



# AI Applications for Construction Engineering & Inspection

Instructed by Dr. Nils J. Gransberg, VP, Gransberg & Assoc., Inc.

November 30<sup>th</sup>, 2023

Oklahoma DOT Training Center

Oklahoma City, OK

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1



## Agenda

2

Time	Module	Event/Topic
7:30 am		Check-In & Breakfast
8:00 am	Module 1	Introduction to AI Applications in Engineering & Construction
10:15 am	Module 2	Planning, Estimating, and Preconstruction Applications
12:00 am		Lunch
12:30 pm	Module 3	Construction Administration & Management Applications
2:00 pm	Module 4	Forensic Applications
4:30 pm		Course Evaluations & Dismissal

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Alternative Delivery Services Programmatic  
Development and Support Services

2



## Nils Gransberg, Ph.D., A.M.ASCE

3

- 20+ Years of Industry Experience
  - Capital Projects Manager & Owner's Representative
  - US Army Corps of Engineers (Retired)
- Adjunct Professor, University of Oklahoma (*Engineering Dept. & Construction Science Div.*)
- Construction Engineering Consultant
  - Capital program development, procurement support, etc. (*Nat'l Park Service, Fish & Wildlife Service, Amtrack*)
  - Claims support, forensic scheduling (*CTRMA, Ontario MoT*)
  - Data driven stochastic cost estimating & risk simulations (*Panama Canal Authority, California Water Service, Caltrans, TxDOT*)
  - Alternative project delivery & mega projects (*GDOT, MnDOT, FAA, etc.*)



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3



# Introduction to AI Applications in Engineering & Construction

## MODULE 1

4

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## What is Artificial Intelligence?\*

\*Excerpts from IBM (<https://www.ibm.com/topics/artificial-intelligence>)

- Alan Turing, the father of computer science, 1950 paper “Computing and Machine Memory” posed the question asking if machines could think (*and proposed the now famous “Turing Test”*)
- John McCarthy, one of the founding fathers of the discipline of artificial intelligence and co-authored the paper which coined the term, defined it as:

*“It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.”*

- The field of AI enables enhanced problem-solving by combining applied computer science algorithms and robust datasets
- Modern AI is considered “Weak” AI or Artificial Narrow Intelligence (ANI)
  - Trained to perform specific tasks (ex: Amazon Alexa, Apple Siri)

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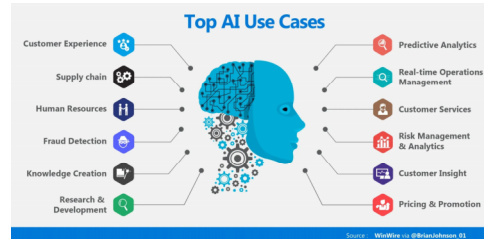
## History of Artificial Intelligence\*

- 1950 – Alan Turing publishes *Computing Machinery and Intelligence*
- 1956 – John McCarthy coins term “artificial intelligence”
- 1967 – Frank Rosenblatt builds first computer based upon a neural network (*Mark 1 Perceptron*)
- 1980’s – Development and widespread adoption of backpropagation algorithms used by neural networks to self-train
- 1997 – IBM’s Deep Blue beats Garry Kasparov in chess (two matches)
- 2011 – IBM’s Watson beats Ken Jennings and Brad Rutter at Jeopardy
- 2016 – DeepMind’s AlphaGo beats Lee Sodol at Go (five game match)
- 2022/2023 – Large Language Models (LLMs) become available to the general public

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- AI adoption has more than doubled in last 5 years
  - Respondents had adopted AI in at least one business unit or function 20% in 2017 to 50% in 2022
- Top AI process applications embedded in products or business processes (*by % of respondents*)
  - Robotic process automation (39%) Computer vision (34%)
  - Natural-language text understanding (33%) Deep learning (30%)
  - Knowledge graphs (25%) Digital twins (24%)
- Most common AI use cases; Cost Decrease; Revenue Increase
 

■ Service Operations	45% Cost Decrease	57% Revenue Increase
■ Product/Service Dev.	30% Cost Decrease	70% Revenue Increase
■ Risk Management	43% Cost Decrease	48% Revenue Increase
■ Supply Chain Mgmt.	52% Cost Decrease	59% Revenue Increase



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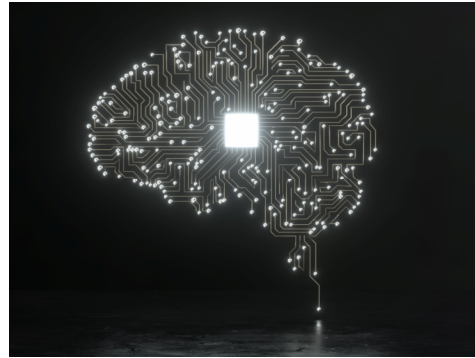
- Machine Learning (ML)
  - Computer programs that utilize neural network(s) to learn from data
  - Relies upon human experts to set hierarchies of model features
  - Typically requires structured data to learn (labeled data)
- Deep Learning (DL)
  - Subset of ML, algorithms comprised of more than three layers of neural networks
  - DL automates feature extraction allowing use of larger data sets
    - Supervised Learning → Using labeled datasets to establish hierarchy of features
    - Unsupervised Learning → Using unstructured datasets to determine hierarchy of features automatically
  - Generative AI models ("*foundational models*") use DL to "learn" from large amounts of raw data and generate statistically probable outputs from input prompts
    - Learns across multiple domains; trained on large, unstructured, unlabeled datasets
    - Ex: GPT-4, DALL-E, LLaMA, Stable Diffusion, etc.

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## Generative AI Applications

9

- Generative DL models are currently used for:
  - Customer service chatbots
  - Smart assistants (Alexa, Siri, etc.)
  - Perform data entry
  - Search and summarize text documents
  - Marketing recommendation engines
  - Automated stock trading
  - Speech recognition (speech-to-text) and translation
  - Create and debug computer code
  - Medical biosensors
  - Computer vision
  - Development of novel antibiotics



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9

## Industry Use Cases\*

\*Gartner, Inc. article "Beyond ChatGPT: The Future of Generative AI for Enterprises" ([link](#))

10

- Generative AI is still a relatively young technology, novel applications will continue to be discovered
- 2023 article looking at industries with a great potential to benefit from generative AI applications:
  - Big Pharma: Drug Design
    - \$1.8B market where 1/3 cost is discovery & development
    - Already used to design drugs within matter of months
  - Material Science
    - Develop new materials based upon maximizing/optimizing physical properties
  - Chip Design
    - Optimized component placement, reduced product development timeline from weeks to hours
  - Synthetic Data for Healthcare Research
    - Data generated from direct observations preserves privacy of research participants
  - Engineering Design
    - Automated design optimized to meet specific goals, specifications, constraints, etc.

