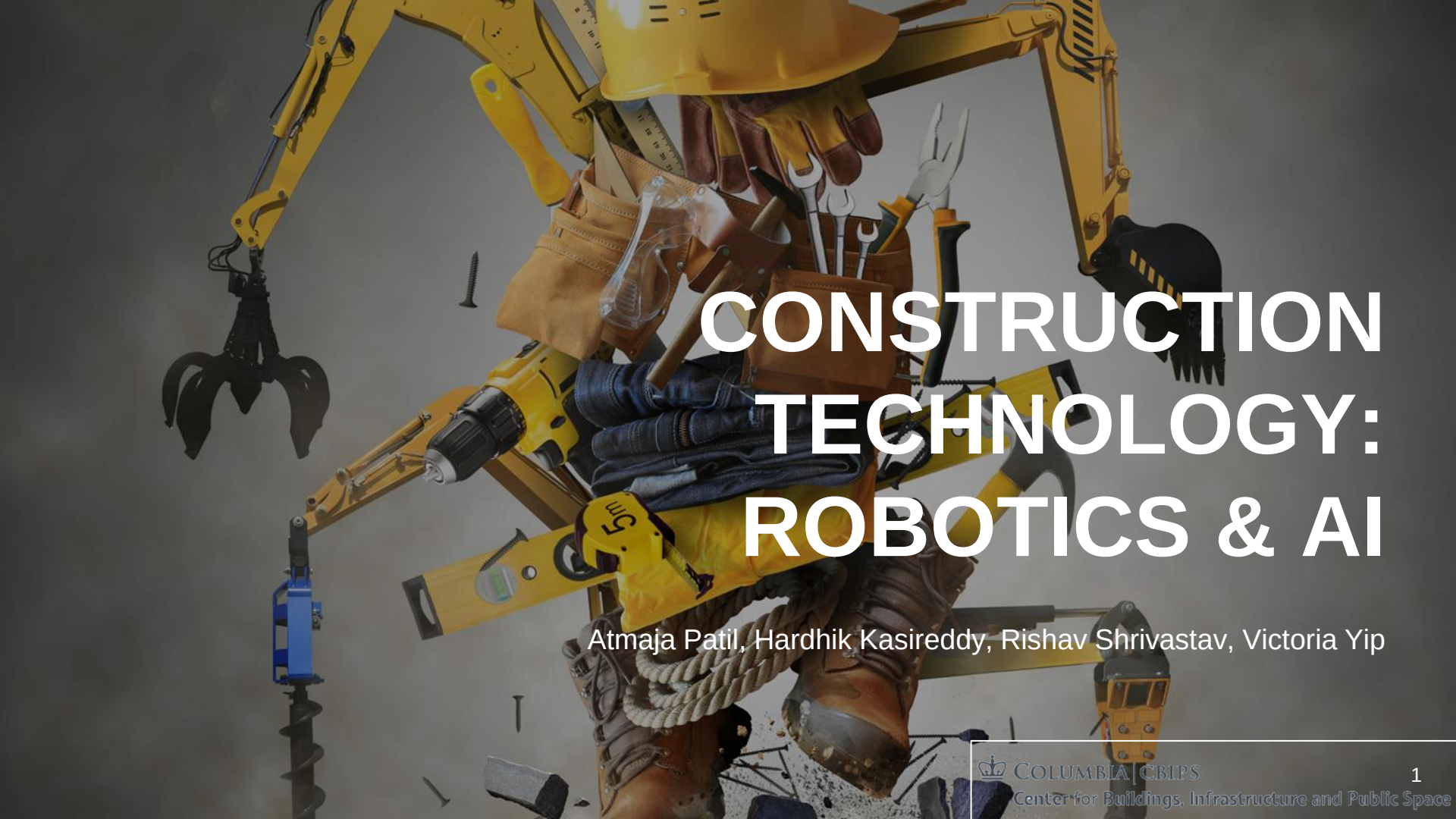


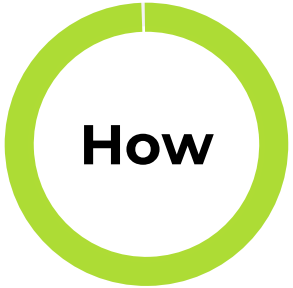
CONSTRUCTION TECHNOLOGY: ROBOTICS & AI

Atmaja Patil, Hardhik Kasireddy, Rishav Shrivastav, Victoria Yip

Table Of Contents

Introduction

- Helping to solve the skills shortage in construction
- Increasing speed
- Providing safer work environments
- Making sites more efficient



