asset list management software to financial planning software, and each package aligns with the 7 steps of AM shown in Fig. 1. Meanwhile, it is also partially linked with a mobile App. that can effectively manage facilities using near field communication (NFC).

4) The introduction of AM in Korea

Fig. 3. below shows the steps of introducing AM in Korea. The direction was initiated in 2017 and is currently at step 2 of 3 in 2021. The first standard for AM in Korea was established in 2016, called the Korea standard (KS), based on international organization for standardization (ISO) standard.

The Law for life cycle management of infrastructures was enacted in 2020, thus laying the legal basis for the introduction of AM. In Korea, a large-scale aging pipe renewal project, about $ 3 billion, is currently underway called "Modernization project". The project guidelines include various regulations for the introduction of AM and are accompanied by extensive asset research so that the AM system can be easily applied. Further, a pipe inspection project, about $ 0.5 billion, is also currently underway to construct a diagnosis DB for most pipes. When the projects are completed, the AM system will be applied in earnest.

5) Empirical case study using INSAM

The system was installed on a trial basis in a small downtown in Y city, Korea, shown in Fig. 4. The water supply system in Y city is a system that supplies an average of 9,000 m3/d to approximately 22,000 customers through one water treatment facility, and the length of the transmission and distribution pipes is 61.5 km. The number of assets was 1,329 (732 pipes, 325 valves, 35 pumps, and the other machinery in purification plant). For system installation, the site was investigated for 2 years to build an asset list, and the data were entered into the software for each step.

Importantly, there is an engineering rationale for figuring out when an asset reaches the end of its useful life. Fig. 5. describes the pipe's useful life prediction procedure using safety factor based on the pipe corrosion depth prediction. Before the system was applied, the lifespan was set according to the accounting lifespan, but after the system was introduced, the lifespan of the asset could be determined using the data obtained through investigation and diagnosis. Since the derived useful life of asset is very important factor in determining the investment scale, it is expected that the accurate identification of the useful life of asset will be of great help in determining the investment time.

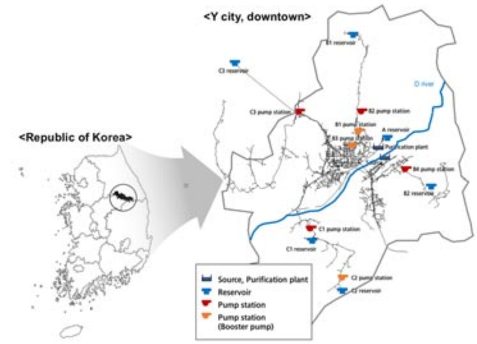


Figure 4: Case study area (Y city, in Korea)

A customer survey identified the level of service that customers evaluated as shown in Fig. 6. In the case of Y city, customer answered that a stable water supply is the most necessary, presumably because the water supply was often interrupted due to leaks caused by improper

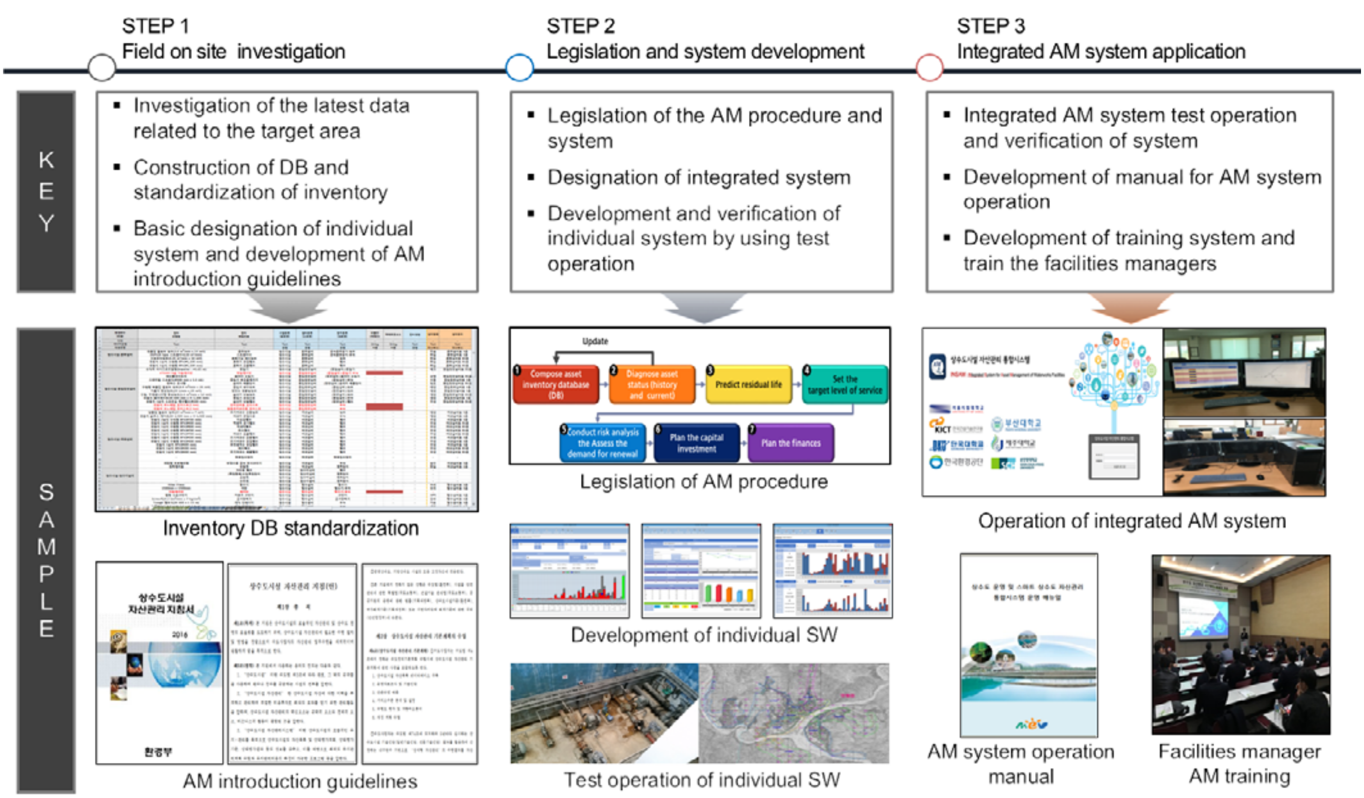


Figure 3. Direction of introducing AM in Korea.

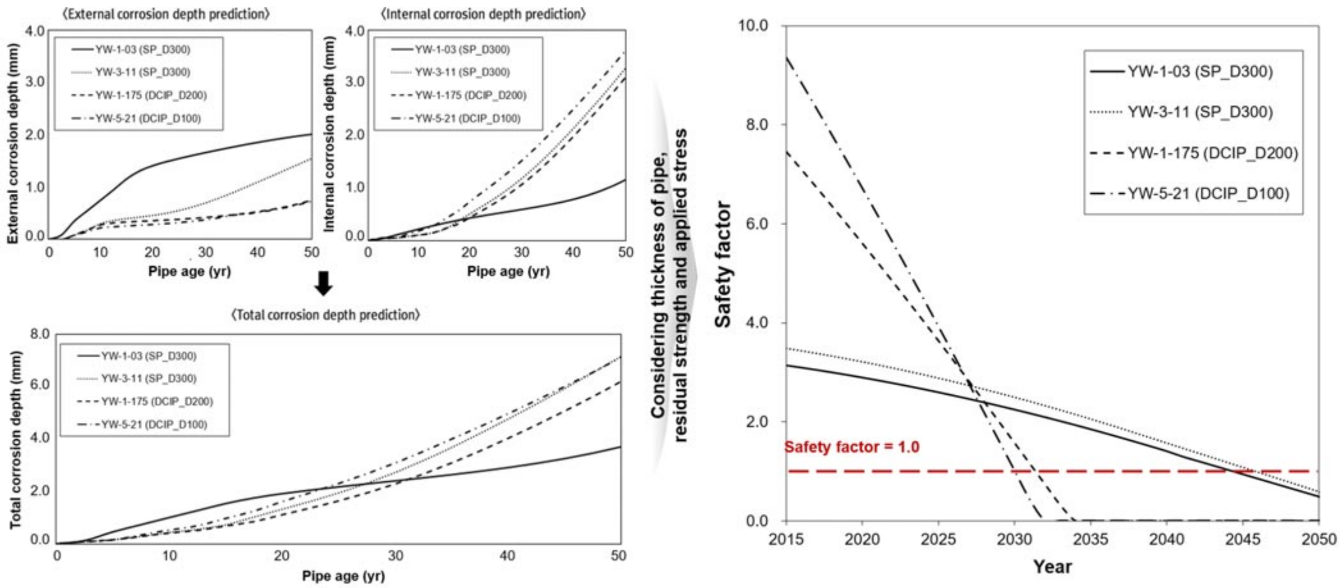


Figure 5. Useful life prediction of pipes using safety factor

management. The survey results were used for gap analysis in connection with the self-diagnosis results of water service provider.

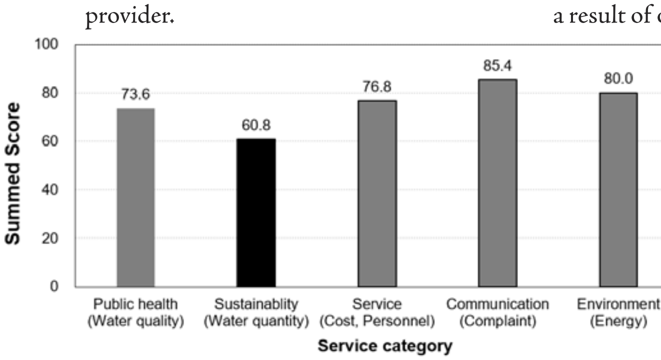


Figure 6. Level of service rated by consumers.

The existing renewal plan was a method based on the lifespan of assets from an accounting point of view. However, as a result of optimizing the renewal plan, it was confirmed that many effects occurred. It was possible to establish a long-term renewal plan for Y city, with the expected outcome of a reduction in renewal costs by more than 15 % compared to the existing renewal plan. In addition, the risks were also reduced by 28 %, resulting in an excellent plan in terms of risk management.

Lastly, an appropriate water rate for water providers was determined to aid them in operating without financial loss. The current water rate (about 9.0 $ / 10 m^3) is approximately 50 % of the production cost. It was determined that if water rate incomes are used to all assets that have reached the end of their useful life, Y city would have to raise its water rate by 1.0 $ / 10 m^3 every 5 years. Such a water rate increase was deemed reasonable, as it was within the range of customer willingness to pay. Fig. 8. shows the

Category	Existing renewal plan	Optimal renewal plan
Residual life	Based on accounting	Based on useful life prediction
Service & Risk	Not considered; Avg. Suspension risk (25.44 m^3/yr, 27 h/yr)	Considered; Avg. suspension risk (18.22 m^3/yr, 19 h/yr) ▼ 28.4 %
Budget	Not considered	Considered; $ 1.0 million constraints
Renewal costs 1)	$ 34.2 million	$ 28.9 million; ▼ 15.5 %
Lifecycle costs 2)	$ 67.7 million	$ 63.3 million; ▼ 6.5 %

1) Considering inflation rate: 2.0 %
2) Considering inflation rate: 2.0 %, Social discount rate: 4.5 %

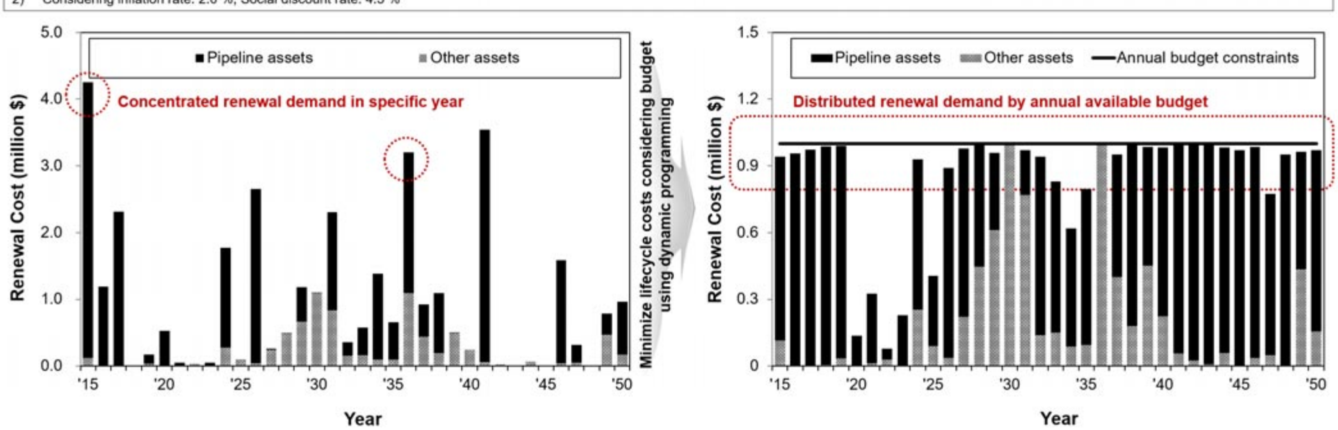


Figure 7. Comparison of renewal plan (Left: Existing renewal plan, Right: Optimal renewal plan)

Category	Existing financial plan	Optimal financial plan
Capital investment	Based on existing renewal plan	Based on optimal renewal plan
Water rate [1]	Same as 2015 (9.0 $ / 10 m³) (In 2050, 18.0 $ / 10 m³)	Raise by 1.0 $ / 10 m³ / 5 yr (In 2050, 25.0 $ / 10 m³) ▲ 38.9 %
Net fiscal balance	- $ 27.9 million during analysis period	$ 0.0 million during analysis period; Securing financial soundness

1) Considering inflation rate: 2.0 %

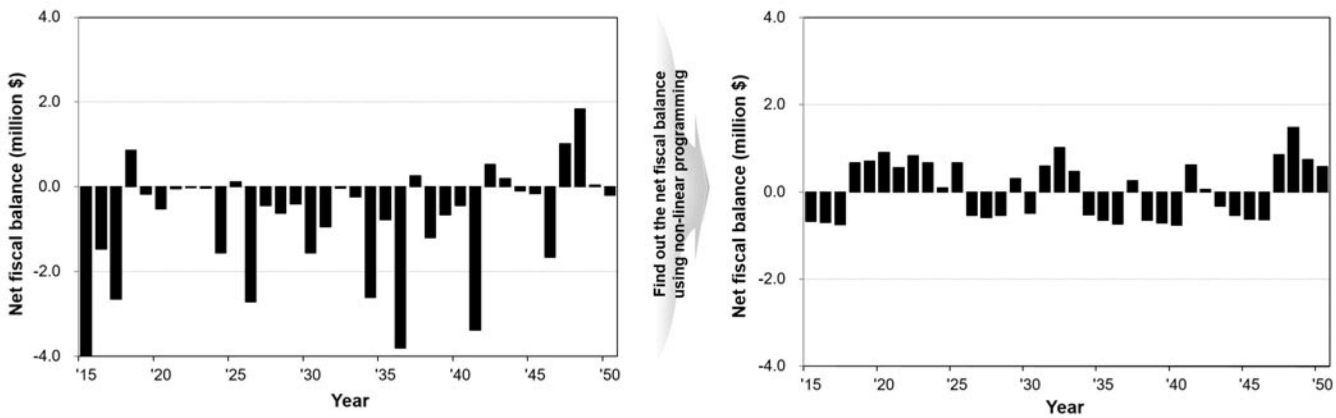


Figure 8. Comparison of net fiscal balance (Left: Existing financial plan, Right: Optimal financial plan)