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10



## Large Language Models (LLMs)

11

- Models trained on a massive amount of public and private data
- Developed to understand and precisely interpret natural human language
- Relies upon natural language input prompts to generate responsive outputs
  - Written outputs indistinguishable from high quality human writing
  - Develop specific content
  - Conduct analysis of a large amount of data
  - Write, complete, debug computer code
- Limited by the specific language(s) trained for and availability of sufficient data in given language
- Operational LLMs
  - GPT (OpenAI)
    - Leading generative AI bot, GPT-4 released in 2023, first multi-modal LLM can process text and images
  - BLOOM
    - Multi-lingual, open-access science LLM funded by French government
  - Claude
    - US & UK; Personal assistant AI bot: text summarization, coding, creative writing, etc.
  - Orca
    - Microsoft LLM, trained on 13B parameters, on par with GPT-4

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AI Applications in CEI



Alternative Delivery Services Programmatic Development and Support Services

11



## ML and AI Applications in Construction\* Link

12

- ML Applications
  - Clash Management
  - Contracts
  - Costs
  - Construction Documents
  - Equipment
  - Labor
  - Monitoring
  - Planning & Scheduling
  - Risk Management
  - Construction Safety
  - Waste
- ML Algorithms
  - Naïve Bayes
  - Fuzzy Logic
  - Random Forest
  - Genetic Algorithm
  - Convolutional Neural Network
  - Recurrent Neural Network
  - Decision Tree
  - Support Vector Machine
  - Multi-layer Perception
  - Logistic Regression
  - Artificial Neural Network

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AI Applications in CEI



Alternative Delivery Services Programmatic Development and Support Services

12

# Planning, Estimating, & Preconstruction Applications

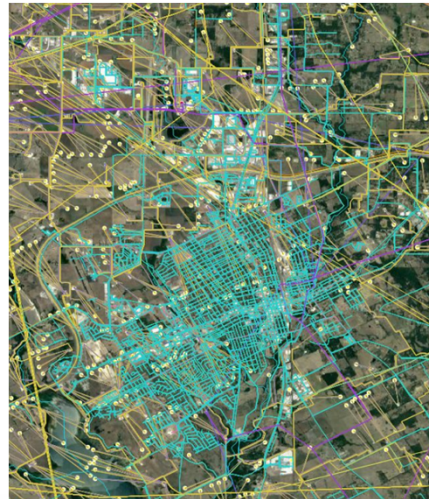
## MODULE 2

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13

# Planning, Estimating, & Preconstruction

- Planning
  - Design Tools
  - LLM Applications
- Estimating
  - Long Range Programmatic Estimating Tools
  - Construction Cost Indexing
- Preconstruction Applications
  - Utility Location, Identification, and Deconfliction
  - Right-of-Way Acquisition
- BIM
  - Preconstruction to O&M



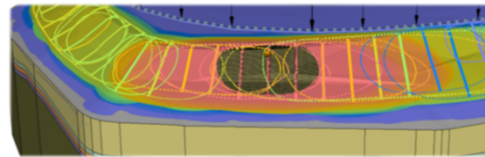
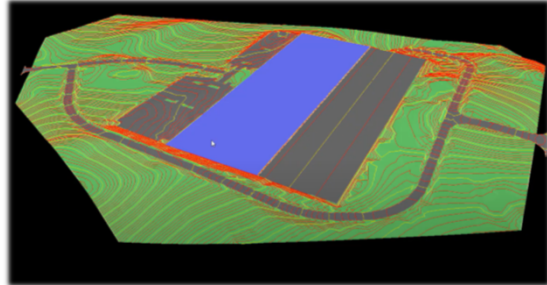
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14

## Automated Design Software

15

- Automate repetitive tasks
  - Drafting
  - Calculations
- Enable increased focus on design decision making
- Generate design alternatives for optimization
- Integrate data across multiple domains
- Specialized Applications
  - Geotechnical Analysis
  - Bridges
  - Hydrology & Hydraulics
  - Tunnels
  - Surveying



Images from Bentley Education OpenSite Designer & Plaxis Designer

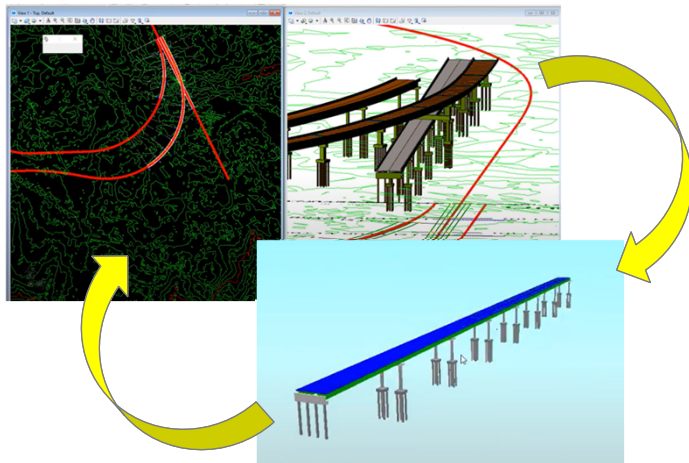
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15

## Automated Design Software

16

- Bridges Design Example:
  - Develop bridge model (libraries)
  - Integrate topographical data and alignment (automate adjustments)
  - Automated conversion from physical model to analytical model
  - Conduct structural calculations using latest AASHTO codes to verify everything works
  - Make modifications as needed throughout
  - Update physical model with changes made to analytical model
  - Generate reports, schedules, etc.



Images from Bentley Education OpenBridge Designer

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16





## LLM Applications

- Search engines like Google and Bing are already enabled with LLMs
  - Replacing Page Rank and Key Word algorithms to increase search result relevance
  - Proprietary LLMs can be used to search internal documents, contracts, records, etc.
- Generative writing and editing applications
  - Composing standard business communications, emails, business letters, memoranda
  - Writing and editing proposals
  - Specifications, code compliance, etc.
- Extracting information from documents or collections of unstructured data
  - Analyzing RFPs to determine what the owner considers the most important aspects of the project
  - Extracting data from a project's daily work reports to support a claim

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## LLM Design Applications

- Using text prompts to do code research:
  - "List the applicable building codes related to the construction of water treatment plants in the United States."

