Artificial intelligence for sewer systems from a PACP™ perspective

It continues to be an exciting time in the infrastructure assessment industry, with advancements in technology as well as increased funding. As it relates to underground sewer infrastructure, NASSCO, Inc. (National Association of Sewer Service Companies) remains the leader in providing the international standard for coding condition of pipelines, laterals, and manholes throughout the United States, Canada, and South America through widely used certification training programs known as Pipeline Assessment Certification Program (PACP™), Lateral Assessment Certification Program (LACP™), and Manhole Assessment Certification Program (MACP™). While NASSCO is currently upgrading this coding language and programs to Version 8.0 for data collection, management, and organization (step 1), sewer artificial intelligence (AI) has made its way into our industry's toolbox for capturing inspection information (step 2). The goal of this document is to inform users about the status of AI within the PACP environment.

In standard PACP pipe inspections, PACP-certified operators utilize remote-controlled closed-circuit television (CCTV) camera systems with varying levels of image resolution and video capture technologies to document structural, operation and maintenance (O&M), construction and miscellaneous observations required during a pipeline condition assessment. Using the rules defined for each defect or feature type, the operator makes one entry at the distance each observation is made based on how far the camera has traversed the pipe from the access point, applying clock positions for the location around the pipe where the defect/feature is seen and an estimated cross sectional area loss to express the severity of the observation. These standards provide the ability for the operator to apply over 200 coding variations while PACP-certified software systems calculate quantitative grades and scores that represent overall condition of the pipeline for rehabilitation planning purposes.

NASSCO recognizes that subjective interpretations of observations by operators can influence coding decisions, however, with proper oversight and quality control, the PACP standard approach provides a high level of correctness and is a valuable tool in the collection of sewer observations and management of pipeline assets. Additionally, NASSCO's PACP sets the standard for image capture by location and speed during an operator's inspection to maintain full perspective of a defect/feature and visibility.

Artificial intelligence (AI) is the theory and development of computer systems that can perform tasks that normally require human intelligence (such as an operator coding pipe defects), visual perception, speech recognition, decision-making, and translation between languages. AI techniques lend themselves to solving complex problems involving large volumes of data. Data, by virtue of its magnitude, can challenge problem solving initiatives. Data, regardless of size or level of complexity, require organization to promote clarity and consistency to make informed decisions. With an estimated 800,000 miles of wastewater sewers and 500,000 miles of lateral sewers in the US alone, pipe inspections and the ability to perform condition assessments have become an attractive candidate for AI processes.

As it relates to condition assessments, the success of AI in sewers requires what is referred to as machine learning (ML), automated defect recognition (ADR) and advance analytical processes (AAP). ML is an

algorithmic process that helps software improve, like humans do, through iterative trial and error experiences using mass amounts of training data (such as photographs or video of known defects/features), to make better decisions or choices. ADR is the software output, that uses ML techniques, to progressively identify defects "observed" within individual images of video. And finally, AAP refers to the broad spectrum of processes uniquely focused on the analysis and leveraging of information in large data compilations. In sewer networks, this can embrace a wide range of studies from deterioration analysis of specific cohorts or eras of pipes, sustainable funding assessments, optimization techniques, among others.

As of 2019, worldwide funding of AI reached an approximate $82 billion funding (Statista). ML applications and platforms had received over half of this funding.