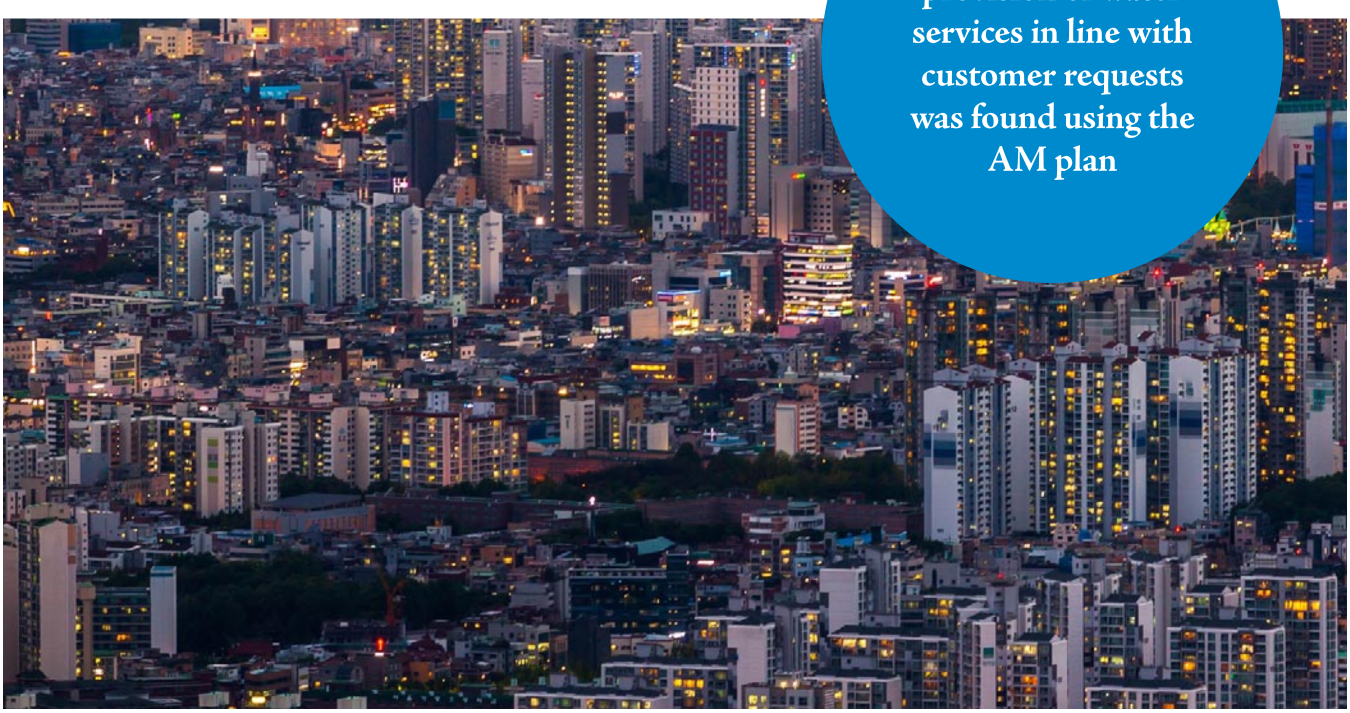
results of optimizing the fiscal balance in consideration of the water rate increase, and represents that financial soundness is secured.

In conclusion, a solution to the provision of water services in line with customer requests was found using the AM plan. Based on this case, Korea is gradually increasing the number of cases of application of AM system. In addition, R&D projects are continuously being carried out, and education program is being developed.

3. Conclusion

Water supply facilities need to be recognized as assets for society and as assets whose value depends on their functional integrity. Proper AM will answer the previously unanswerable questions such as, "How much does each water supply facilities?", "When should partial or complete replacements be accomplished?", "What are the costs involved?", "What finances must be peremptorily allocated?" etc. As mentioned in the introduction, AM can solve many of our problems. It should continue to evolve with more detailed investigations and sophisticated modeling techniques. It is believed that the case study in Korea will be a good reference for water service providers in countries or industries in a similar position to Korea wishing to develop a similar solution.

A solution to the provision of water services in line with customer requests was found using the AM plan



Key task of each step of AM

The objectives and key tasks of each step are shown in Table, which summarizes the ideal AM tasks proposed by Korean government (Ministry of Environment) and researchers. AM is still being gradually introduced in Korea, so each water provider is implementing the key tasks within the scope of their ability, albeit that the government recommends that all steps be performed.

Step	Objective and key task
Compose asset inventory DB	• Classify assets into "managed" and "not managed" (In Korea, assets worth more than 5,000 $ are managed).Standardize and systematize asset lists and identify items to be contained in the lists (In Korea, 5 levels of asset classification exist based on the water supply process). • Standardization enables anyone to investigate data according to the same procedures and standards. • If the geographical information system (GIS) is established in target facilities, link all assets with GIS to capture the basic status of assets and to output data analysis results.
Diagnosis asset status (history and current)	• Build the 3 DBs that can be used in subsequent steps and analyze the results. • Current status DB: This consists of data when the asset is first investigated. (in case of pipes: installation year, material, diameter, length, etc.) • History DB : This consists of data that identify asset history (renewal, rehabilitation, repair, leak recovery, etc.). (in case of pipes: time of breakage, consequence of breakage (suspension time and population, economic damage), renewal method, etc.) • Diagnosis DB : This consists of data containing the results of all the past visual inspection and specimen detailed inspection (in case of pipes: time of inspection, corrosion area and depth, soil corrosiveness, results of stress test, ovality, etc.) • Various methods can be used for diagnosis. Recently, technologies that can evaluate and record conditions in real time using information and communication technology (ICT) are in the spotlight.
Predict residual life	• If no data to predict the residual life of an asset are available, it is based on accounting standards. (In Korea, the lifespan of metal pipes is 30 years and that of plastic pipes is 20 30 years.). If a more accurate lifespan can be determined using the 3 DBs built, it will aid decision-making. • Define the residual life in one of the following ways: • Physical life: based on the structural safety factor considered external and internal stresses and residual strength • Service life: based on the historical customer complaints and functional aspect of asset (for example, water quality problems and malfunctions) • Economical life; based on the lifecycle cost of assets (installation cost, maintenance cost, renewal cost, etc.) • Guaranteed life: based on the suggestion of manufacturer
Set the target level of service	• Define the service items and evaluate the level of service currently provided to customers. (In Korea, 33 service items are being evaluated.) • Use a survey to identify the gap between the perspective of the water service provider and the customer to set the target level of service. • Consider factors that may change in the future: • Water demand: A function of natural or anthropogenic changes in population or changes in living conditions resulting in the rebuilding of the district metered area (DMA) and reservoir. • Water quality regulations: A function of customer demand for higher quality tap water or discovery of new contaminants that may add more water treatment process such as membrane treatment. • Water pressure: If the water pressure is lowered for leakage management, the water system may be adjusted to have an appropriate range of water pressure by including pump station or pressure reducing valves. • Calculate the cost once the target service level has established.
Conduct risk analysis and Assess the demand for renewal	• Calculate the risks in accordance with an accepted model: • Risks can be defined in various ways but are commonly calculated using the probability of failure (POF) and the consequence of failure (COF) • For the risks associated with suspension in water distribution networks, for example, the POF is a function of the failure rate based on the diagnosis DB and history DB, the COF is a function of the hydraulic analysis or cost analysis. • Use the risk model functions to identify criticality in the system and prioritize asset renewal. • Evaluate the residual life prediction result and the level of service result; predict renewal timing and costs along with the necessity for the reduction or expansion of facilities in the future.
Plan the capital investment	• If the renewal is concentrated in a specific year, the annual budget may be exceeded (In Korea, the water supply system is financed by the government, so a certain level of budget is allocated every year.). Distribute the concentrated demand for renewal properly using optimization algorithm or various scenario analysis. • Establish a long-term optimal renewal plan that minimize risk and lifecycle costs within a limited budget and calculate the necessary investment costs. When optimizing, risks or goals and will of water provider can be thought as a priority.
Plan the finances	• Simplifying the complex financial structure and formulate the trends of each financial items. • Based on the water service business management performance recorded in the past financial statements (balance sheet, profit and loss statement, cash flow statement), a revenue and expenditure forecast can be made for the water service provider, and resources can be allocated. • Readjust the capital investment plan and resources to make rational fiscal balance by comprehensively considering the depreciation of assets, liabilities (loan, borrowings), equity, government subsidy, etc. • Use the consumer's willingness to pay for readjustment of the water rate, which accounts for a large portion of the revenue.

PROFILE: Fluid Waste Services Inc.

Serving the Community with Safety and Efficiency

Fluid Waste Services Inc. was founded in 1989 by Chip McAuley and his wife Sonnie. FWS is now proudly owned and operated by their daughters Morgan (CEO) and Margo (VP).

It started as a sewer cleaning company with one combination cleaning truck operating out of Chip and Sonnie's backyard – with Chip handling the day-to-day jobs and Sonnie handling the sales, knocking on the doors of local businesses asking if they needed their grease traps pumped. Thirty-three years later, FWS has grown to offer more than a dozen services in the utility maintenance industry with a fleet of over 30 vehicles, 50+ employees, two locations, and the desire to continue growing under a new generation of female leadership.

> "Focus on finding the right people and best equipment"

Back in the 1980s while working for a plumbing company in Indianapolis, Chip recognized the standard of service for companies that could high pressure jet was pretty low. And in that, Chip saw an opportunity. He convinced his wife to put everything they owned up for a loan to purchase a combo truck and start a company, called Fluid Waste Services.

Chip's goal in starting FWS was simple: build an organization that serves its community with the absolute highest-quality service. In order to do that, Chip put his focus on finding the right people and the best equipment. By prioritizing and investing in his employees and the machinery they used daily, Chip created a place where men and women could have life-long careers and truly become experts in the industry.

FWS is now made up of over 50 individuals who are trained to do things the right way, without cutting corners and without sacrificing safety. One example being the company's policy to always have two crew members in a truck to increase the level of safety and efficiency on every job site. Regardless of what may seem easier in the moment, or what the competition is doing, FWS stays true to its core values of safety, professionalism, reliability, efficiency, adaptability, and teamwork.

When you meet Chip, you remember him. He is the kind of person you enjoy being around. He is true to his word, he is relentless in finding solutions, and he constantly holds himself to the standard of doing the right thing. Fluid Waste Services is a mirror of those qualities. As his daughters take the reins, they bring their own unique values to the table, but stay steadfast in their commitment to the qualities their father Chip founded the company upon 33 years ago.

Fluid Waste is available Monday through Friday for scheduled work and 24/7 for emergency services.

How Will Ripple Effects of Financial Impact on Water Infrastructure be defined for the Future?

By: Kevin KwangHyuk Im,
Lyles School of Civil Engineering, Purdue University

Water, sewage, and other systems sector is the vital and essential infrastructure of the nation that provides critical services. These systems serve as the cornerstone of municipal systems, economical safety, various businesses, security, individuals and households, public health, government management, economic activity, and government operations of the nation.

While the country is focused on community vulnerability and the immediate health crises related to the COVID-19 pandemic these days, we also face long-term potential health crises associated with the water, sewage, and other systems sector.

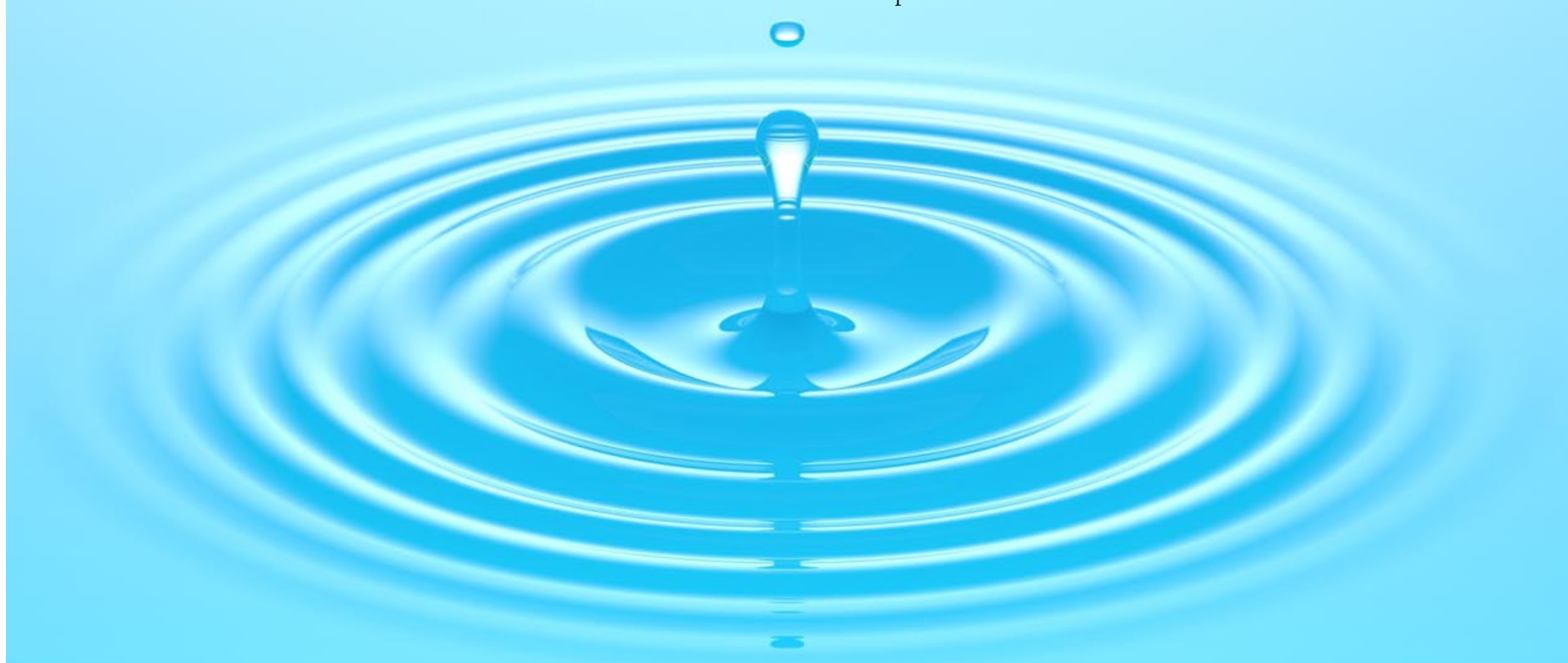
In the era of a contagious disease or epidemic disease, the water infrastructure systems such as distribution pipelines, conveyance systems, water treatment plants, water storage tanks have made society dependent on the safe and sanitary water systems that are increasingly using an increasing amount of clean water sources. Therefore, our society is becoming reliant on water, which implies that disruption to water supply services and sustained contamination of water resources will result in bigger economic and societal losses.