**ChatGPT**  
The construction of water treatment plants in the United States is subject to various building codes and standards. The specific codes and standards can vary depending on the location, size, and nature of the project. Some of the relevant codes and standards that may apply to water treatment plant construction in the U.S. include:

1. **International Building Code (IBC):** The IBC is widely adopted across the U.S. and provides comprehensive regulations for building design and construction.
2. **International Plumbing Code (IPC):** The IPC contains provisions for plumbing systems, including those related to water treatment facilities.
3. **National Electrical Code (NEC):** The NEC sets the standard for electrical installation and is important for the electrical components of water treatment plants.
4. **American Water Works Association (AWWA) Standards:** AWWA develops standards for the water industry, including standards for water treatment plant design, construction, and operation.

5. **National Fire Protection Association (NFPA) Standards:** NFPA provides standards related to fire protection, and certain NFPA standards may be relevant to water treatment plant construction.
6. **Environmental Protection Agency (EPA) Regulations:** The EPA sets regulations and standards related to water quality and treatment. Water treatment plants must comply with these regulations.
7. **Local Building Codes:** In addition to national codes and standards, local building codes play a crucial role. These codes can vary from one jurisdiction to another, and it's important to comply with the specific requirements of the local authority having jurisdiction (AHJ).
8. **State-Specific Regulations:** Some states may have additional regulations and codes that water treatment plants must adhere to.

It's important to note that regulations and codes can change, and it is crucial to consult with the local building department, environmental agencies, and other relevant authorities to ensure compliance with the latest standards and requirements for water treatment plant construction in a specific location. Consulting with a professional engineer or architect experienced in water treatment projects is also advisable.

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- Specification drafting using text prompts:
  - “Write a performance specification for traffic striping that complies with the MUTCD”

<p><b>TRAFFIC STRIPING PERFORMANCE SPECIFICATION</b></p> <p><b>1. PURPOSE:</b> The purpose of this specification is to outline the requirements for the application of traffic striping in accordance with the Manual on Uniform Traffic Control Devices (MUTCD). The traffic striping is intended to enhance road safety, improve traffic flow, and provide clear guidance to road users.</p> <p><b>2. APPLICABLE STANDARDS:</b> All work shall conform to the latest edition of the MUTCD published by the Federal Highway Administration (FHWA). In case of any conflicts between this specification and the MUTCD, the MUTCD shall take precedence.</p> <p><b>3. MATERIALS:</b> All materials used for traffic striping shall comply with the specific thermoplastic material selected shall have retroreflective properties as specified in the MUTCD for the relevant roadway type and speed.</p> <p><b>4. STRIPING CONFIGURATION:</b> The striping configuration shall be in accordance with the MUTCD and shall be limited to:                  - Centerlines                  - Edge lines                  - Lane lines                  - Stop lines                  - Yield lines                  - Crosswalks                  - Bicycle lanes</p>	<p><b>5. DIMENSIONS:</b> The dimensions of all striping elements, including width, length, and spacing, shall meet or exceed the requirements for the specific roadway type and speed limit. The application of striping dimensions shall be in accordance with the MUTCD.</p> <p><b>6. RETROREFLECTIVITY:</b> All striping materials shall maintain adequate retroreflectivity to meet or exceed the minimum values specified in the MUTCD. The retroreflectivity levels shall be maintained throughout the warranty period.</p> <p><b>7. APPLICATION METHOD:</b> The application of traffic striping shall be carried out using methods that employ qualified personnel and appropriate equipment to ensure proper application and durability.</p> <p><b>8. INSPECTION AND TESTING:</b> Prior to acceptance, the striping work shall undergo thorough inspection to verify compliance with MUTCD standards. Retroreflectivity levels shall be tested using an approved method, and the results shall be documented. The inspection process shall be conducted by qualified personnel as defined by the MUTCD.</p>	<p><b>9. MAINTENANCE AND WARRANTY:</b> The contractor shall provide a warranty for the striping work, ensuring that it remains in good condition and complies with MUTCD standards for a specified period. Any necessary maintenance or repairs to address defects or deficiencies shall be promptly carried out by the contractor during the warranty period.</p> <p><b>10. RECORD KEEPING:</b> The contractor shall maintain comprehensive records, including materials used, application details, inspection reports, and retroreflectivity test results. These records shall be made available for inspection by the appropriate authorities upon request.</p> <p><b>11. COMPLIANCE WITH LOCAL REGULATIONS:</b> In addition to complying with MUTCD standards, the contractor shall adhere to any applicable local, state, or federal regulations governing traffic control devices and striping.</p> <p><b>12. ACCEPTANCE:</b> The completed traffic striping work shall be subject to final acceptance by the relevant transportation authority. Acceptance criteria shall include compliance with MUTCD standards, proper retroreflectivity levels, and overall conformance to this specification.</p> <p><b>13. REVISIONS:</b> Any revisions or updates to the MUTCD during the course of the project shall be promptly incorporated into the striping work to ensure continued compliance.</p> <p>This specification is intended to guide the application of traffic striping in accordance with MUTCD standards. Deviations from this specification must be approved by the responsible transportation authority.</p>
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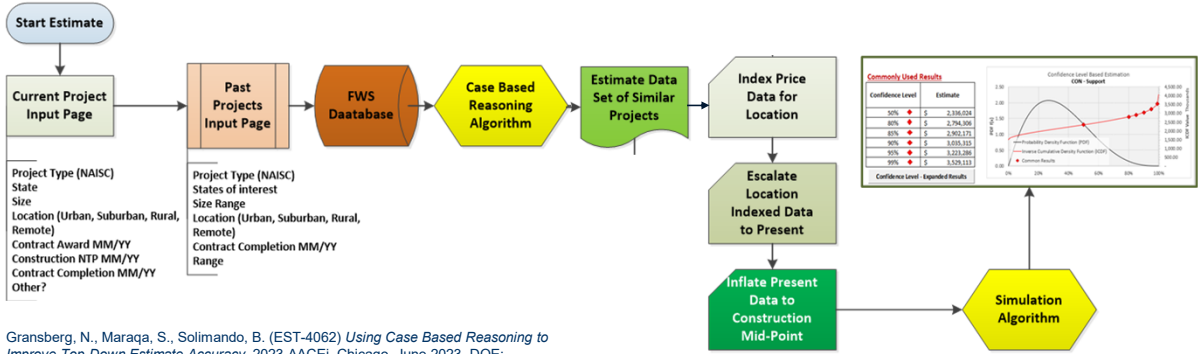
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- Early estimates of probable cost are crucial to programming **sufficient funding** for planned future projects
- DOT Challenges:
  - Minimal design (typically only narrative scope)
  - Long list of potential projects
  - Staff allocated to pending and current FY projects
  - Estimate must be sufficiently accurate to avoid “going back to the well”
- Top-Down Parametric Estimate Tool
  - Case Based Reasoning (CBR) ML algorithm used to select **highly similar** historical projects
  - Normalization algorithms **convert historical cost** data
    - Historical costs to Year of Expenditure (YOE)
    - Adjusts for geographic location
  - Monte Carlo Simulation **generates credible range** of project cost using statistical confidence intervals
- First developed for Caltrans (~2010) to improve performance of ~\$14B annual program