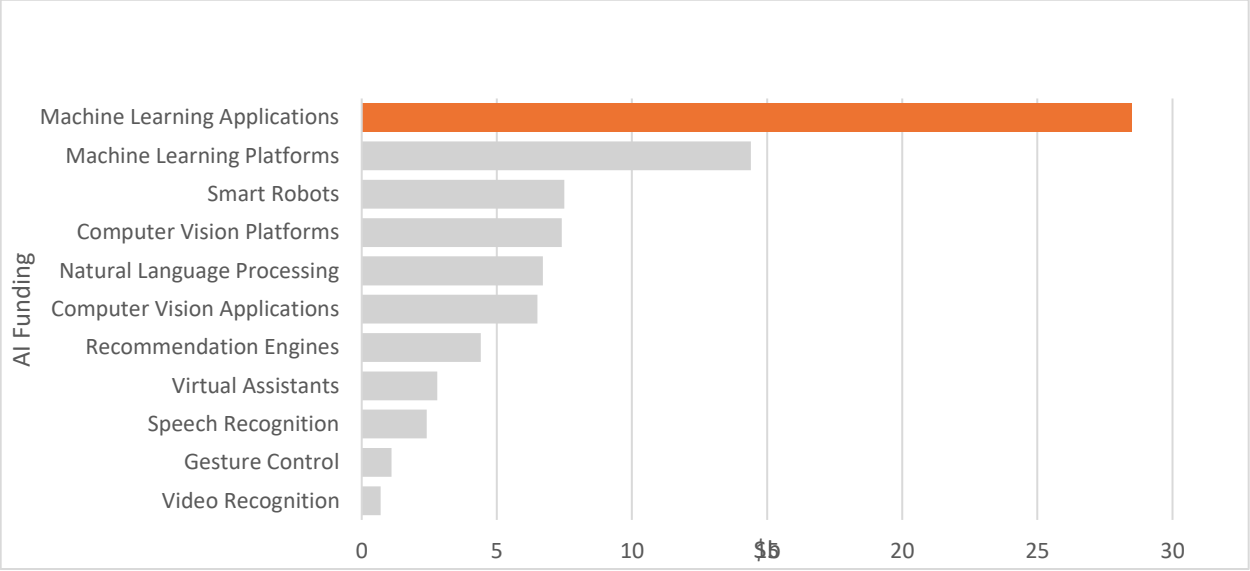

Figure 1: data applied from https://www.statista.com/chart/17966/worldwide-artificial-intelligence-funding/

PACP was built on sound engineering practices focused on consistency, clarity, and science in terms of classifying visual observations to provide both qualitative and quantitative condition assessment definitions, such as:

- the ability for an operator to make observations that are readily replicable. They do not have to be perfect but do need to be replicable enough such that a diverse group of reasonable individuals applying the same visual standard should arrive at the substantially same conclusion, and
- the ability to make observations that are relevant in terms of understanding the structural and operational significance. Many successful engineering studies have been completed by the ability to look at combinations of PACP observations, the pipe materials involved and the ground conditions around the pipe to make informed decisions on how much to spend, when to spend it and what to spend it on.

Merging the PACP condition assessment standard with other data sources that influence pipe remaining useful life requires significant organizational and data management skills, which is where AI comes in. Using the PACP standard, many of the concepts that are evolving through AI can apply to sewer condition assessments by providing increased automation and data processing, however this also increases the

importance of data verification by trained operators assigned to performing the work of coding defects/features in pipelines to reduce errors that can result on a larger scale during ML and ADR. AI and advanced analytics can support the work by improving productivity, accuracy, and the ability to solve increasingly complex problems facing the aging infrastructure industry.

NASSCO recognizes the use and growth of AI and ML within the sewer inspection and rehabilitation industry and is actively providing leadership on the subject, including the development of a workgroup and collaboration with software and hardware developers. Presently there are no AI systems that are certified by NASSCO for recognizing every PACP/LACP/MACP observation; however, end-users may not need this level of functionality if the observations that are recognized and captured are consistent with their individual goals for CCTV inspection. Regardless, the present advantage of AI for CCTV pipe inspection is its efficiency to code large volumes of legacy and new inspection data in a cost-efficient manner that is consistent with the quality standards per the "Guidelines for Quality Control (QC) of NASSCO's PACP, LACP and MACP Surveys," April 2022. The NASSCO AI workgroup additionally recognizes the following uses for AI-collected inspection data:

- Training aid to supplement and improve PACP coding for novice inspection personnel or operators becoming familiar with code classification for pipe types that they do not have experience coding.
- Improved workflows whereby an AI algorithm is used as first inspection followed by manual operator checks to correct missing or inaccurately coded defects/features
- Quick coding of legacy inspection video for benchmarking purposes
- Cross bore identification
- Embedment of NASSCO QC guidelines for automated quality validation

As the market evolves, NASSCO's Software Committee, Infrastructure Condition Assessment Committee, Technical Advisory Council and other industry professionals will determine the best approach for assessing and rating ADR software products and their level of accuracy as they pertain to NASSCO's PACP, LACP and MACP codes. While that process has not yet been defined, NASSCO will ensure that it presents a fair picture of AI/ADR technological capabilities and how they are applied in the field, knowing that it will evolve as the technology becomes more developed, advanced, and accepted in the future. NASSCO is committed to providing similar written updates on the subject to inform the industry, our users, and our membership on the advancement of AI in the PACP-environment. Later this year, watch for the release of PACP Version 8.0 which will incorporate current AI knowledge to support our students' understanding of this topic.

As a reminder, NASSCO requires license agreements for all software products that utilize NASSCO's intellectual property relating to PACP, LACP and MACP codes, including ADR and import/export functions using existing PACP-inspection databases. Interested vendors should contact NASSCO for assistance.