American Society of Civil Engineer's Report Card for Water Infrastructure for over two decades

Drinking Water		Wastewater	
2020	D	2020	D+
2017	D	2017	D+
2013	D	2013	D
2009	D-	2009	D-
2005	D-	2005	D-
2001	D	2001	D
1998	D	1998	D+

Figure 1. American Society of Civil Engineer's Report Card for Water Infrastructure for over two decades (Source: Figure created by the author)

Nevertheless, the most recent American Society of Civil Engineers (ASCE) infrastructure report card had already assigned a "D" to the drinking water infrastructure and a "D+" to the nation's wastewater infrastructure. Figure 1 shows the grades of the American Society of Civil Engineers' Report Card for water infrastructure for the last few decades. Since 1998, the grades have been near failing, averaging only Ds, due to current infrastructure conditions and investments that do not seem to have improved for over



a decade. Water infrastructure report cards using the A to F school report card format provide a comprehensive assessment of current water infrastructure status and needs, and the grades are based on the eight criteria of capacity, condition, funding, future need, operation and maintenance, public safety, resilience, and innovation.

Taking these effects above into consideration, the insufficiency of capital investment of water infrastructures will cause financial impacts to our industries and communities, which means that we need to consider alternative plans and pay attention to the issue.

Given the fact that water service problems may cause the financial impact of dozens of billions each year, this fact has implications for the significance of a sustainable water supply's ability to enhance and support societal and economic value.

A well-organized plan associated with water, sewage, and other systems sector will demonstrate that managing appropriate investment strategies and taking appropriate financial actions can minimize the financial impact due to the inefficiency of water systems.

What interconnectedness of water sector is saying

Capital investment in the water sector financially affects our social system, oil and natural gas sector, electric power sector, environment, administrative and support services, transportation, and so on. In other words, efficient capital investment of water infrastructure can have an affirmative financial impact and societal influence. The capital investment caused by the financial impact of affirmative action will greatly affect one or more economic systems. Figure 2 shows the interconnected sectors that are composed of critical infrastructure such as oil, electric power, natural gas, telecom, water, transportation, and so on.

If there is a lack of financial investment in the water, sewage, and other systems sector, it will gradually affect economic impacts to one or more sectors. A direct financial impact of water services would be the direct change of productions and needs due to tangible lack of capital investment for water infrastructure, and an indirect financial impact would be the change other infrastructures suffer due to the lack of capital investment for water infrastructure based on infrastructure relationships.

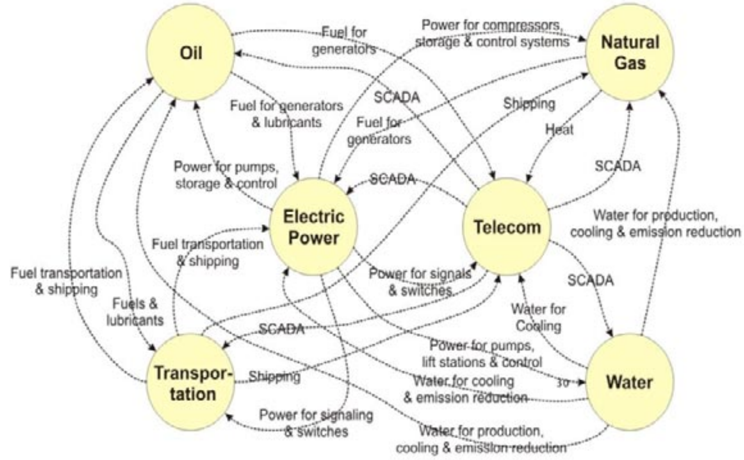


Figure 2. Interconnected Sectors Associated with Critical Infrastructures (Source: After Rinaldi et al. 2001)

The technical coefficient matrix and the input–output model

To measure ripple effects that predict the effectiveness of water infrastructure capital investment, the technical coefficient matrix and input–output model have been used. It shows how to connect one or more economic systems and it is a model for the interconnectivity between over 400 sectors. The used data has been released as part of the 2018 comprehensive update and revised for the 2021 annual update from the Bureau of Economic Analysis. It is used the detail-level make and use tables from the input-output accounts for the years 2012.The data will represent industrial-economic interconnectedness and interdependencies across all other industries in the U.S. economic system. The definitions of each element of the normalized make matrix and the normalized use matrix can be summarized as follows:

Water needs essential ingredients from diverse sectors

- Normalized make matrix (V^): The amounts of the different commodities in the columns produced by the industries in the rows
- Normalized use matrix (U^): The amounts of the different commodities in the rows consumed by the industries in the columns
- Total industry output (X): The value of all commodities produced by a particular industry
- Total commodity output (Y): The value of all the intermediate industry consumptions and exogenous demands
- Exogenous commodity demand (e): The amount of commodity uses other than the intermediate consumptions by industries
- Value added (zT): The amount of industry inputs other than commodities

The overall procedure for technical coefficient matrix

Figure 3 shows the key point diagram for the interconnectedness matrix. Above all, the first equation shows that the product of the normalized make matrix and the normalized use matrix is the input-output model A matrix. The second equation shows the correlation between the final consumption of industry output, the normalized make matrix, and the exogenous commodity demand. The third equation shows the correlations between the total industry output, the normalized make matrix, and the total commodity output. The fourth equation shows the correlations between the total commodity output, the normalized make matrix, the total industry output, and the exogenous commodity demand. The fifth equation shows the correlations between the normalized make matrix, the total commodity output, the total industry output, the normalized use matrix, and the exogenous commodity demand. The sixth equation shows the correlations between the total industry output, the input-output model A matrix, and the final consumption of the industry output.

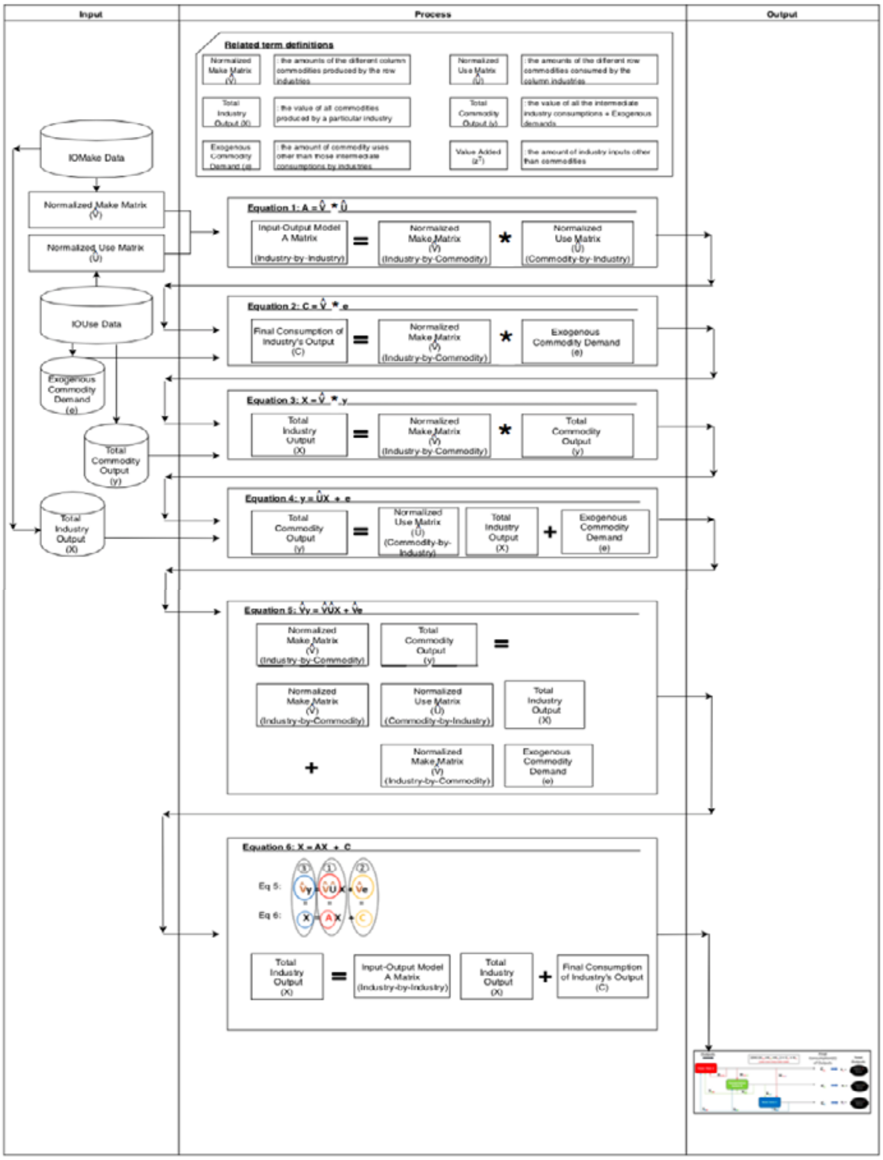


Figure 3. The Key Point Diagram for Interconnectedness Matrix (Source: Figure created by the author)

Value of interconnectedness in terms of water, sewage and other systems

Figure 4 shows the value of interconnectedness in terms of the demand-side of water, sewage and other systems (IO code: 221300) sector for the year 2012. It can be interpreted that the overall trends of the value of interconnectedness for the year 2012 were somewhat fluctuant when comparing to the past year.

The highest relationships with the water, sewage and other systems in the interconnectedness matrix on the demand-side was IO code 2123A0 (Other non-metallic mineral mining and quarrying) in the year 2012. The second most related sector on the demand-side was IO code 325120 (Industrial gas manufacturing). The third most related sector on the demand-side was IO code 493000 (Warehousing and storage). The fourth most related sector on the demand-side was IO code 811200 (Electronic and precision equipment repair and maintenance). The fifth most related sector on the demand-side was IO code 325180 (Other basic inorganic chemical manufacturing).

The historical input-output data of the make and use matrices for the years 2012 is utilized to evaluate the ripple effects regarding the effectiveness of water infrastructure capital investment. To measure the economic benefit's contribution from one sector to another sector, the interdependency matrix for economic benefits is created by the technical coefficient matrix and the vector of the as-planned productions of a sector. This is a year-based assessment, and it has been defined as the values of interconnectedness across over 400 infrastructures for the years 2012. The interconnectedness matrix in one year has 164,025 interconnectedness relationships that represent the values of interconnectedness on interrelated industries, respectively.

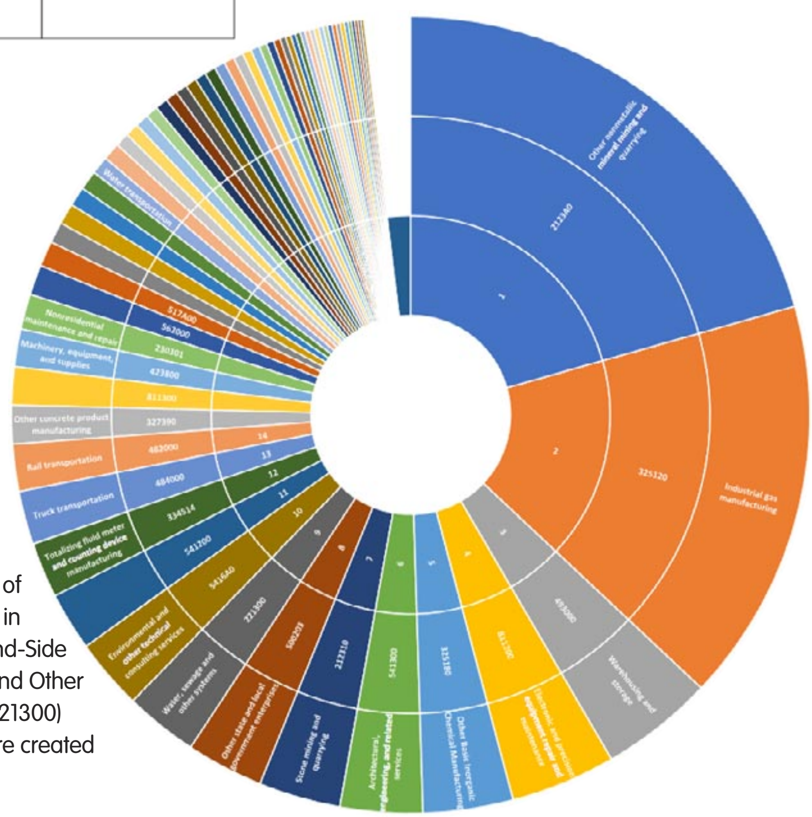


Figure 4. The Value of Interconnectedness in Terms of the Demand-Side of Water, Sewage and Other Systems (IO code: 221300) sector (Source: Figure created by the author)

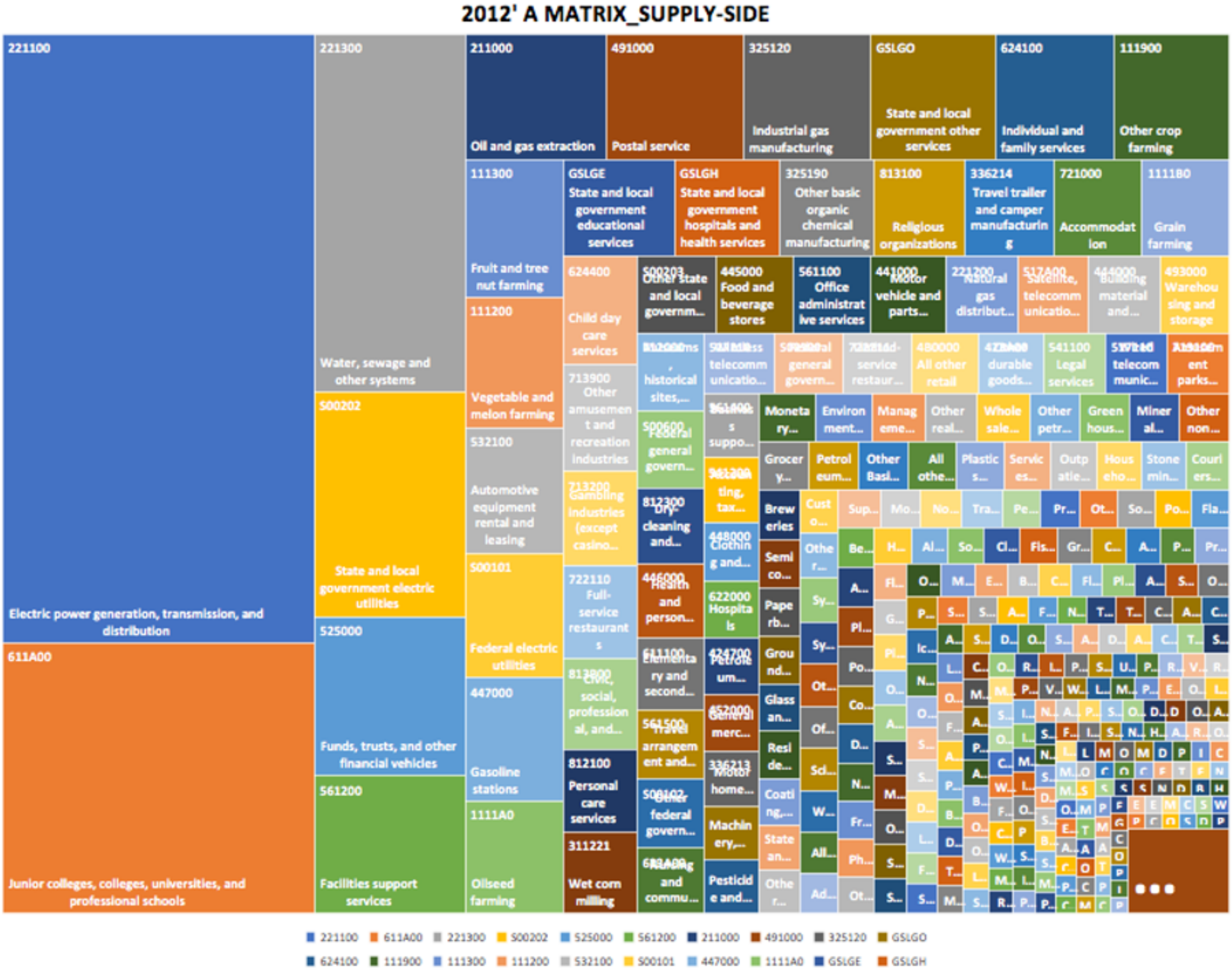


Figure 5. The Value of Interconnectedness in Terms of the Supply-Side of Water, Sewage and Other Systems (IO code: 221300) sector (Source: Figure created by the author)

On the flip side, Figure 5 shows the value of interconnectedness in terms of the supply-side of water, sewage and other systems (IO code: 221300) sector for the year 2012. The highest relationships with the water, sewage and other systems in the interconnectedness matrix on the supply-side was IO code 221100 (Electric power generation, transmission, and distribution) in the year 2012. The second most related sector on the demand-side was IO code 611A00 (Junior colleges, colleges, universities, and professional schools). The third most related sector on the demand-side was IO code 221300 (Water, sewage and other systems). The fourth most related sector on the demand-side was IO code 500202 (State and local government electric utilities). The fifth most related sector on the demand-side was IO code 525000 (Funds, trusts, and other financial vehicles).