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- Developed for US Fish & Wildlife Service in 2020-2021 under Great American Outdoors Act
  - USFWS has 8 small regional construction service centers responsible for programming, planning, procuring work in all 50 states and territories; average staff ~8 employees per service center



Gransberg, N., Maraqa, S., Solimando, B. (EST-4062) *Using Case Based Reasoning to Improve Top-Down Estimate Accuracy*, 2023 AAACEI, Chicago, June 2023. DOE: <http://dx.doi.org/10.13140/RG.2.2.33932.28808> AAACEI Presentation [link](#)

- Tool utilizes a database composed of historical projects coded by characteristics:
  - State/Territory: 55 state & territory postal abbreviations
  - Project Location: Urban, Suburban, Rural, Remote
  - Asset Type: 6 primary assets, 18 sub-assets
  - Construction Year
  - Project Size: Small, Medium, Large
  - Project Type: New, Alteration/Repair
- Pairwise comparison matrix using professional judgement to "set ground rules" for CBR algorithm
  - Compares relative importance/influence of each characteristic against the other five (-5 to +5)
- CBR algorithm defines and scores each database project's similarity to the target estimate and sorts by score rank order

Estimate Factor Variables	State/Territory	Project Location	Asset Type	Construction Year	Project Size	Project Type
State/Territory	1					
Project Location		1				
Asset Type			1			
Construction Year				1		
Project Size					1	
Project Type						1

Figure 3—Pairwise Comparison Variable Scoring Matrix

Variable Influence Scoring Method	
1	A is slightly more influential than B
2	A is moderately more influential than B
3	A is strongly more influential than B
4	A is very strongly more influential than B
5	A is extremely more influential than B
Negative	Use negative values if B is more influential than A

Figure 4—Pairwise Comparison Matrix Variable Scoring Method

Gransberg, N., Maraqa, S., Solimando, B. (EST-4062) *Using Case Based Reasoning to Improve Top-Down Estimate Accuracy*, 2023 AAACEI, Chicago, June 2023. DOE: <http://dx.doi.org/10.13140/RG.2.2.33932.28808> AAACEI Presentation [link](#)

- Normalization Algorithms
  - Converts project total cost to unit cost based upon estimate units
  - Indexes unit cost from construction year to YOY
  - Indexes unit cost to target estimate state/territory
- Estimator can manually add or remove normalized projects prior to running the simulation
- Monte Carlo Simulation
  - 1,000 iteration simulation is run, generating distributions for the estimate
  - Plots Probability Density Function (PDF) & Cumulative Density Function (CDF)
  - Calculates Total Cost by confidence interval
- Predictive accuracy validated at  $\pm 1$  Standard Deviation of Mean actual values
  - Accuracy improves with asset granularity & database size

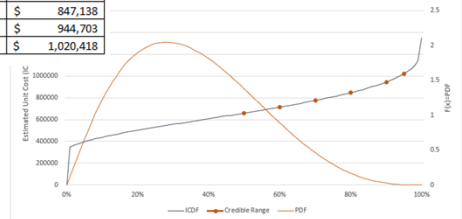
Adjusted Selection of Projects

Project Rank	Asset Type	Total Unit Cost
1	Housing/Comfort Station	\$ 424.53
2	Housing/Comfort Station	\$ 386.13
4	Housing/Comfort Station	\$ 231.50
5	Offices/Warehouses/Building General	\$ 481.07
9	Offices/Warehouses/Building General	\$ 286.05
16	Offices/Warehouses/Building General	\$ 906.67
17	Offices/Warehouses/Building General	\$ 655.13
22	Offices/Warehouses/Building General	\$ 432.79
24	Offices/Warehouses/Building General	\$ 1,032.39
29	Offices/Warehouses/Building General	\$ 653.58

Credible Range

Confidence Level	Total Estimated Project Cost
50%	\$ 660,061
60%	\$ 714,837
70%	\$ 775,377
80%	\$ 847,138
90%	\$ 944,703
95%	\$ 1,020,418

Credible Range of Estimated Costs



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- Construction Costs
  - Costs are primarily **commodity driven** (price of Portland cement, rebar, barrel of asphalt, etc.)
  - Markets are **highly regionalized** (DFW vs Muleshoe) and can vary substantially by **segment** (roads & bridges vs. utilities)
  - Costs are **dynamic** and can change slowly or rapidly depending on market conditions
- Construction Cost Indexes have historically required a major undertaking to gather sufficient cost data, clean, sort, and normalize it to be useful for indexing
  - Bureau of Labor and Statistics, Engineering News Record, Dodge Analytics, etc.
  - The COVID pandemic and its fallout has reduced the usefulness of cost data which ages rapidly
- ML algorithms reduce the level of effort required to develop relevant indexing tools and allow for generation of synthetic cost data where useful data is lacking

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## Construction Cost Indexing

25

- Amtrak Construction Cost Indexing (ACCI) was developed in early 2023 to provide a tool to index programmatic cost estimates as part of an overhaul of their capital program to restore service throughout the Northeast Corridor funded with \$22B through the Bipartisan Infrastructure Law
- Amtrak did not have a reliable historical construction cost dataset, so RS Means cost data from 2017 to 2022 was collected for materials and installation for each divisions and each city in the Northeast Corridor
- Median values for subdivisions were used to calculate the division values for each city for each year
  - Site Work and Track Structure
  - Railroad Building Facilities
  - Communications and Signals
  - Electric Traction
- The index value for each city represented the relative cost for that city compared to RS Means' 30-city national average for that year

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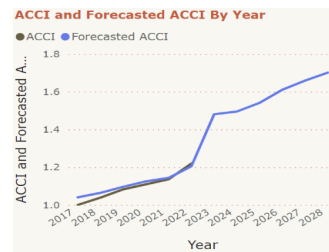
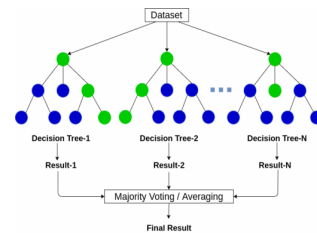
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## Construction Cost Indexing

26

- Random Forests ensemble algorithm was used to forecast the index values for the upcoming 5 years using Year, State, City, and Division as parameters
- Random Forests is an ML algorithm utilizing ensemble learning that combines Bootstrap Aggregation and Feature Randomness (replacement) to generate a set of decision trees
  - Generates 400 to 1,200 decision trees from dataset observations and random sampling
  - Effective tool to prevent model overfitting with Bootstrapping alone
  - The average value calculated across all trees determines the relative importance of each variable on its predictive ability



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AI Applications in CEI



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26

SOUTHERN PLAINS TRANSPORTATION CENTER

# Construction Cost Indexing

**Construction Cost Index**

Apply Filters & Weights

State, City

State:  Connecticut  Delaware  Maryland  Massachusetts  New Jersey  New York  Rhode Island  Virginia  Washington, D.C.