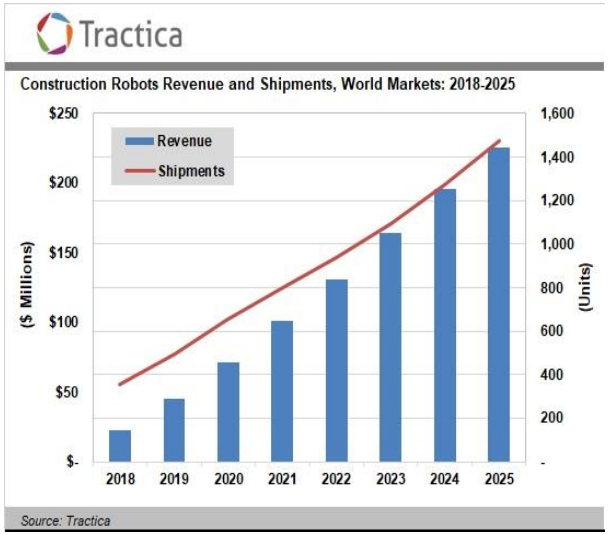
- Bricklaying Robots
- Demolition Robots
- Exoskeleton Robots
- Project Scheduling Robots
- Surveying Robots
- 3D Printing Robots

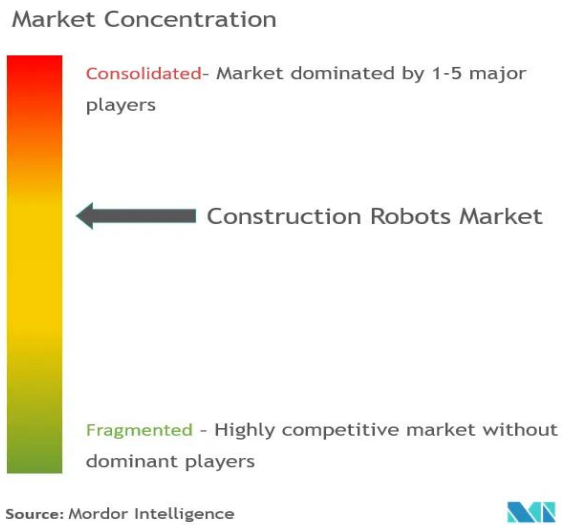
- 300,000 unfilled construction jobs in the U.S.
- An expectation that an additional 747,000 workers will be needed by 2026
- It is expected that there will be a displacement or replacement of at least 49 percent(2.7 million workers) by 2057: MEPI

- Advanced Construction Robotics
- Branch Technology
- Built Robotics
- Construction Robotics
- Dusty Robotics
- FBR – Fastbricks Robotics
- Hyperion Robotics
- KEWAZO
- OKIBO
- Scaled Robotics

- Asia
- North America
- Europe
- Mid-Western Countries
- Middle East

Market Analysis





Robotics and AI in Geotechnical Construction

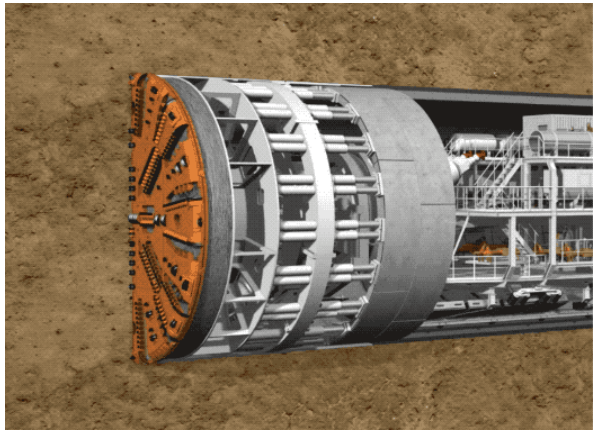
https://railsystem.net/tunnel-boring-machine-tbm/