Value of interdependence in terms of water, sewage and other systems

Water needs the essential ingredients from diverse sectors. Figure 6 shows the value of interdependence in terms of the demand-side of water, sewage and other systems (IO code: 221300) sector for the year 2012. It shows the most water-intensive sectors for water, sewage and other systems sector as suppliers. Water indicates a demander. Industrial gas manufacturing (325120) is the largest provider for the water sector in the United States. In other words, the highest relationship with the water, sewage and other systems in the interdependency matrix on the demand-side was IO code

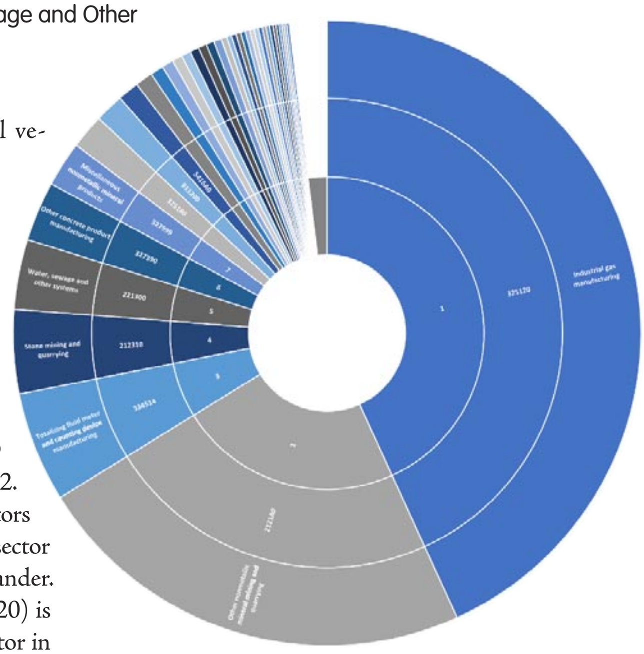


Figure 6. The Value of Interdependence in Terms of the Demand-Side of Water, Sewage and Other Systems (IO code: 221300) sector (Source: Figure created by the author)

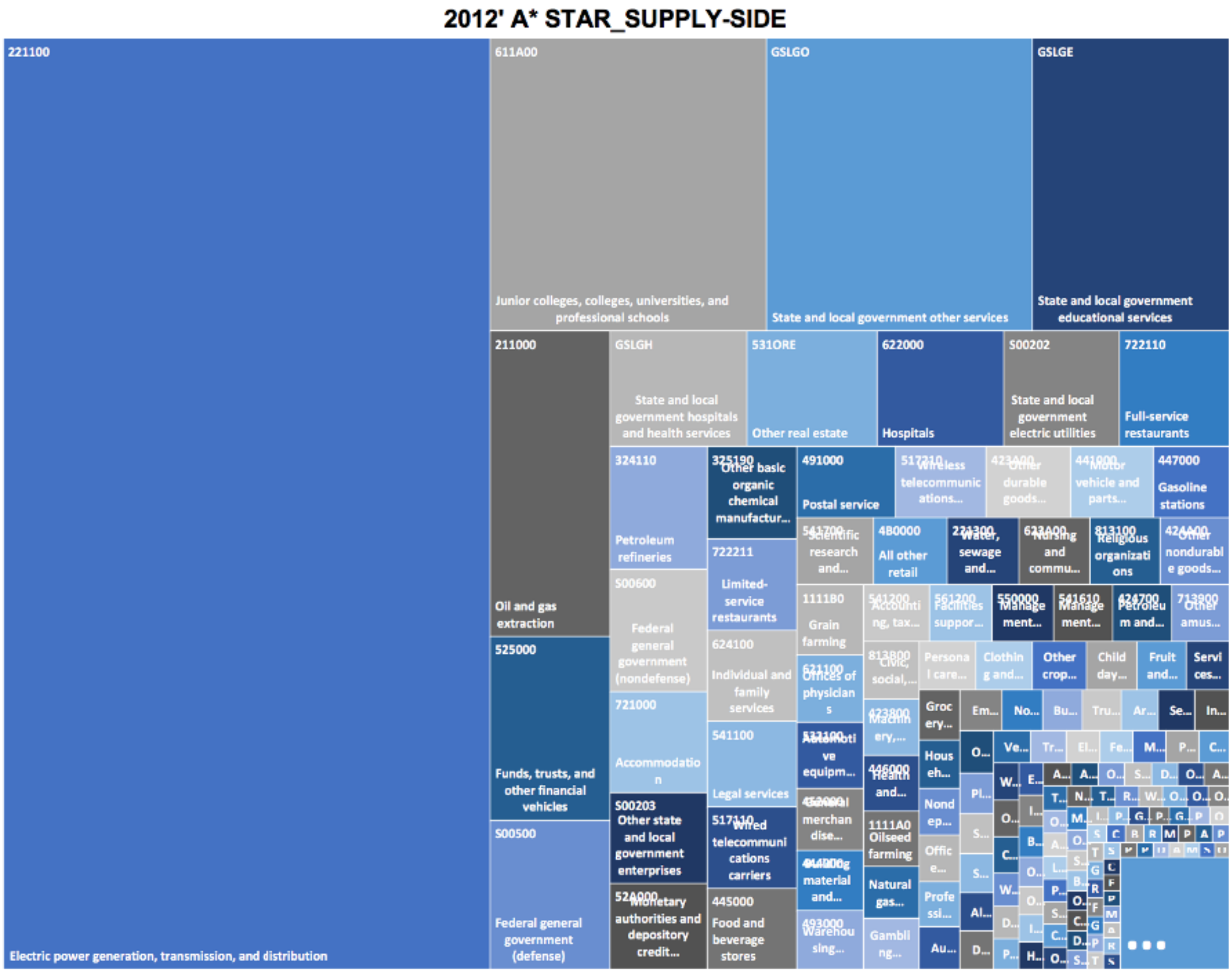


Figure 7. The Value of Interdependence in Terms of the Supply-Side of Water, Sewage and Other Systems (IO code: 221300) sector (Source: Figure created by the author)

325120 (Industrial gas manufacturing). The second-largest relationship with the water, sewage and other systems in the interdependency matrix on the demand-side was IO code 2123A0 (Other nonmetallic mineral mining and quarrying). The third-largest relationship with the water, sewage and other systems in the interdependency matrix on the demand-side was IO code (Totalizing fluid meter and counting device manufacturing).

On the other hand, water can be the vital ingredient that fuels all other sectors. Figure 7 shows the value of interdependence in terms of the supply-side of water, sewage and other systems sector for the year 2012. It shows the most water-reliant sectors for water, sewage and other systems sector as demanders. Water indicates a supplier. Electric power generation, transmission, and distribution (221100) is the largest user of water resources in the United States. In other words, the highest relationship with the water, sewage and other systems in the interdependency matrix on the supply-side was IO code 221100 (Electric power generation, transmission, and distribution) in the year 2012. The second-largest relationship with the water, sewage and other systems in the interdependency matrix on the supply-side was IO code 611A00 (Junior colleges, colleges, universities, and professional schools). The third-largest relationship with the water, sewage and other systems in the interdependency matrix on the supply-side was IO code GSLGO (State and local government other services).

> Water can be the vital ingredient that fuels all other sectors

There is a possibility that people don't associate a glass of beer or a gallon of petroleum with their water supplies. However, virtually all end-user products rely on water resources to varying degrees.

Significance of ripple effects of financial impact on water infrastructure

Municipal governments have owned and controlled 85 percent of water utilities and 54 percent of sewer utilities. However, most fall under the public works department or utility department (The American Public Works Association (APWA)). APWA pointed out that municipal governments cannot resolve the need for additional federal support and funding, and they may only offer a limited plan of what communities can afford. As federal aid for water infrastructure capital needs has declined (from 31 percent in 1977 to 4 percent in 2017), the expenditure of regional and state has accounted for a much larger share, affecting financial operations and soundness adversely. Increased challenges and risks of the water, sewage, and other systems (IO code: 221300) sector due to the lack of capital investment in the water infrastructures ultimately lead to increased physical, societal, and economic risks. APWA insists that the Environmental Protection Agency should promptly request from Congress and Congress should provide a considerable amount of money in federal funding for capital investment in water infrastructure.

Taking all these things into consideration, the ripple effects of the financial impact on water infrastructure show the economic benefits of additional federal support in water infrastructure between interdependent sectors within the economic system to facilitate the federal government's share of capital investment. This approach of predicting the ripple effects from the additional capital investment in terms of the water infrastructures will help in creating a paradigm shift in the current state of practice.

Virtually all end-user products rely on water resources to varying degrees

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Status of Asset Management in Germany

By: Dr. Ing. Robert Stein, Stein & Partner GmbH

IN THE ASSET MANAGEMENT of wastewater infrastructure systems, a paradigm shift has occurred in the Federal Republic of Germany over the last 17 years. The starting point was the realization that essential technical and commercial data used as a basis for asset management are insufficient. These quality deficits primarily concern defect and condition classes in the area of technical data and book and residual book values in the area of commercial data.

The problem with the defect classes of sewers and pipes is that they are recorded over a long period of time with the help of CCTV inspections. Fifteen or more years can pass before a drain and sewer system is fully inspected. The same applies to repeat inspections, although in Germany the time limit for such inspections is 10 years. With such long periods of time, the normative assessment and classification systems of defects can change, so that, as a rule, there are no homogeneous and thus comparable assessments in the database. Regardless of this, only a small amount of defect and condition data represents the current situation (see Figure 5). In addition, the condition class is defined by the most severe single defect detected in a sewer section. This may be sufficient to derive a rehabilitation priority, but not to derive a rehabilitation decision regarding the need for repair, renovation or replacement of the sewer section [STEIN04a], [STEIN04b], [STEIN05a]. It is also critical that an "imprecise", unprofessional or non-compliant defect assessment by the inspector can lead to one or more class changes in the condition class. The condition class is therefore not a very resilient criterion.

Book or residual book values are also of limited use as management information for optimizing investment decisions. The depreciation period on which the book values are based is often an estimated, political value. Ideally, the depreciation period represents the actual mean value of the technical useful life of asset elements within the network. This means that even in the ideal case, many network objects are not usable for such a long time that depreciation losses will occur and, on the other hand, are usable for a longer time without being able to generate revenue in the form of fees [STEIN09a], [Stacho19]. Thus, key figures like the Remaining Useful Life (RUL) are just a subjective estimation and a realistic derivation of object specific (Remaining) Useful Life is therefore not possible.

To compensate for the deficits of condition class and residual book values described above, STEIN [STEIN14a], [STEIN13a], [STEIN16a] developed the object-specific key figures substance class and substance value as supplementary management information in 2003, which revolutionizes the quality and scope of data-based asset management by including aging models. The process as well as the results that are possible with this information in the context of an extended Urban Infrastructure Life Cycle Management process are explained using the example of the asset management system STATUS.

Fabric deterioration class as basis for the d the substance value

An extended evaluation concept has been integrated into STATUS, which divides the evaluation of a sewer system into a condition class and a fabric deterioration class, as explained in Figure 1.

The condition class of a sewer section (Table 1) as an indicator for the actual function fulfillment (priority) is determined analogously to the standard evaluation models also in STATUS by the most severe single defect within the considered sewer section. However, the difference is that the discrete condition classes are not used, since the defect assessment is already carried out in a stepless manner, taking structural boundary conditions into account. This allows a realistic evaluation of the individual defects without loss of information due to classification in a discrete defect and condition class. To further increase the quality of information and analysis, the defects are classified according to their impact on the environment (leak tightness), stability and operation. This differentiation avoids that e.g. defect assessment, like deposits, influence the stability evaluation of a sewer section. Management decisions from a structural, operational or environmental point of view can thus be derived cleanly and separately from each other.