City: ALBANY | ALEXANDRIA

Year: 2017 | 2028

Division:  Selected all  Communication & Signals  Electric Traction  Railroad Building Facilities  Site Work & Track Structure

Communication & Signal W...: 1.00

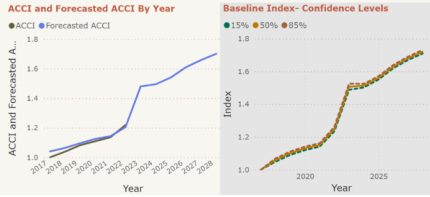
Electric Traction Weight: 1.00

Railroad Building Facilities: 1.00

Site Work & Track Struct...: 1.00

**Construction Index**

Year	2017		2018		2019	
	ACCI	Forecasted ACCI	ACCI	Forecasted ACCI	ACCI	Forecasted ACCI
CONNECTICUT	1.000	1.035	1.030	1.056	1.062	1.079
DELAWARE	1.000	1.039	1.040	1.063	1.079	1.096
DOVER	1.000	1.031	1.040	1.057	1.077	1.090
Communication & Signals	1.000	1.028	1.035	1.052	1.075	1.088
Electric Traction	1.000	1.027	1.030	1.048	1.055	1.051
Railroad Building Facilities	1.000	1.037	1.047	1.061	1.063	1.095
Site Work & Track Structure	1.000	1.034	1.048	1.066	1.066	1.094
NEWARK	1.000	1.036	1.039	1.060	1.079	1.092
Communication & Signals	1.000	1.030	1.038	1.053	1.050	1.059
Electric Traction	1.000	1.033	1.036	1.055	1.076	1.086
<b>Regional Index</b>	<b>1.000</b>	<b>1.040</b>	<b>1.039</b>	<b>1.064</b>	<b>1.083</b>	<b>1.096</b>



- Early Cost Estimating Example:
  - Project is \$25.5M in 2022
  - 4-year duration, starts in 2024
  - Midpoint of construction is 2026

Variable	Value
Current Year	2022
Estimated Project Cost (current dollar value)	\$25.5M
Current Year Index	1.21
Construction Mid point (Year)	2026
Forecasted Cost Index value for 2026	1.52

■ Cost at midpoint:

$$2026(\$) = \$25.50M \times \frac{1.52}{1.21} = \$32.03M$$

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SOUTHERN PLAINS TRANSPORTATION CENTER

# Utility Location

- Claims due to unforeseen conditions ranked #2 in the Americas in HKA's 2022 CRUX Insight report ([link](#)) behind scope changes
  - ~\$11B annually utility location & damage prevention market

Planning	Design	Construction	Maintenance
ASCE 38-22 (SUE)		Damage Prevention	
Pursuits, Bidding & Scoping <b>\$2B</b>	SUE & Engineering <b>\$2B</b>	Private Locating <b>\$1.5B</b>	Public Locating <b>\$3.5-4B</b>
4M	CT2 utility engineers KCI Colliers	ELM UTILITY SERVICES GPRS RECON UTILITY SERVICES	USIC* STAKE CENTER UtiliQuest
			Screening & Ticketing <b>\$1.5B</b> KorTerra Urbint 811 IrthSolutions

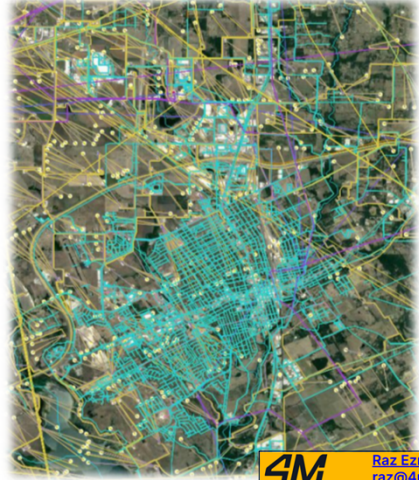


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## Utility Location

29

- Primary challenges to reliable subsurface utility locating
  - Multiple sources of existing utility location data
  - Absence of widely adopted standards
    - Variations between federal, state, municipalities, private owners, and corporations
    - Different types of files: digital & physical
  - Large variety of unstructured datasets
  - Quality variation in as-built documentation
    - Ex: major communications companies typically track line location within ±100ft and rarely track installation depth
  - Subsurface detection is challenging task for computer vision



**4M** Raz Ezra, 4M  
raz@4m-a.com

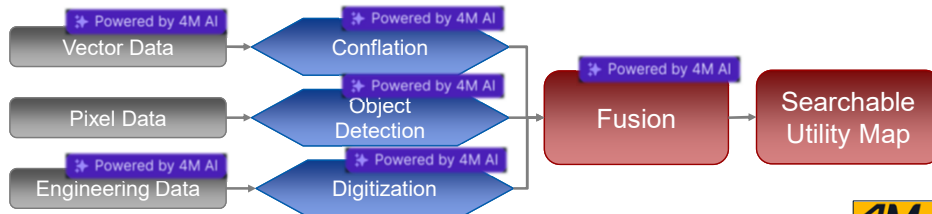
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## Utility Location: AI Model

30

- Ensemble DL applications used to process widely varied data:
  - Vector Data – GIS Platforms, GIS Servers
  - Pixels Data – Videos, Images, News
  - Engineering Data – Plans, As-builts, GeoPDF Maps
- Fusion operation utilizes statistical probability to plot heat maps of likely utility locations
  - Web portal functions similar to popular map applications with ability to drill down