Tunnel Boring Machines (TBM)

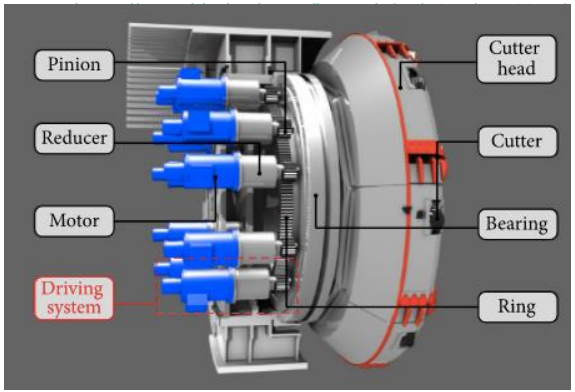
Recap: Constructed in situ, leaves surrounding and above ground undisturbed (unlike drilling & blasting)

Generally require human monitoring, recent technological developments in autonomizing

Use of TBM to drill U-55 in Berlin



https://www.cat-bus.com/2018/01/far-from-boringmeet-the-most-interesting-tunnel-boring-machines/



How TBMs work

Cutter Driving System - rotating cutter head is pushed forward to tunnel through in-situ ground

Disc cutters - mounted on cutter head to cut and crush rock, cutters on outermost circumference need to be replaced more often.

Varying and unpredictable geological conditions - replacement of disc cutters requires **stop work**, reduces efficiency

Case Study

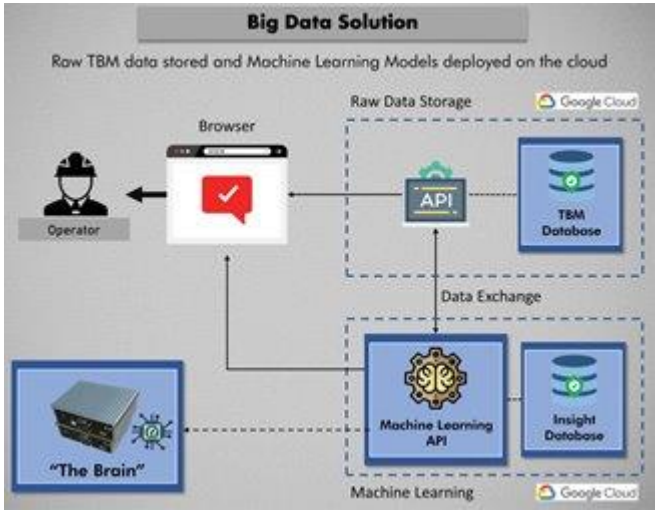
Autonomous TBMs and Big Data - ASME, Kuala Lumpur

Mass Transit Rail Corporation - $6 billion transit tunnel project

Development of variable-density TBM, works in soils of all types and consistencies - combination of Earth Pressure Balancing Machines and Slurry Machines

TBM is integrated with Big Data to automatically generate predictive and prescriptive analytics and insights

Traditionally rely on operators to control the steering system, advancement, excavation and slurry operations - AI and Big Data allow for the optimized efficiency and reduced human error