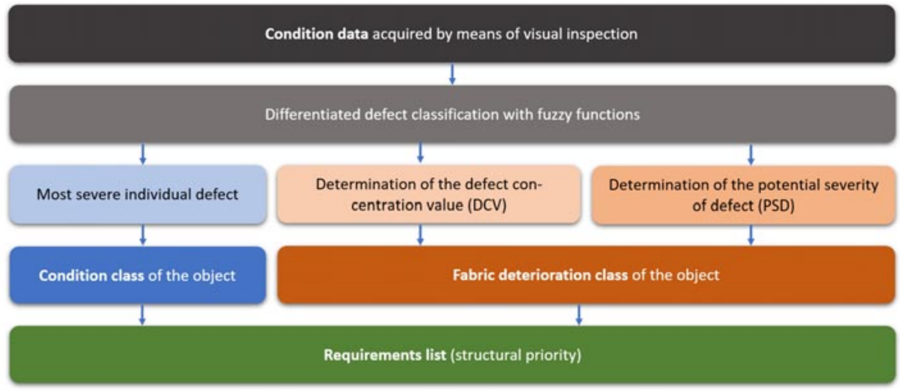


Figure 1: Workflow of "object assessment" based on the Fabric deterioration classification

The fabric deterioration (Table 2) represents the overall condition of a sewer section, considering all defects in the section, and thus characterizes the remaining wear reserve until the occurrence of the mandatory replacement. A rehabilitation action with a correspondingly high wear reserve - even before it is completely consumed - enables the use of more cost-effective rehabilitation solutions (renovation or repair). Thus, with the exact knowledge of the fabric deterioration of a sewer section, foresighted and cost-optimized planning on a secured data basis is possible. The fabric deterioration assessment takes into account all the defects listed and assessed in the sewer section with their respective individual defect class as well as their spatial distribution or concentration and their individual defect length. The consid-

(Individual) Defect class		**Section related Condition class** (Rehabilitation priority)	
Differentiated into protection goals: environment / tightness, operational safety, structural stability	DC 5 No defect	Differentiated into protection goals: environment / tightness, operational safety, structural stability	CC 5 No defect
	DC 4 Minor defect		CC 4 Subordinate action
	DC 3 Slight defect		CC 3 Long-term action
	DC 2 Medium defect		CC 2 Medium-term action
	DC 1 Severe deficiency		CC 1 Short-term action
	DC 0 Very severe defect		CC 0 Immediate action

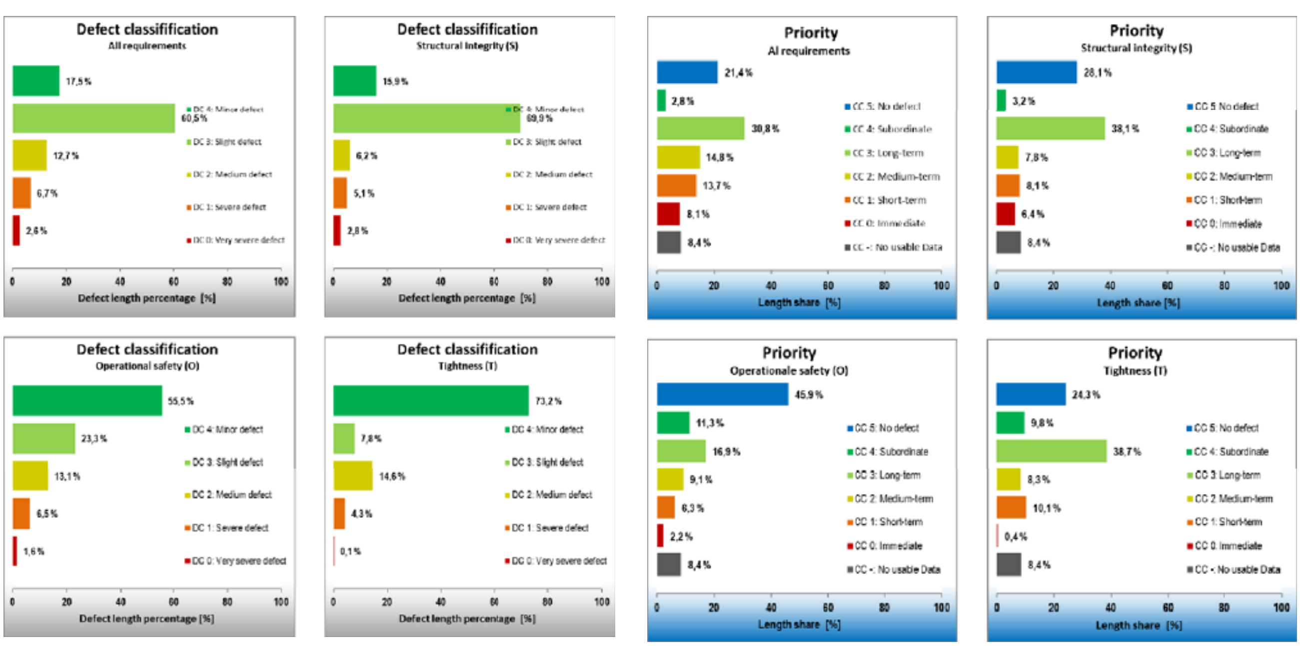


Table 1: Defect and condition classes and graphical representation by protection goals in % and [km]

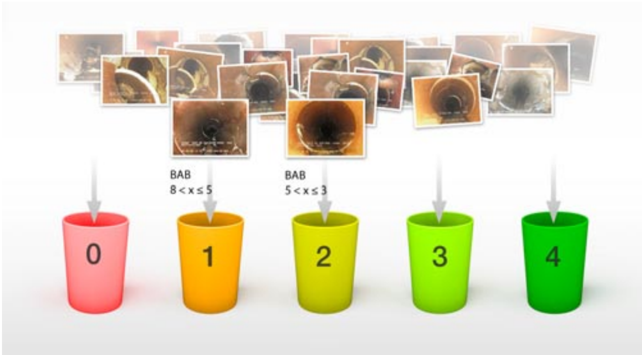


Figure 2: Principle of condition classification with rigid class boundaries [STEIN-ISM]

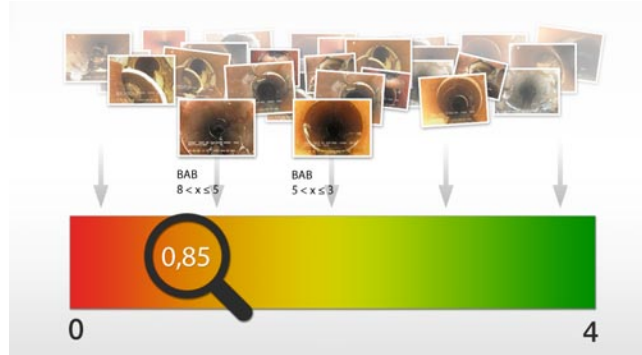


Figure 3: Principle of condition classification with no class boundaries (continuous assessment) [STEIN-ISM]

eration of all defects significantly increases the resilience of the fabric deterioration class as an important management criterion. For the analysis according to protection goals, only those defects are considered that have also been assigned a defect class in the corresponding protection goal.

Figure 4 shows the difference between condition class and fabric deterioration class.

Figure 5 shows an example of the relationship between condition class and fabric deterioration class. It is clearly visible that the critical fabric deterioration class (Wear reserve used up) at the time of inspection is much lower at 1% than the condition class at 12.2%. This shows that even sewer sections with severe individual defects can still have good fabric deterioration class. However, the figure also shows that condition data collected over longer periods of time do not allow a realistic assessment of the current structural situation. The actual rehabilitation

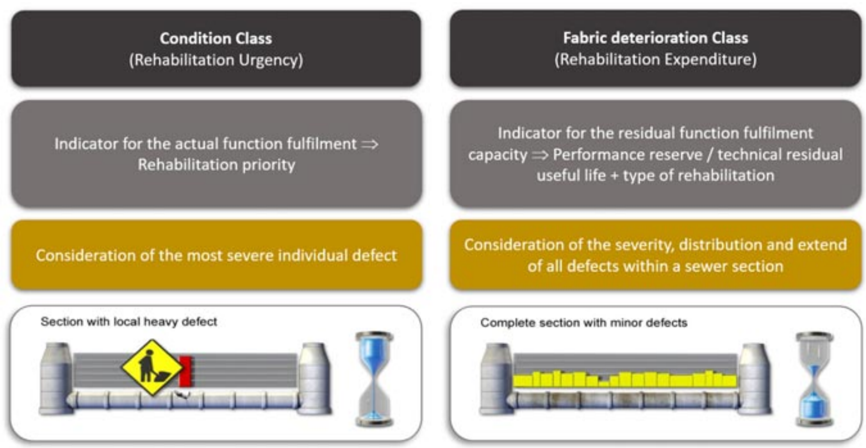


Figure 4: Comparison of condition and fabric deterioration assessment (sewer section) [STEIN14a]

Fabric deterioration class

Differentiated into protection goals: environment / tightness, operational safe ty, structural stability

Classification

FDC 5 Full wear reserve

FDC 4 Very high wear reserve

FDC 3 High wear reserve

FDC 2 Medium wear reserve

FDC 1 Low wear reserve

FDC 0 Wear reserve used up

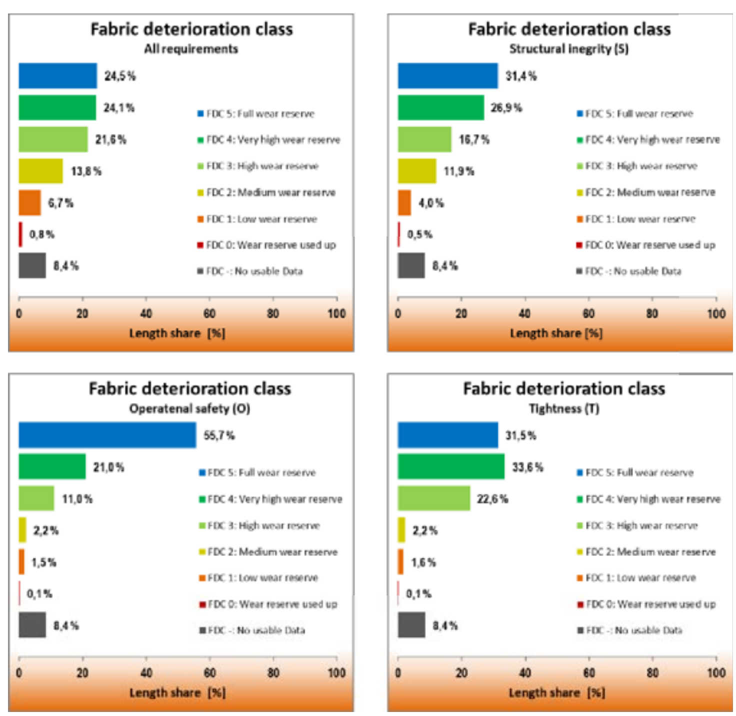


Table 2: Fabric deterioration classes and graphical representation by protection goals in % and [km]

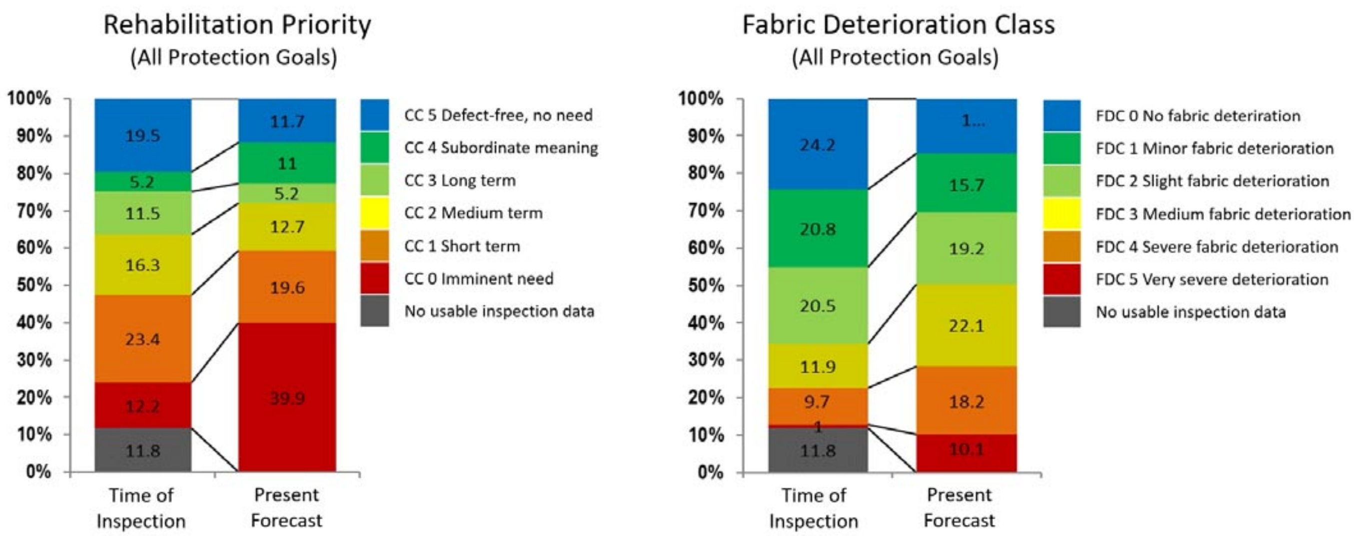


Figure 5: Database gap between historic records and the current state and comparison of condition classes (left) and fabric deterioration classes (right) at the time of inspection (left) with the current situation (present forecast) (right)

task can only be identified by a present-day forecast of the development of condition classes and fabric deterioration classes.

Remaining useful lives and net asset values

With the help of the fabric deterioration class and the replacement costs, the net asset value can also be calculated. This value represents the physical value of a sewer network or an individual sewer object, considering all existing defects. The net asset value is expressed in current prices. At the time of proper construction, the net asset value of a structure and the replacement value are identical. At the time of decommissioning of the structure for technical reasons, the net asset value is exhausted and is 0.

With the help of the STATUS aging model, the deterioration of the condition and the consumption of the wear reserve (fabric deterioration) can now be predicted. The results of this process include object-specific (residual) useful lives. This makes it possible to visualize potential depreciation losses, considering the respective depreciation periods (Figure 6).

Strategy development and optimization

Strategic planning should include optimizing the strategy selected. This includes determining the metrics for evaluating the maintenance or rehabilitation program, such as the budget, rehabilitation project duration or completing the project by a specific date. For this purpose, the process analysis of the current management approaches and their optimization is required to capture the conditions, criteria and limits of intervention decisions. It must be ensured that all background and boundary conditions influencing the client's decision on the main type of rehabilitation (repair/ renovation/ replacement) and the timing of the rehabilitation are transferred without contradiction into a transparent decision model. This means that all rehabilitation decisions made within the framework of the strategies can be traced at any time and justified on the basis of the decision model (Figure 7).

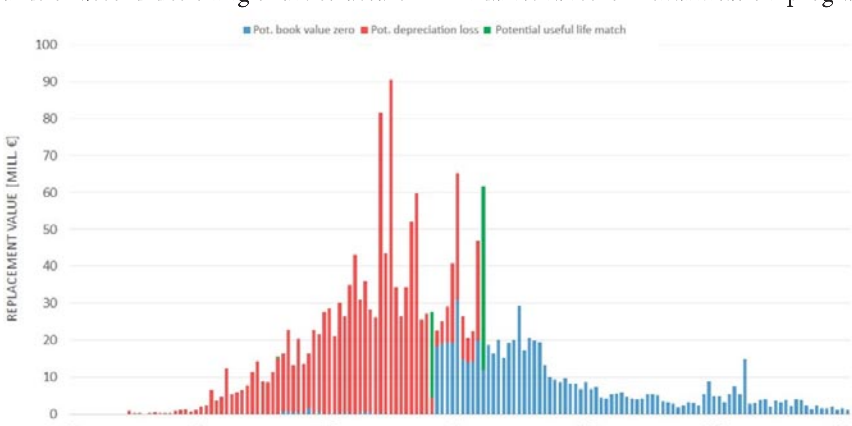


Figure 6: Significance of fabric deterioration development for the useful life related to the replacement cost (based on undisturbed ageing of the network) – the green color symbolizes sewer sections, which fit into the depreciation period of the client (70 and 80 years), red color symbolizes sewer sections, which will probably not reach the end of the planed depreciation and the blue color represents sewer sections which not contribute to the book value (book value = 0)

Deriving the most appropriate strategy is an iterative optimization process. As a rule, network operators formulate at least 3 objectives, all of which are to be achieved:

1. Reduce risks in the network by reducing the most critical defects.
2. Preservation of asset value and minimization of depreciation losses
3. Stabilization of fee income and transparent communication with administrative bodies and citizens.