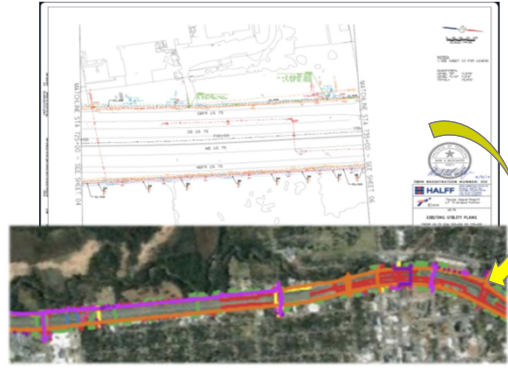


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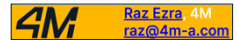
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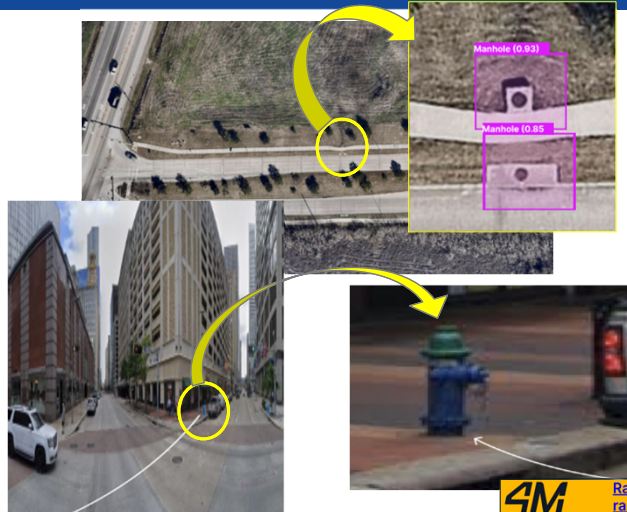
- Model base layer uses GIS map files and existing geotagged utility data
- As-built plans are processed using an AI digitization engine
  - Converts PDF and image files into accurate geo-aligned vectorial layer files
  - Extracts utility location indicators, meta data, and vector data
  - Vector data is overlaid on GIS base model
- Pixel data is processed using AI computer vision
  - Used to increase data quality, coverage, and confidence



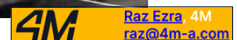
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- Multiple sources of pixel data:
  - Aerial/satellite photography
  - Open-source mapping images (ex: Google Streetview)
  - Historical photographs
  - News article images
  - Videos
- Object Detection
  - Vertical Detection
  - Horizontal Detection
  - AI algorithm locates, identifies, categorizes, and geo-tags each object



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## Utility Location: Image Processing

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- Object detection (*photogrammetric*) algorithms scan both current and historical satellite and aerial imagery highlighting visual evidence indicating existence of buried utilities
  - Subtle changes in pixel colors of vegetation
  - Indications of underlying linear/non-organic features
  - Other indicators gleaned from algorithmic training



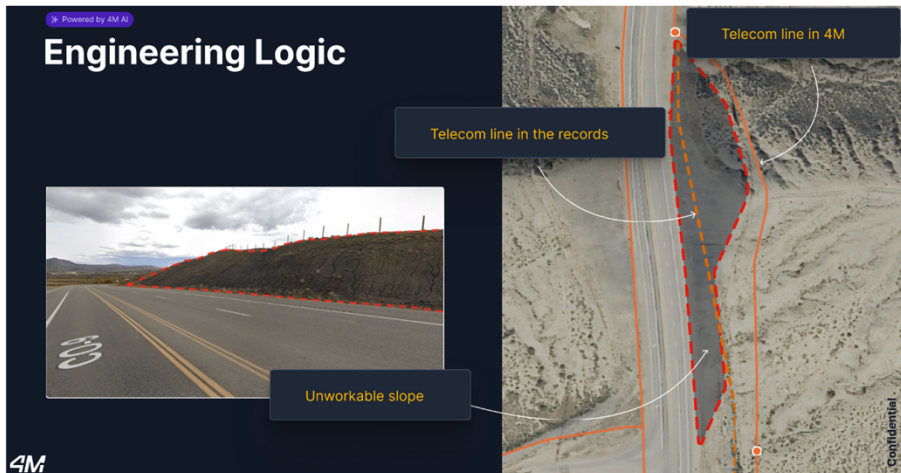
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## Utility Location: Image Processing

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- Application of engineering logic
  - As-built records showing locations in unworkable conditions
  - Algorithm indicates most likely location given existing site conditions



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34

35



Utility Location: Interface

**Projects**

Search project name

-  ODOT Training Center Example  
Nils Gransberg - Oklahoma, OK  
28 Nov 2023
-  US 84 Sudan-Muleshoe  
Nils Gransberg - Lamo, TX  
28 Nov 2023
-  Highway Improvement  
4M Analytics - Bell, TX  
Demo Project

+ Create new project



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35


36



# Construction Administration & Management Applications

## MODULE 3

AI Applications in CEI



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## Data Visualization & Dashboards

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- Data visualization is an important management tool across industries that allows complex information to be easily displayed, readily understood, and identify important trends that would otherwise be difficult to discern
- Dashboards have become a popular tool to centrally integrate information flows across domains to improve management functions and decision making
- Construction management software typically provides dashboards integrating the project schedule, budget, documents, communication, etc.
  - CM software tends to be market segment specific (ie – Procore & commercial, HCSS & heavy civil, etc.)
  - Some platforms include Earned Value and Risk Management and other specialized capabilities

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## Data Visualization with Power BI

38

- Microsoft Power BI is a suite of software apps, services, and connectors for reporting, data visualization, and business intelligence that can integrated disparate data sources, file types, and platforms in fully customizable dashboards
  - Powerful data mining, preparation, and storage capabilities
  - Integrates many visualization apps, including visualizations coded in R
  - Power Query for importing data and transform mapping for models
  - Dashboards update in real time (pull and push)
  - Reports, files, and documents don't need to be emailed if dashboard is mapped to a shared drive
- Integrates Azure Machine Learning
  - Image recognition, text analytics, ability to create ML models
- Power BI has a relatively steep learning curve for new users but there are plenty of free tutorials available online for anyone interested

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- River Renew Project (DB) – Alexandria, VA
  - Wastewater Project to upgrade mixed storm and sanitary sewer system (cir. 1800's) (\$615M)
    - Wastewater treatment facility upgrades and expansion
    - 1.5-mile 12' dia. tunnel catchment
  - Analysis of Quality Management Documentation
    - Submittals
    - RFIs
    - NCNs – Nonconformity Notice