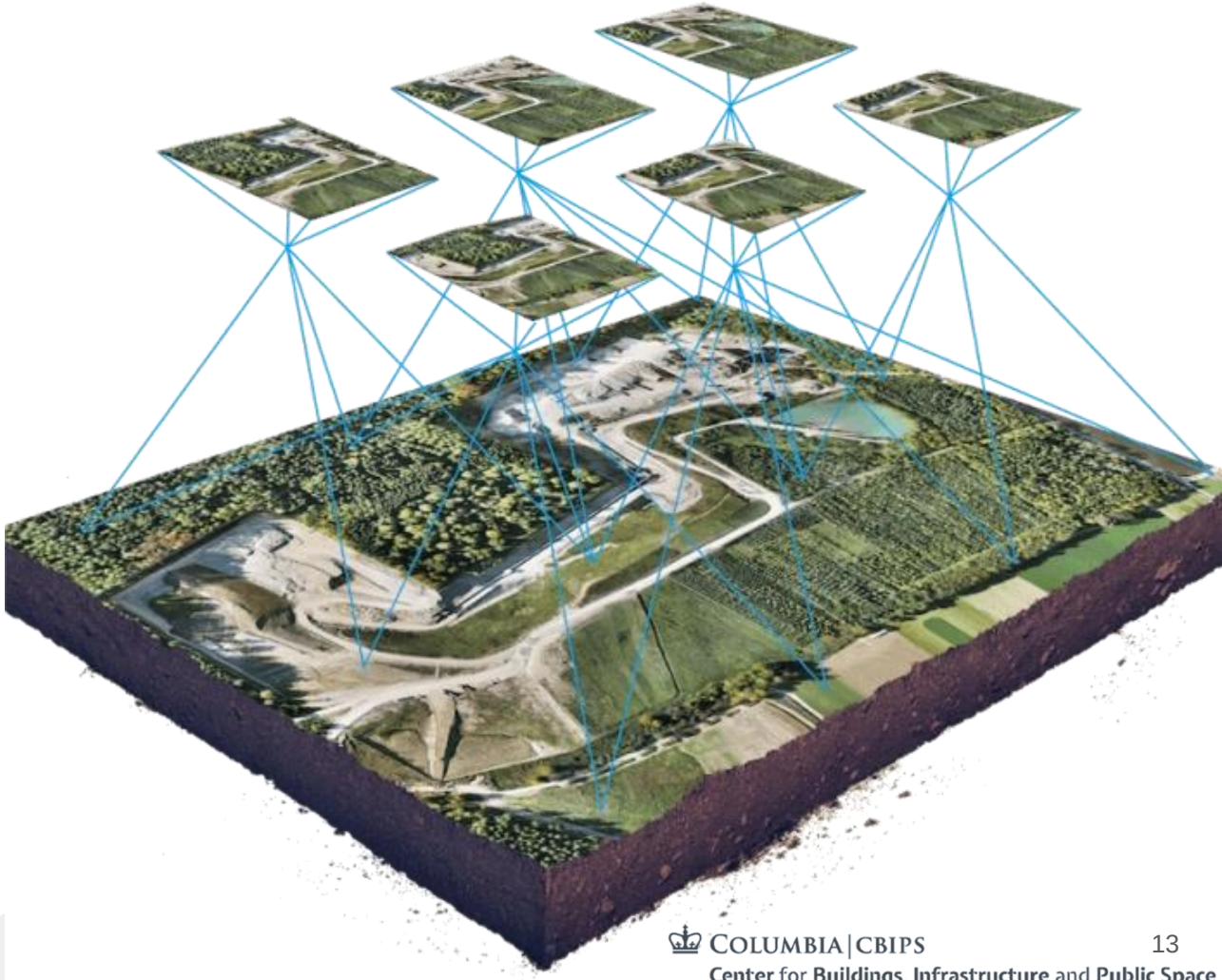
https://www.asme.org/topics-resources/content/big-data-spurs-autonomous-tunneling

Robotics & AI in Surveying

Drones:

A drone survey refers to the use of a drone, or unmanned aerial vehicle (UAV), to capture aerial data with downward-facing sensors, such as RGB or multispectral cameras, and LIDAR payloads.

During a drone survey with an RGB camera, the ground is photographed several times from different angles, and each image is tagged with coordinates.



https://wingtra.com/drone-mapping-applications/surveying-gis/

Deliverables:

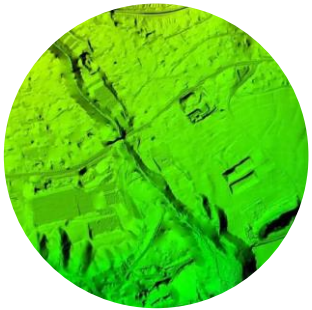
Orthomosaic Maps

3D Point Cloud

Digital Surface Model (DSM)