The optimal path of action to achieve these objectives must consider a wide range of structural, hydraulic, operational, and environmental issues of similar priority, while respecting social, legal, economic, and environmental constraints. The result of this iterative process is the

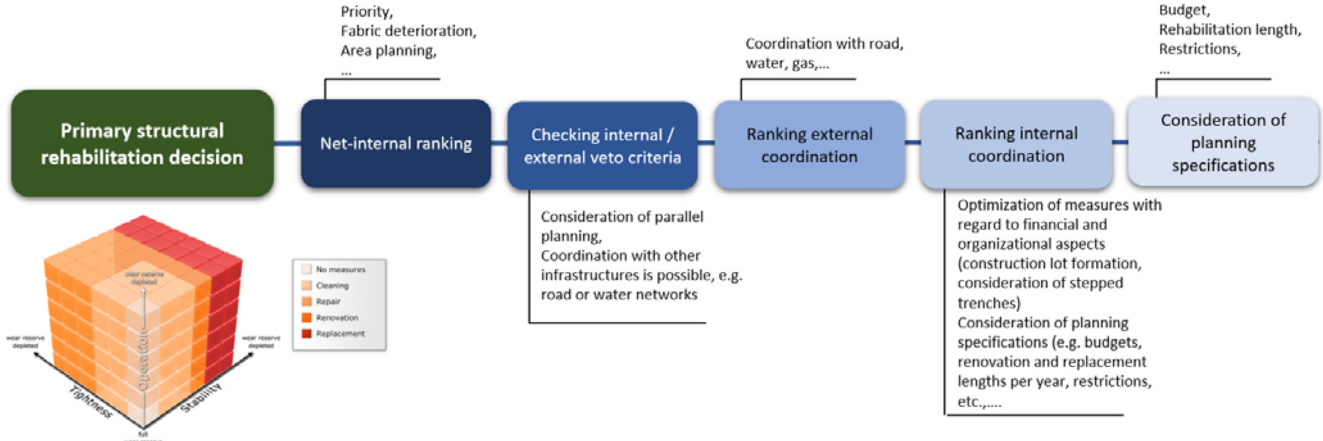


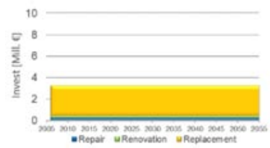
Figure 7: Example of influencing criteria on the client's decision-making process [STEIN-ISM]

"optimized strategy."

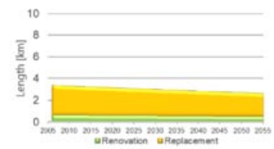
To be able to evaluate individual strategies in terms of their effectiveness and efficiency as part of the strategic optimization process, a benchmark is required. This benchmark is provided by the "carry on" strategy. This strategy variant implies that the previous rehabilitation practice of the network operator is continued for the future. Thus, it is investigated how the drain and sewer system will develop with unchanged actions and current budgets. The "carry on" strategy is the most important reference strategy, as it can be used to analyze the previous approach and examine its future stability and sustainability, and to examine the effectiveness of alternative strategies.

The following tables show the effects of the "carry on" and "optimized" strategies in terms of investments, rehabilitation length, rehabilitation backlog, condition and fabric deterioration development.

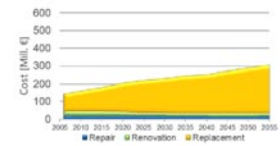
Table 4 compares the cumulative financial / asset values over a period of 30 years for the "carry on" and the "optimized" strategy. In addition, the "natural", undisturbed network aging in the form of the "zero investment" strategy is listed as a further reference system. As expected, undisturbed network aging, which does not involve any investment in the network, leads to the highest level of asset depletion, amounting to € 135 million. It is interesting to note that a continuation of the original rehabilitation practice (carry on) also leads to a loss of net asset value in the amount of € 13 million. To assess the efficiency of the optimized strategy, rehabilitation costs should be taken into account. If these are



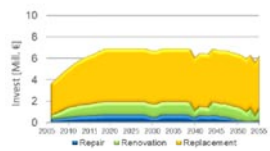
"Carry on" strategy: investments in the network per year for repair, renovation and replacement - budget is always utilized, indication of insufficient budget



"Carry on" strategy: Lengths of rehabilitation per year for renovation and replacements

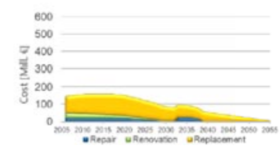


"Carry on" strategy: Rehabilitation backlog - cumulative measures per year that have not been realized based on planned costs - risks in the network increase, resilience decreases



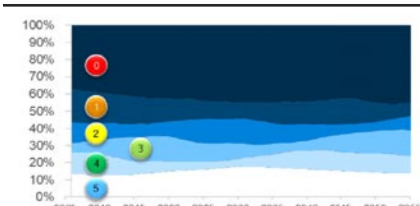
"Optimized" strategy: investment in the network per year for repair, renovation and replacement - budget increase in the first 7 years 1% and another 7 years 0.5%.

"Optimized" strategy: rehabilitation lengths per year for renovation and replacement - increase of renovation budget significantly increases annual renovation length



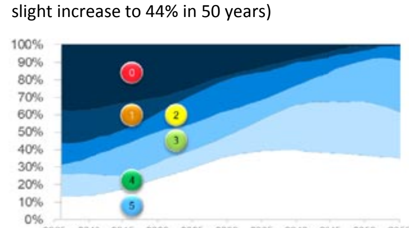
"Optimized" strategy: rehabilitation backlog - cumulative measures per year not realized based on planned costs- risks in the network decrease, resilience increases, probability of successful strategy implementation is high

Table 3: Comparison of investments, rehabilitation length and rehabilitation backlog

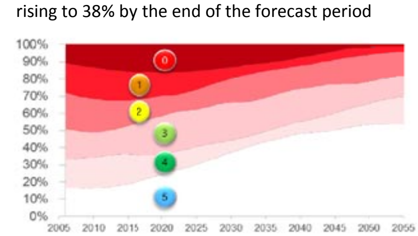


"Carry on" strategy: High percentage of critical defects (required Immediate action CC 0 = 37%) and slight increase to 44% in 50 years)

"Carry on" strategy: At the start time, 11% of the sewer sections with "wear reserve used up" (FDC0), rising to 38% by the end of the forecast period



"Optimized" strategy: "Reduction of risks in the network" objective is achieved in the long term



"Optimized" strategy: "Preservation of net asset value" target achieved in the medium term

Table 4: Comparison of condition and fabric deterioration development

deducted, the results are negative for all 3 strategy scenarios, but the differences are enormous. If "carry on" would lead to a negative balance of € -110.05, this is only € -45 million for the optimized strategy. The delta of 65 million thus corresponds to an adjusted value retention of € 2.3 million / year. If the income from fees is included in the form of a "net asset value balance", it becomes clear that an increase in the rehabilitation costs by 92% can lead to an increase in the net asset value balance by 360%.

		Zero-Investment	Carry-on	Optimized
1	Net Asset Value Start	255	259	259
2	Net Asset Value End	119	246	400,42
3	**Delta (2-1)**	**-136**	**-13**	**141,42**
4	Rehabilitation Costs	0	97,5	186,76
5	**Delta (3-4)**	**-136**	**-110,5**	**-45,34**
6	Income & losses from fees (total)	40,98	167,03	305,99
	Net asset value balance (total)			
7	**Delta (6-5)**	**-95,02**	**56,53**	**260,65**

Table 5: Financial comparison for a forecast period of 30 years in millions of euros for a drainage system with a length of 480 km

Summary

Network operators are trying to achieve three main objectives with their asset management approaches:

- Reduce risks in the network by reducing the most critical defects
- Preservation of asset value and minimization of depreciation losses
- Stabilization of fee income and transparent communication with administrative bodies and citizens.

These goals can only be achieved with modern asset management systems that can calculate and forecast a realistic, engineering-based assessment of the structural / fabric deterioration of an object and its asset value as well as its development over time. With this information base, network-specific, well-founded and reproducible effectiveness analyses of strategy in relation to the above-mentioned objectives are possible. This makes the long-term consequences of current strategy decisions transparent and allows strategies to be adapted to the respective targets. With the help of "STATUS", this forward-looking strategic planning is possible in a consistent and reproducible manner. The exact and resilient integrated forecast model allows a well-founded prediction of the network development, both for an "intervention-free" network aging and due to a selected strategy, by means of a realistic, mathematically exact modeling of the aging processes of sewer sections and manholes.

With this decision support, a consistent assessment of risks as well as risk development and its impact on service levels and performance targets is possible. Investments can be safely planned and effectively allocated over longer periods of time, ultimately enabling sustainable asset development and transformation while optimizing budget allocation.

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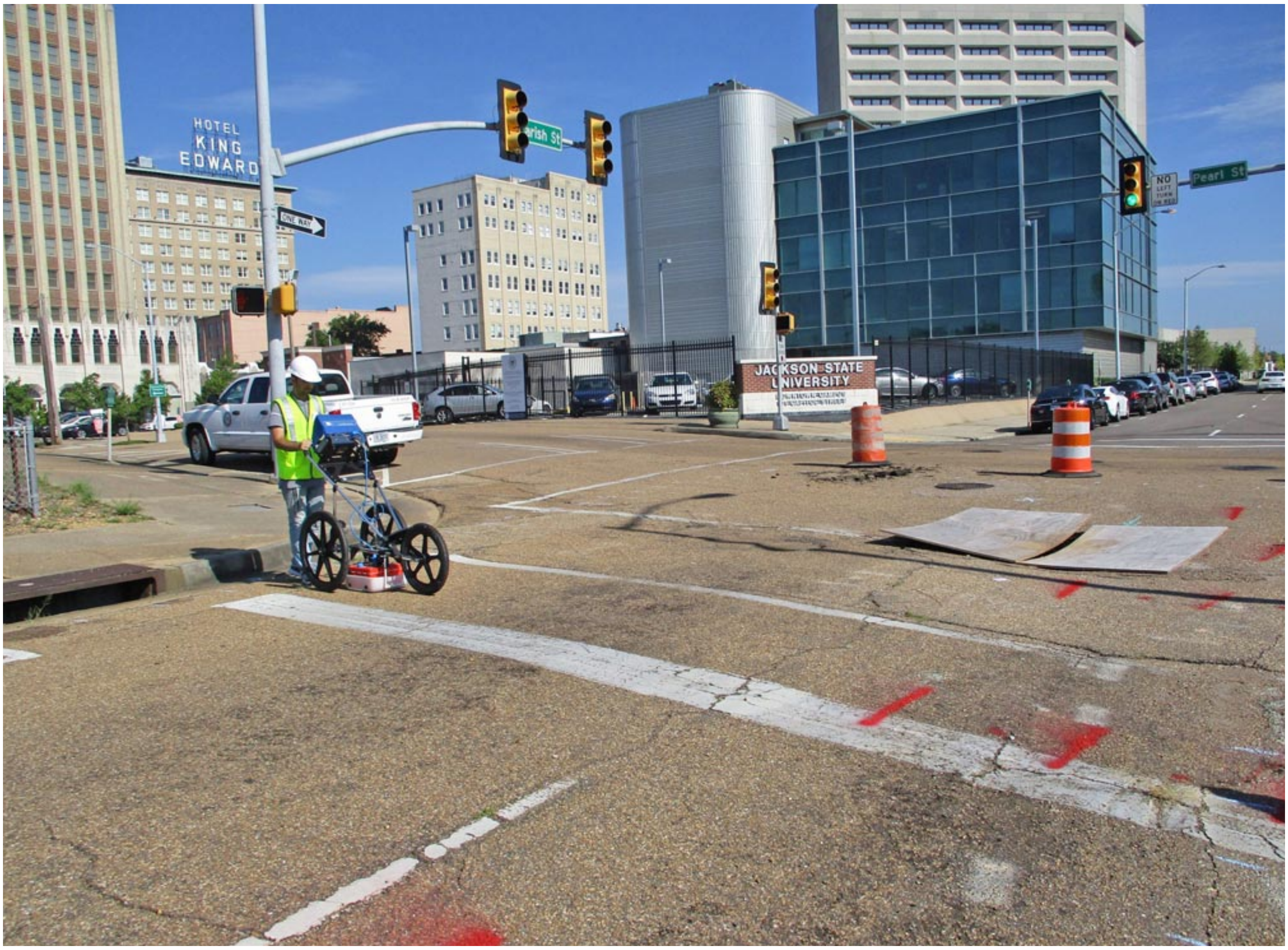
Dr.-Ing. **Robert Stein** is the Managing Associate of Stein & Partner GmbH and Managing Director of S & P Consult GmbH. His business activities include project management, realization of major projects, coordination of interdisciplinary project teams, management of international advanced training and educational activities in the field of underground infrastructure systems. His main research activities focus on network asset management, especially research and development of remaining life assessment tools for decision support on maintenance and rehabilitation of water and wastewater infrastructures, the further development and improvement of microtunneling and pipe jacking capacities, and on new training concepts and methods.



GPR for Utility Locating Offers Safety, Efficiency, and Revenue Benefits

By: Peter Masters, GSSI

Residential and commercial inspectors, plumbing and utility contractors, and electricians are finding the use of ground penetrating radar (GPR) provides a host of safety, efficiency, and revenue benefits. Rather than relying solely on the national 811 call-before-you-dig phone number to avoid unintentional digging into an underground utility line, general contractors, subcontractors, and inspectors are adding GPR units to their locating toolbox and integrating them with other locating tools to enhance accuracy on the job site.

GPR Technology addresses wider needs

In the past 20 years, GPR utility locating equipment has been more readily adopted by surveyors and engineers. Already accustomed to deploying electronic equipment during the construction process, surveyors and engineers successfully used GPR to augment the 811 process.

In more recent years, engineers and project managers for subsurface utility engineering (SUE) contracts began routinely specifying that contractors do more to prevent unknown problems from buried underground utilities. GPR service providers established a niche serving electricians, plumbers, and contractors tasked with establishing utility locations.

Now, with powerful, high quality and lower cost utility locating GPR equipment available, inspectors, electricians, and plumbing and utility contractors are asking why they are paying to use GPR equipment when they can purchase a unit and do it themselves.

Utility locating tools – 811 system, EM and GPR

Before contractors begin their projects, they utilize the 811 system to get the approximate location of all public utilities by marking them with spray paint or flags. Making that call technically satisfies a contractor's legal responsibility.

Nonetheless, many believe that the 811 system is simply not adequate – the safety implications of hitting a gas line and the expense of idling their workforce has driven them to be more proactive in identifying underground utility lines.

Most utility locators use an electromagnetic (EM) line locator to check for active utilities. Electric lines are harder to trace with GPR than EM, making EM much quicker and easier to use than GPR. While EM is faster, its positioning is not as accurate as that of GPR, which can provide horizontal and vertical position within a couple of inches. These two methods complement each other, since GPR works better for non-metallic objects and EM for metallic objects. If both tools indicate the presence of a pipe, it provides a higher level of confidence.

GPR technology for utility location and depth that won't break your bank

The trend in the GPR utility world has gravitated towards the use of small, portable, and inexpensive units. Leading this standard is GSSI's UtilityScan® system, released in 2017. UtilityScan was originally designed for municipalities, electrical contractors, and utility installers, but has since been adopted for use in environmental and archaeology applications due to its size and cost.

UtilityScan features

UtilityScan's small size makes it very simple to deploy. Weighing in at only 37 pounds, the UtilityScan is built for quick assembly, scanning, and break down. When folded down, the system can fit in the back of a small vehicle or even in the overhead compartment aboard a commercial jetliner. The compact size makes it extremely portable and easy to maneuver around obstacles on busy streets and construction sites.

One key feature of UtilityScan is the robust wireless antenna tested for rugged job sites. UtilityScan incorporates GSSI's patented HyperStacking technology, which has proven to increase depth penetration in challenging soils while also providing high near surface data resolution. UtilityScan is rugged, built to withstand any job site around the world. This system is IP65 rated, making it the right tool to handle rain, snow, and muddy conditions.

Another feature of UtilityScan is that it can be equipped with LineTrac®, which helps locate specific power sources situated underground, including AC power and induced RF energy present in conduits. LineTrac has coils that detect power radiated from electrical cables, combined with GPR radar into a single box. This feature lets users produce an overlay on the radar data that represents the presence of AC power and/or induced RF energy present in conduits. UtilityScan then integrates the EM and GPR readings and produces the image on the screen.