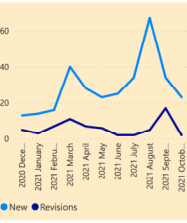
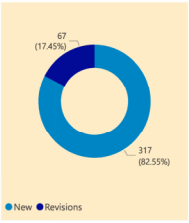
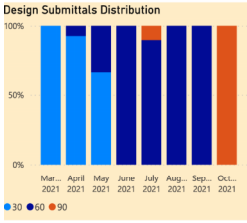
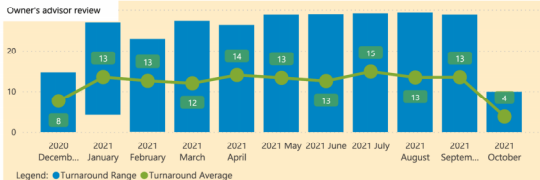
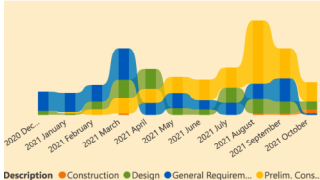


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Quality Management Dashboard

**384** Total Submittals  
**67** Revisions  
**317** New



Unique ID	Submittal Title
1-0	Safety Manager's Qualifications
1-1	Safety Mng'r's Quals
2-0	Sched Engr's Quals
2-1	Sched Engr's Quals
3-0	180 Day Submittal Register
4-0	Preliminary SOV
4-1	Preliminary SOV
4-2	Preliminary SOV
4-3	Preliminary SOV
5-0	Preliminary Baseline Schedule
5-1	Preliminary Baseline Schedule
5-2	Preliminary Baseline Schedule
5-3	Preliminary Baseline Schedule

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# Quality Management Dashboards

■ Drill down capability



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# Construction Monitoring

- Monitoring and documenting construction progress is an important engineering function for both Owner and GC
  - Tracking and documenting contractor progress
  - Quality control and quality assurance activities
  - Preparation and review of pay applications
  - Assisting in dispute resolution
- Site visits, inspections, and observation activities are staff-intensive
- Maintaining a presence on multiple sites over long distances can be a challenge to engineering firms to staff



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# Construction Monitoring

- Persistent monitoring technology is sufficiently mature, rugged, and available as a “turn-key” solution to close staffing gaps
- Camera technology has continued to improve over recent years with increases in the image quality, storage capacity, integration of fully remote access and controls coupled with reduction in cost associated with widespread adoption
- Integrated AI-powered image processing applications have increased practical uses for construction observation and monitoring platforms outside of traditional applications



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Construction Monitoring and Intelligence

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# Construction Monitoring

- Portable powered PTZ cameras use a combination on onboard batteries charged via solar panels can be delivered and put into service in a couple of hours
- Tilt up towers can reach up to 60', rated for 115 mph wind, no special equipment to install
- Utility pole attachment obviates need for battery box and solar panels, can be powered off transformer
  - Can be good option for linear projects w/o shoulder, tight site lines, high tree coverage



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## Construction Monitoring

45

- Ruggedized mobile trailer are built to stay on a remote site for the duration of a project and be easily moved as work progresses
  - 24' winch up mast, dual PTZ cameras, 5G & FirstNET Band 14 capable, dual service modem, large solar array and backup battery



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## Monitoring Portal

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The screenshot shows a web-based monitoring portal. On the left is a navigation sidebar with a 'SKYFlint' logo and a user profile for 'Casey Davis'. The main content area is titled 'Gilcrease 1' and includes a 'Weather Forecast' section with a current temperature of 34°F and a 7-day forecast. Below the weather is a 'Panorama' view of a construction site. On the right side, there are several camera viewports: a large 'Panorama' view at the top, a 'Live View' window, a 'Camera Controller' with directional buttons, and several smaller 'Live View' windows for different camera angles (Elgin NW 1x, Greenwood Home, Greenwood NW 1x, Jobford). A bottom navigation bar contains the text 'AI Applications in CEI', the 'Gransberg & Associates, Inc.' logo, and the 'SkyFlint Critical Technologies' logo.

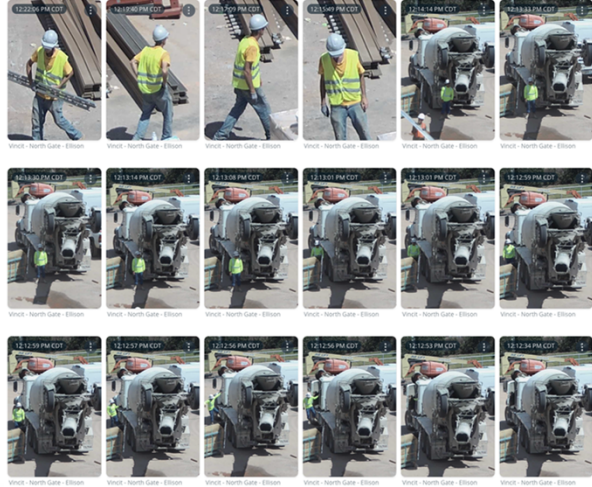
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# AI Computer Vision Automation

- Automated security analytics have multiple applications
  - Trainable algorithm can be given text prompt commands or images with directions
    - Ex: "Show me any concrete mixer trucks"
  - Computer vision can recognize logos, faces, license plate numbers, etc.
  - Able to program alerts tied to specific commands
  - PTZ camera can automatically follow and zoom



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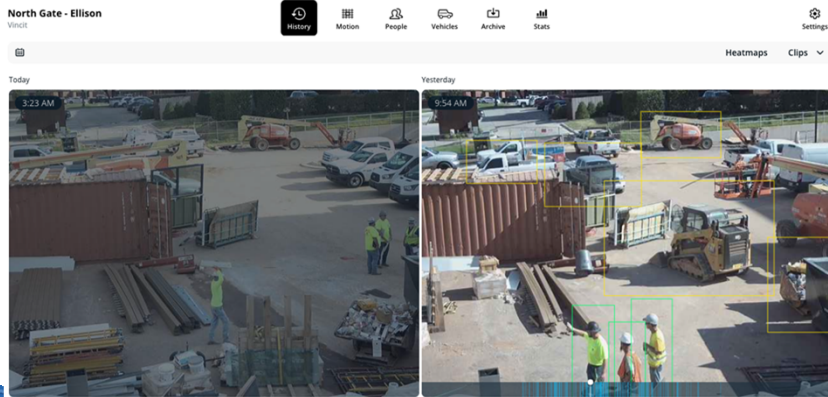


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# AI Computer Vision Automation

- Automated security analytics have multiple applications
  - Able to detect, identify, and track individuals, equipment, etc.
  - Can record 4 video feeds over a single cellular connection