UtilityScan integrates with GPS systems, allowing users to trace their steps and gain a bird's-eye view of their survey. Users can also simultaneously place American Public Water Association (APWA) color-coded marks on 2D data and a geo-referenced map. The on-screen 3D data collection mode allows users to easily define the time slice depth and thickness in the field with the 3D data on the screen. The map window can be minimized to view the 3D display full screen.

UtilityScan uses a wireless tablet-based system with a bigger screen, better viewing experience, and a Windows-based user interface (UI). Perhaps the biggest shift into mainstream adoption has been the ease of use. Using a modern, user-friendly interface means operators need less technical experience to collect and interpret data, leading the way to faster onboarding than previously available.

GPR can provide contractors with more confidence than simply relying on the 811 system. GPR for utility locating is more accessible than ever with small, portable, and inexpensive systems on the market.

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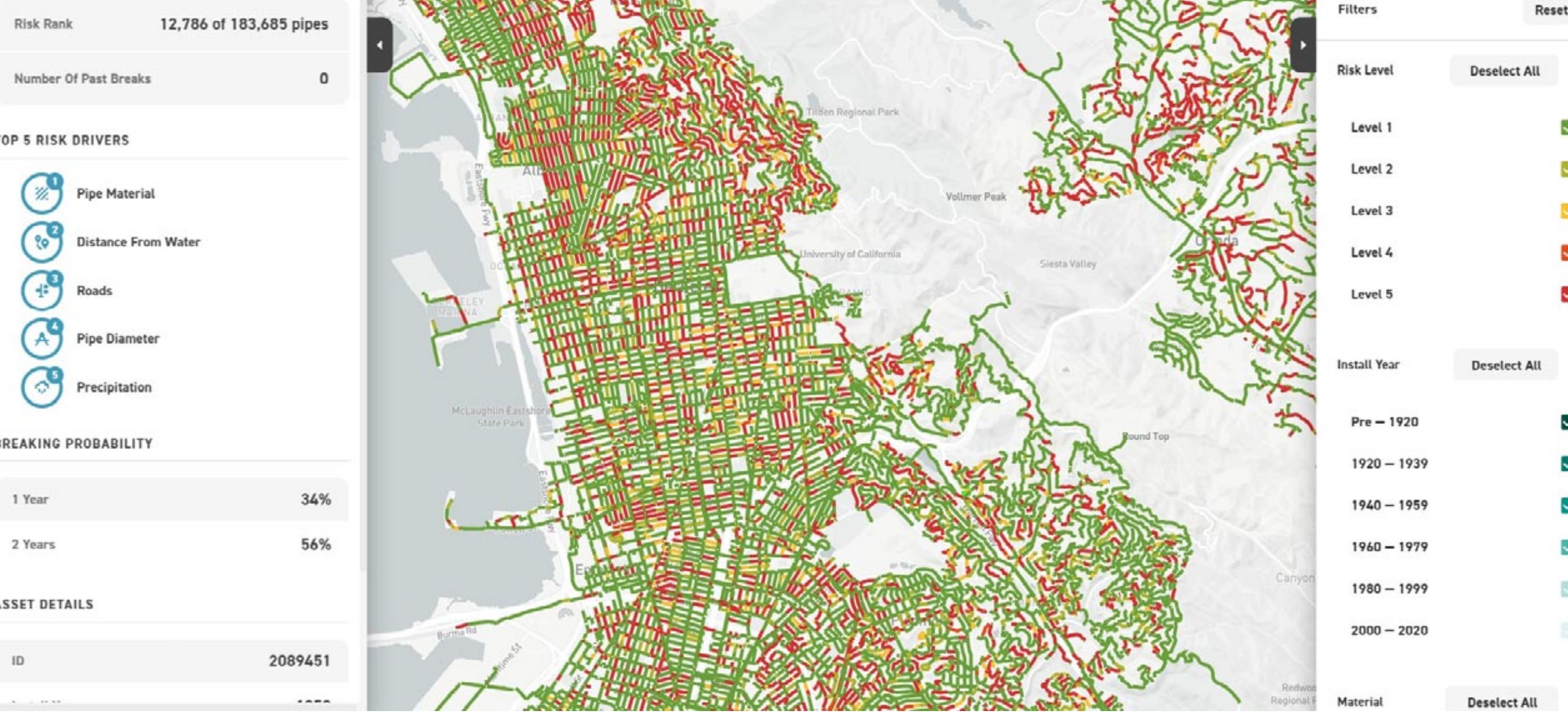
Peter Masters is the Regional Sales Manager for the eastern United States at GSSI. He has extensive experience in technical sales and marketing across a range of industries. Since joining GSSI, Peter has focused on business development and sales of GSSI's utility detection and structural inspection product lines. Peter and his family live in Marblehead, Massachusetts.



The Application of Digital Solutions in Underground Water Pipe Infrastructure Asset Management

By: Greg Baird, President,
Water Finance Research Foundation

Water asset management programs

The first basic steps of an infrastructure asset management program are to know what assets you own, where they are located and in what condition they are in. Determining the condition of an underground water pipe to estimate the **remaining useful life** (RUL) has been a challenge for all water utilities. Understanding how much to spend and on which technologies to use to conduct condition assessments in order to make risk mitigation and funding decisions has overwhelmed many water asset managers trying to develop a water asset management plan.

One definition or major goal of asset management is to achieve the **longest useful life** of each asset at the **lowest cost** while delivering the expected **level of service**. If we unpack this generalized statement, "longest useful life" would entail pipe material selection, proper design and installation and inspections optimized for the installed environment with periodic pipe condition assessments and analysis to direct operations. Condition based evidence is necessary to make changes to maintenance strategies, timely repairs, the application of trenchless technologies and rehabilitation methodologies as well as open cut replacement.

Lessons learned include a simple aged based (straight-line depreciation) planned intervention will always be wrong considering all of the ongoing and changing variables that can influence the performance and useful life of a pipe. Even the best decay curves with historical data change over time. In asking the question, "*How long will my pipe last?*", one must first ask about the design, construction, installation, and inspection of the pipeline.

Water utility pipe installation implications

If a water utility did not install large diameter pipes correctly, on average, a utility is losing 20 percent to 50 percent of the pipe's service life. If a utility did not consis-

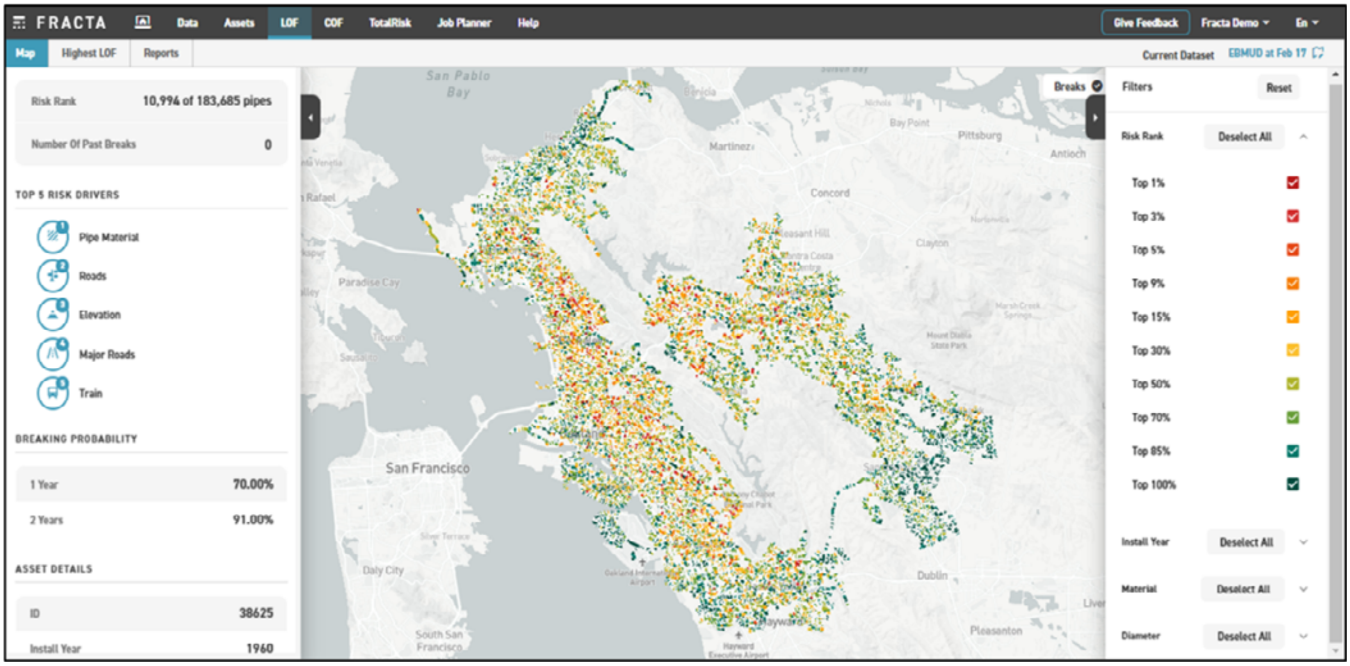


Image 1: AI/Machine Learning Dashboard for Water Main Break Predictions (Fracta, Inc)

tently inspect the pipe during installation, then the utility may be foregoing 10 percent to 30 percent of the potential service life for that pipe segment. When it comes to long term underground infrastructure which can last 50-300 years doing things correctly has huge dividends or on the other hand - high costs and risks from decision making errors. Essentially, with all of the variables influencing pipe service life – condition assessments are needed to identify high risk pipes and also avoid replacing the 40 percent - 70 percent of good pipes condemned by age-based planning assumptions.

Estimating the remaining useful life has been a challenge for all water utilities.

Pipe material inventories

Pipe material selection needs to be appropriate for its location, dealing with many variables such as environmental issues and operating conditions. Specifications should be open to allow for the engineering review and analysis of cost and longevity given the built environment. 91 percent of all the installed water mains in the US utilized a combination of cast iron at 28 percent, ductile iron at 28 percent, PVC pipe at 22 percent, and asbestos cement at 13 percent. Now, only two materials ductile iron and PVC remain as the competing options off the list of historical infrastructure for new installations and replacement. Each pipe material has different pipe characteristics meaning that the

installed environment and operational/environmental factors act differently on each pipe material and can be different for each pipe segment.

A lesson learned from recent studies point out that 75 percent of all utilities have some corrosive soils. Utilities with a higher percentage of iron pipe may experience a higher percentage of corrosion-related breaks. Analysis of soil corrosivity shows that, traditionally, the thickness of the iron pipe wall provided the additional corrosion protection. Cast iron pipes manufactured after World War II have significantly higher failure rates as a result. Cast iron pipe in highly corrosive soil is expected to have over 20 times the break rate of cast iron pipe in low corrosive soils. Corrosion is an important failure mode for cast iron and is the predominant failure mode for ductile iron pipe. Cast iron and ductile iron pipe corrode at about the same rate. Modern ductile iron pipe is about 76 percent thinner than cast iron and in highly corrosive soils has over 10 times the break rate, than a ductile iron pipe in low corrosive soil. The many types of corrosion can also be combined with other environmental conditions, all contributing to water main failures because of the wall thickness of metallic pipes has decreased overtime. Condition assessment technologies, both internally and externally, have been focused on cast iron and ductile iron pipes due to corrosion, and larger diameter PCCP transmission pipes due to the high **consequence of failure** (**CoF**). PVC, with non-corrosive and longevity characteristics, has been left out of the heavy investments in pipe direct condition assessment technologies as a result.

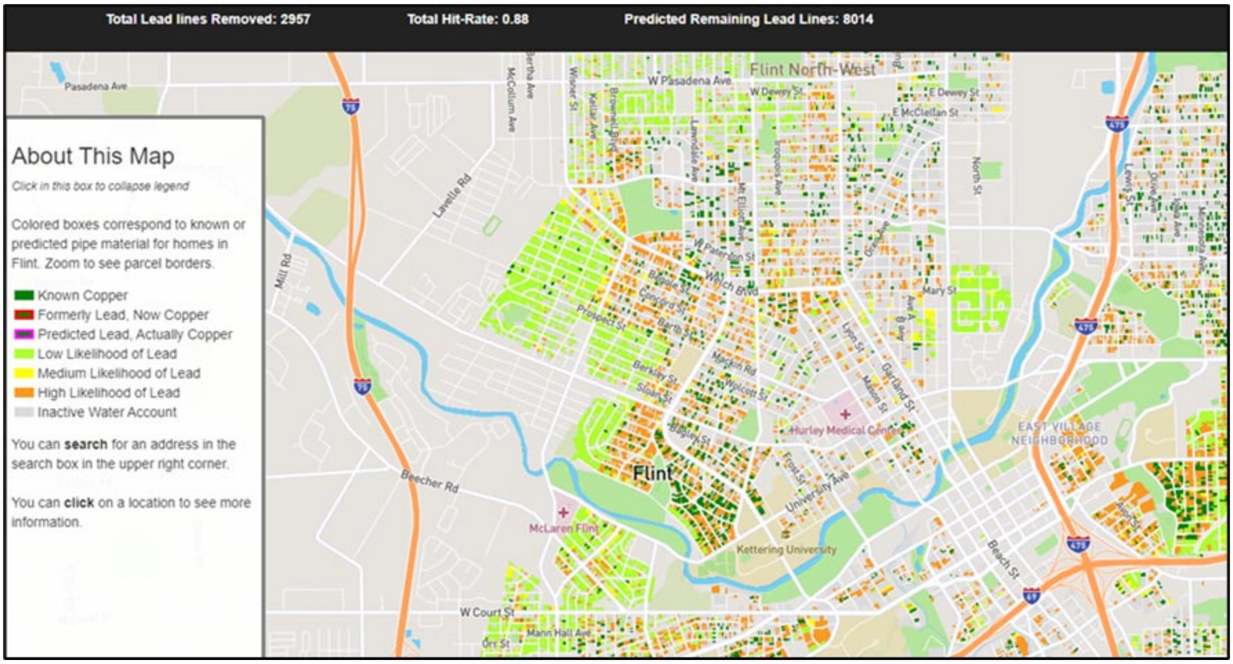


Image 2: Service Line Inventory Map Flint Michigan (BlueConduit)

Pipe diameter matters

In the total inventory of water pipes, 85 percent of water mains are less than 12 inches in diameter. 67 percent of all water mains are 8 inches or less in diameter. 18 percent of water mains are 10 to 12 inches and 9 percent are 14 to 24 inches in diameter. A national metric of the replacement rate of water mains is 0.8 percent which equates to a pipe replacement cycle of 125 years with the average pipe break occurring at 50 years. Typical water pipe planning for replacements ranges between 1.0 percent and 1.6 percent equivalent to a 100 year and 60-year replacement cycle. A water distribution system as defined by most water utilities considers pipe sizes less than 16 or 24 inches in diameter and anything larger as a transmission pipeline.