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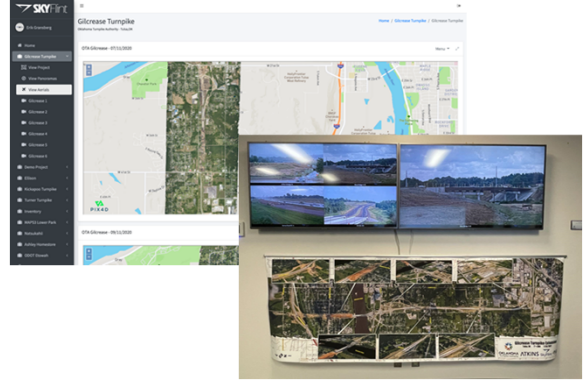
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# Drone and Aircraft Applications

- Wide Area Aerial Survey
  - Uses a calibrated camera and sensor pod to capture high resolution photogrammetric imagery
  - Fixed or rotary wing aircraft can capture more points in a single flight than a drone and can fly at higher altitudes to improve capture angle
- AI enabled post processing and cloud access has reduced turn around times for RTK tied aerial surveys and associated imagery to roughly a day's time



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# Turner Turnpike Timelapse



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# Forensic Applications

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51

52



# Forensic Applications

- Forensic analyses and investigations occur in some shape or form whenever there is a failure, claim or dispute to separate the facts from impressions and opinions
- Forensic analysis can be conducted for:
  - Schedule delays, critical path impacts, adverse weather
  - Budget busts, escalation, acceleration
  - Quality issues, workmanship, design failure
  - Anything else in dispute
- DL applications have the potential to improve forensic applications but have not been fully realized at this time



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## Automated Forensic Schedule Assembler

53

- Daily Work Reports (DWR) provide an excellent source of actual project data captured by inspectors, engineers, and contractors.
  - Typically, collected by state DOTs through their proprietary construction management software
  - May not be looked at outside of payment processing unless there's a delay or a dispute
- Data includes:
  - Activities: Location, Work Activities, Work Quantities, Contractors/Subs
  - Equipment: Types of Equipment, Quantities/Count, Hours Used
  - Labor: Labor Classifications, Number of Laborers, Labor Hours
  - Materials: Types of Materials, Quantities Used, Quantities Stored
- Assembling as-built schedules using DWR data can be a tedious process that readily benefits from automation

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## Automated Forensic Schedule Assembler


54

- Dr. Joseph Shrestha, then a grad student at Dr. David Jeong's Data Research Lab at Iowa State, developed the framework to automate the assembly of as-built schedules from DWR data between 2015-2017
- The assembler used the following steps:
  - Pull data and preprocess (ML Algorithm)
    - Identifies, extracts, and organizes data associated with schedule activities
  - Data Mining (ML Algorithm)
    - Converts raw data into schedule activities in tabular format, extrapolating actual start and finish dates
  - Interpretation/Evaluation
    - Human inspection step prior to assembling activities into as build schedule

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## Automated Forensic Schedule Assembler

**DWR Data**

- General Information
- Weather information
- Civil rights
- Other remarks
- Material name
- Material quantity stored
- Quantity used

**Work activities**

- Location
- Work activities
- Work quantities
- Contractors
- Equipment
- Labor
- Stockpile
- Equipment type
- Number of Equipment
- Hours used
- Labor type
- Labor number
- Labor hours

Project	Unique ID	Task Name	Actual Start	Actual Finish
18	R20014A6-18	48" AL.C.C.ST.PIPE CLVT.-34G	Tue 8/9/05	Wed 8/10/05
19	R20014A6-19	18" SIDE DRAIN	Tue 8/9/05	Thu 8/18/05
5	R20014A6-5	UNCLASSIFIED EXCAVATION	Thu 8/11/05	Mon 9/12/05
6	R20014A6-6	COMPACTED EMBANKMENT	Thu 8/11/05	Mon 9/12/05
13	R20014A6-13	MAINTENANCE OF TRAFFIC	Mon 8/15/05	Fri 12/18/05
22	R20014A6-22	48" FES C.ST.PIPE CLVT.	Mon 8/15/05	Tue 8/16/05

Data mining


Interpretation/  
Evaluation

**Data Selection and preprocessing**


```

1 SELECT w.cont_id AS Contract_ID,
2       w.prj_nbr,
3       a.item_cd AS Item_Code,
4       a.item_mstr_shrt_desc AS Item_Description,
5       Min(w.dwr_dt1) AS Start_Date,
6       Max(w.dwr_dt1) AS Finish_Date
7 FROM   fa_line_mstr AS f
8        INNER JOIN
9        a_work_items AS w
10       ON a.item_cd = w.item_cd
11        INNER JOIN
12        a_contract_items AS c
13       ON (a.item_cd = c.item_cd)
14          AND (w.item_cd = c.item_cd)
15          AND (w.contract_id = c.contract_id)
16 GROUP BY w.cont_id, w.prj_nbr, a.item_cd, a.item_mstr_shrt_desc, w.cont_id
17 HAVING  ((w.prj_nbr) = "R20014")
18         AND (w.cont_id) = "R20014";

```




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## Predicting Cost Impacts of Nonconformance

- New study just published in ASCE developed a framework to predict the cost impact of nonconformance incidents, quality failures, etc. that required rework.
- Developed a robust classification system using a Random Forest (RF) algorithm reinforced with Gravitational Search Algorithm (GSA) (to tweak the model for optimal results)
- Model were interpreted using Shapley Additive Explanations (SHAP) algorithm to:
  - Identify precursors of severe quality issues
  - Understand relative importance of each feature
  - Determine conditions that result in elevated cost of quality

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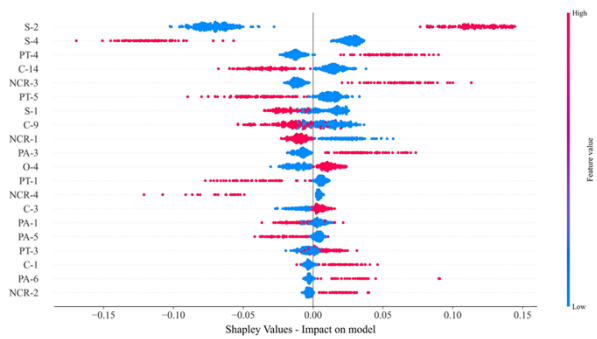



Fig. 8. Interpretability of the proposed model using SHAP method.

Koc et al, 2024, ASCE, DOI: [10.1061/JCEMD4.COENG-13857](https://doi.org/10.1061/JCEMD4.COENG-13857)

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# Thank You!

If you have any questions or could use our assistance in the future, please don't hesitate to reach out

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