Pipe diameter matters! As an example, overall ductile iron pipe has a break rate of 5.5 breaks per 100 miles of pipe for all sizes, but studies also show a 15.1 break rate for ductile pipe pipes less than 12 inches in diameter. As a general rule of thumb, larger diameter pipes are more expensive, have less breaks therefore a lower **likelihood of failure (LoF)**, but if a break does occur the consequence of failure is more severe. As an example, a 16-inch diameter pipe break could cost $100,000, a 36-inch diameter pipe $800,000 and an 84-inch diameter pipe over $1.5M just in direct costs, not including water loss and other indirect and societal costs which can average between 50 percent and 66 percent of a utility's direct costs with the repair. For these larger diameter transmission lines for raw water or treated water the cost is too high and the loss of water delivery to a community too disruptive to allow for failures. As a

result, condition assessments for these perpetual lifelines should occur every 10 years and even more frequently if there are known issues. There is also a business case for continuous monitoring for understanding any change in the condition of these pipes or building redundancy into the system to prevent or mitigate catastrophic failures costing millions of dollars.

New water digital solutions for pipe asset management

Digital solutions for pipe condition assessments can be applied to the entire pipe network very economically where a direct condition assessment is only cost-effective for pipe segment evaluations.

One example of a digital solution is how **Machine Learning (ML)** gives com-

The replacement rate of water mains is 0.8 percent which equates to a pipe replacement cycle of 125 years with the average pipe break occurring at 50 years.

puters the ability to learn without being "programmed". Machine Learning uses automated and iterative algorithms, to learn about patterns in big data, detecting anomalies, and identifying a structure that may be new and previously unknown. ML is not statistics and is not rules based. Rules are based on what a human knows about the data. When ML is combined with statistical analysis, it identifies relationships that may other-

The exterior of the Flint Water Plant in Michigan. Concerns over Flint's water quality and lead content have made national headlines. (Image: iStock)

wise have gone undetected. ML can surpass human capability and software engineering capability to make use of very large data sets.

A **Digital Desktop Condition Assessment** using ML produces an accurate model using machine learning to predict water main Likelihood of Failure (LoF) scores, direct utility leak detection efforts, better focuses preventative maintenance crews, validates capital replacement plans and aligns master planning efforts. With 90 percent of water assets being location based and most water main pipe data in GIS files, the intersection of GIS and ML was inevitable for both analysis and visualization.

Machine Learning algorithms need a large amount of historical and geospatial data. Incorporating a Machine Learning condition assessment tool into a proper infrastructure and asset management program will contribute to the reduction of the economic impacts incurred from water main breaks, and more efficient allocation of capital by water utilities. The more data a model contains, the more robust the model. As utilities are, over time, constantly collecting data such as new breaks and installed pipes, that data can continually be fed into a machine learning model.

New pipe data strengthens the predictive power of a machine learning algorithm. Machine learning can also benefit utilities with limited asset or breakage data by "filling in the gaps." Machine learning can utilize hundreds of streams of data (climate, environmental, soil, corrosion, elevation, etc) in order to perform certain predictions and begins to learn patterns that can inform situations where many of the usual data points may not be available creating a new digital revolution in advanced asset management practices. AI/ML models empower utilities to move from reactive to preventative and predictive water asset management. This technology provides a 20-30 percent improvement over traditional methods helping utilities make fast, accurate and cost-efficient decisions associated with direct condition assessment locations, water main repair, rehabilitation, and replacement.

Pipe material selection needs to be appropriate for its location

Predictive ML models using historical water pipe breaks, combined with hundreds of operational and environmental location specific data, performs well for cast iron and ductile iron pipes less than 24 inches in diameter. This is because of the amount of historical break data needed and the pipe material's given corrosion properties. ML models have not been as productive providing predictive main breaks estimates with PVC pipes, due to the pipe's attributes of being non-metallic and having low main breaks.

Another recent application of statistical models and Machine Learning which has been very accurate, reliable and cost-effective in determining the location of lead(Pb), galvanized, copper and PVC service lines. This data science solution is to address part of the EPA's Lead and Copper Rule improvement compliance which requires water utilities to develop an accurate inventory of service lines

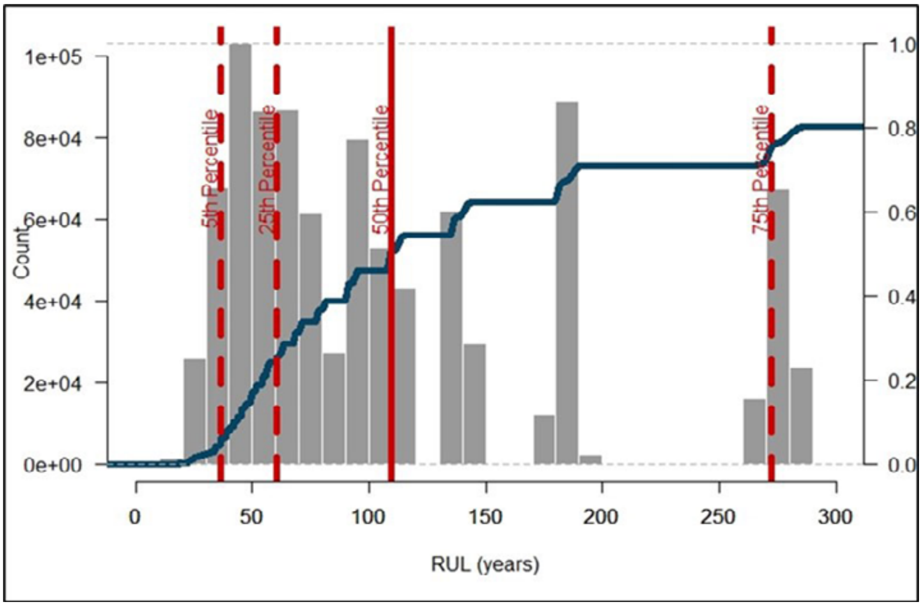


Image #3: Transient Pressure Sensor Analysis for PVC RUL (Xylem)

> Asset Management requires continual business process improvement and the use of new technologies and methodologies to strive for an overall lower life cycle cost for each asset

both on the utility ownership side and the private ownership property side. This water quality/asset digital solution was originally developed for Flint Michigan to increase the speed and to reduce the cost of removing the risk of lead(Pb) poisoning for customers by "digging where the lead(Pb) is" and avoiding unnecessary excavations saving the city and state millions of dollars.

The IoT of water: sensors

Where Machine Learning and direct condition assessment technologies are considered less productive, the use of **Sensors** is a growing trend as the unit costs have dropped and the battery life has increased. Sensors of all types are being used for water quality and asset management applications measuring flow, temperature, pressure, etc in real time, providing monitoring and alarms with wireless connections in any kind of operational environment.

One example of where sensor technology for transient pressure monitoring and analysis has been tried is for pipe asset management in determining the remaining useful life (RUL) of PVC.

Properly designed water systems should not have large, repeated surges. In a 2012 extensive survey of utilities, it was determined that 83 percent of utilities can keep pressure fluctuations in their system to be less than 20 psi (0.21 MPa) and an average supply pressure of a water system is 77 psi (0.53 MPa). A more recent 2018 survey indicated an average water system pressure of 69 psi (0.48 MPa) representing the water industry's recognition that pressure management can be used to reduce both leaks and breaks.

PVC pipe has two distinct lives, one based on steady state conditions and the other based on cyclic (fatigue) conditions. Although, in practice few fatigue-based failures have been reported for PVC pipes, laboratory tests confirm that the fatigue mode of failure remains a possibility that might compromise the life cycle of PVC pipe systems. This issue is in trying to determine the very long time frame when cyclic could become an issue.

> Recent studies point out that 75 percent of all utilities have some corrosive soils

Design engineers must select an appropriate pipe wall thickness (or DR) that will accommodate both maximum pressure and repeated surge pressure events. Methods for assessing the number of cycles to failure have been developed for PVC pipe over the past 50 years. The current approach requires input of a mean stress and a stress amplitude and typically requires a root finding approach to calculate a number of cycles to failure as developed by Utah State University's Buried Structures Laboratory. Experience has shown that this method can be difficult and time-consuming for most design engineers to use.

Literature supports an expected life of 100 years for PVC pipe, regardless of diameter and pipe class based on an AWWA Research Foundation study which estimated that the designed life of a PVC pipe is in excess of 110 years. International "dig up" and inspection studies have also confirmed this expectation. The use of sensors in real world conditions monitoring active pipes in the built operations environment may provide additional insight into PVC's longevity and remaining useful life.

Fatigue analysis by using field monitoring data of pressure under actual operating condition tends to be more accurate, yet complex compared to the analysis only based on the design specifications. Sensor technology can capture all of the pressure surges which can be in form of cyclic surges in pipe. Cyclic surging is a regularly occurring pressure fluctuation produced by action of such equipment as undamped pressure control valves, oscillating demand, or other cyclic effects. Cyclic surges may cause fatigue damage and should be designed out of the system. The Utah State University's Buried Structures Laboratory determined that most cyclic pressure found in water distribution systems has no effect on PVC regardless of duration. The cyclic pressure life may be a critical parameter if the system is operating "out of control" and the "amplitude" and "frequency" of the cyclic pressures are extremely high and continuous.

This may have some application to the operating environments of force mains.

In this example dataset (focused on PVC water mains), captured over several months of monitoring at a specific location of concern between two hydrants, the cyclic pressure is used to calculate a range of remaining useful life RUL in years. The model assumes book end or limiting parameters of a safety factor of 2.0 and a catalog life of 100 years. Given these parameters, and the cyclic pressures recorded, the estimated **average remaining useful life RUL for the monitored PVC water pipe segment** is over 100 years for a 40-year-old PVC pipe segment, which makes the average expected life at over 140 years using the constraints of the model. On the lower side at a 25th percentile the RUL is approximately 60 remaining years, or an expected overall life of 100 years, and at the 75th percentile approximately 270 remaining years of life beyond the 40 years already in operation. Without the safety factor of 2.0, or an expected life of 100 years, the unconstrained model would have calculated the PVC water pipe to have a much higher estimated RUL or expected pipe performance life.

> Technology must and will help address the most pressing needs for aging water infrastructure

Asset Management requires continual business process improvement and the use of new technologies and methodologies to strive for an overall lower life cycle cost for each asset. While there is not a simple push button approach to all of the intelligence a utility requires to make better asset management and resources allocation decisions, AI/Machine Learning models, cloud platforms, IoT approaches, digital solutions and sensor technologies can provide a path of innovation for any size of utility. Technology must and will help address the most pressing needs for aging water infrastructure, funding, affordability, sustainability, water equity and workforce challenges.

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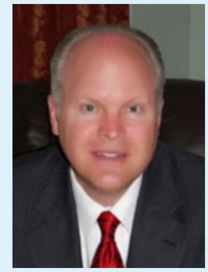

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UIT

Students at the 2022 UCT Conference.

Purdue Underground Infrastructure Team Organized Student Delegation to 2022 UCT Conference

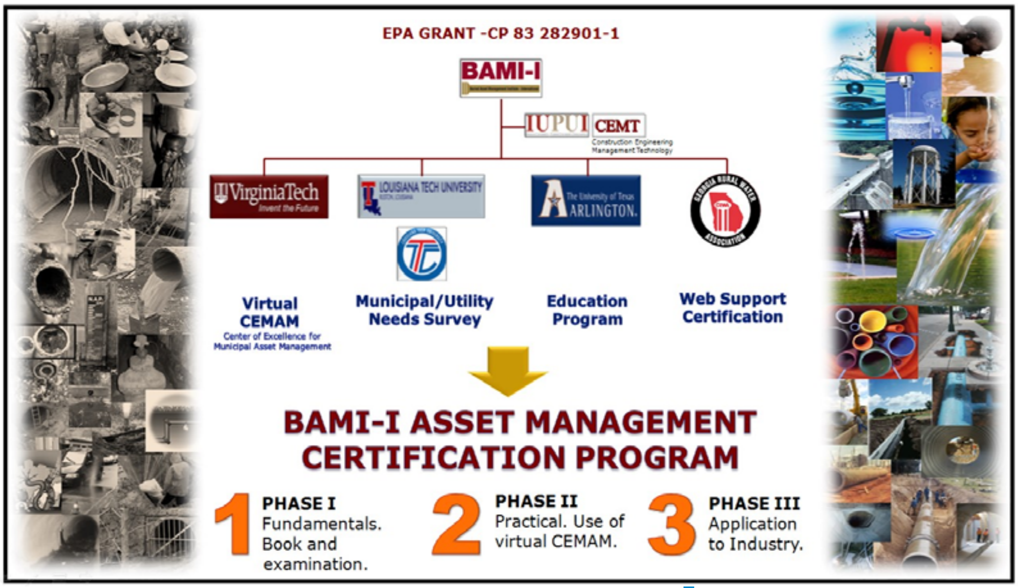
In the summer of 2020, Dr. Iseley joined Purdue University's Division of Construction Engineering and Management (CEM as a Beavers Heavy Construction Distinguished Fellow and Professor of Engineering Practice. He has since formed the Underground Infrastructure Team (UIT), which currently includes Wei Liao, Saleh Behbahani, Kibum Kim, KwangHyuk Im.

A key mission of UIT at CEM is to expand the impact of Purdue's underground engineering field in the industry and to attract more young generations to this area. Exposing students to as many events in the industry as possible is an important initiative to achieve this mission. The Underground Construction Technology (UCT) conference is a great place for the students to be involved and interact with experts from the heavy civil and underground construction industry. Dr. Iseley was an instructor for two courses at Purdue in the 2022 spring semester: the Development of Underground Space (DUS) and the Construction Business Management (CBM). He reached out to the students to see whether they are interested in attending the UCT conference on Jan 25-27, 2022 in Fort Worth, Texas. About 30 students expressed their willingness to attend the UCT. To ease the financial burden on students and build strong working relationships between industry and Purdue CEM., he decided to seek industry support for sponsorship. Gratefully, the following companies provided various levels of financial support: ACE Pipe Cleaning, Bowen Engineering, Boyer Inc., BrainDrip, Danby, National Water Main Cleaning, PVC Pipe Association, QuakeWrap, SAK, and Waterline Renewal Technologies. These companies made it possible to implement this activity.

We were fortunate to have a 25-member Purdue delegation (including 22 students) at UCT. In order to make their conference experience more focused and productive, each student was assigned tasks prior to departure, such as conducting issue-specific research interviews with exhibiting companies and attending presentation series of their own interest. After the conference, students were required to report on the results of their participation and present them in the classroom. Some questions were set: What kind of business organization do they have? what is their focus? what is their mission statement? and what do they do to motivate employees? etc. Also, Purdue CEM had a booth in the UCT exhibition hall. This helped to introduce the Purdue CEM program to people who visit the booth.

Most of the students were very conscientious in com-

Exposing students to as many events in the industry as possible is an important initiative



pleting their tasks. They gave great presentations in class. For most of the students, this was their first experience with an industry conference. It was encouraging to see the excitement and appreciation which they expressed. One of the students wrote: All in all, I got out of my comfort zone and talked to several companies and people within the construction industry. I obtained a lot of knowledge and information on the underground/utility sector of the construction industry. I really enjoyed the seminars that took place in the morning. I learned about HDD locators, current technology that geophysics are using, laws and codes that are used to identify and work with underground utilities, and safety within the underground construction scene. I also learned about polymer concrete and different materials that are being used to make pipes.

It was a rewarding trip for all parties involved. But we want to emphasize that this would not have happened without the support of industry companies. We would like to thank all of our sponsors for their generous support. We would also like to thank the Purdue CEM faculty and students for their encouragement and support of our initiatives. Going forward, UIT will continue to be committed to its mission. We hope to build deeper relationships between the industry and young students in more ways, such as lectures by professionals in the classroom, student observation at construction sites, and internships, to name a few.

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