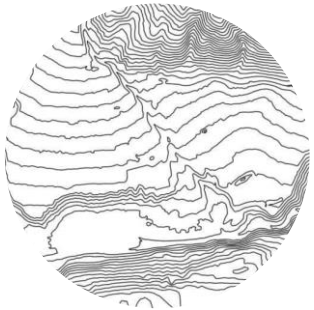
https://wingtra.com/drone-mapping-applications/surveying-gis/

Deliverables:



Digital Terrain Model

(DTS)



Contour Maps

3D Textured Mesh

https://wingtra.com/drone-mapping-applications/surveying-gis/

Applications:

LAND SURVEYING/CARTOGRAPHY

LAND MANAGEMENT & DEVELOPMENT

STOCKPILE VOLUMETRIC MEASUREMENT

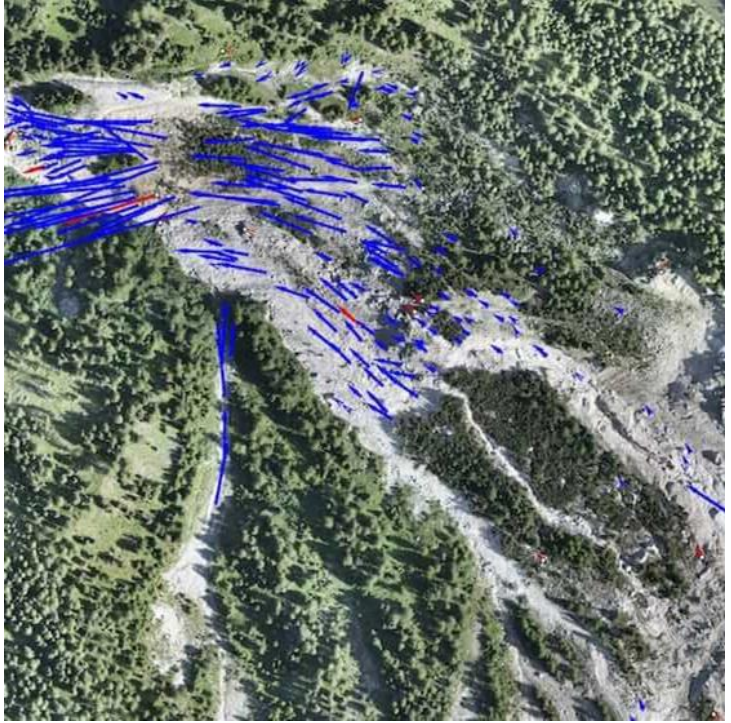
SLOPE MONITORING

URBAN PLANNING

Cadastral map overlaid on ariel image

https://wingtra.com/drone-mapping-applications/surveying-gis/

Volume measurement of Landfill in Bahamas



The length of the strokes represents the velocity of the earth movement. The longer the stroke, the faster the earth movement

https://wingtra.com/drone-mapping-applications/surveying-gis/

Process:

LEGAL PERMISSION

Federal Aviation Administration's (FAA) regulations: users must obtain a Part 107 remote operator's license

CHOOSE THE RIGHT SOFTWARE

Choose a solution made specifically for your intended application. Eg. **mdMapper**: surveying and mapping

TRAINING & SUPPORT

Basic training on use of the aircraft, flight planning, safety, and other necessary skills.

https://coptrz.com/5-steps-to-start-drone-surveying/
https://www.microdrones.com/en/content/how-do-i-get-started-with-using-drones-for-surveying/

Case Study I

A

ABOUT

Independence bridge over Willamette river, Oregon

B

AIM

Identify small defects and potential problems

C

TECHNOLOGY

DJI Phantom 3 Pro

D

RESULT

55 mins of Ultra high definition video for upstream and downstream

http://depts.washington.edu/pactrans/wp-content/uploads/2015/03/2015-S-OSU-82_Dan-Gillins_Cost-Effective-Bridge.pdf

Missing bolt-nut

Connection of a steel member to a concrete tower

Cracking of a concrete railing

http://depts.washington.edu/pactrans/wp-content/uploads/2015/03/2015-S-OSU-82_Dan-Gillins_Cost-Effective-Bridge.pdf

Case Study II

A

ABOUT

Sewer Inspection, Barcelona

B

AIM

Inspect the damage done to the underground sewer

C

TECHNOLOGY

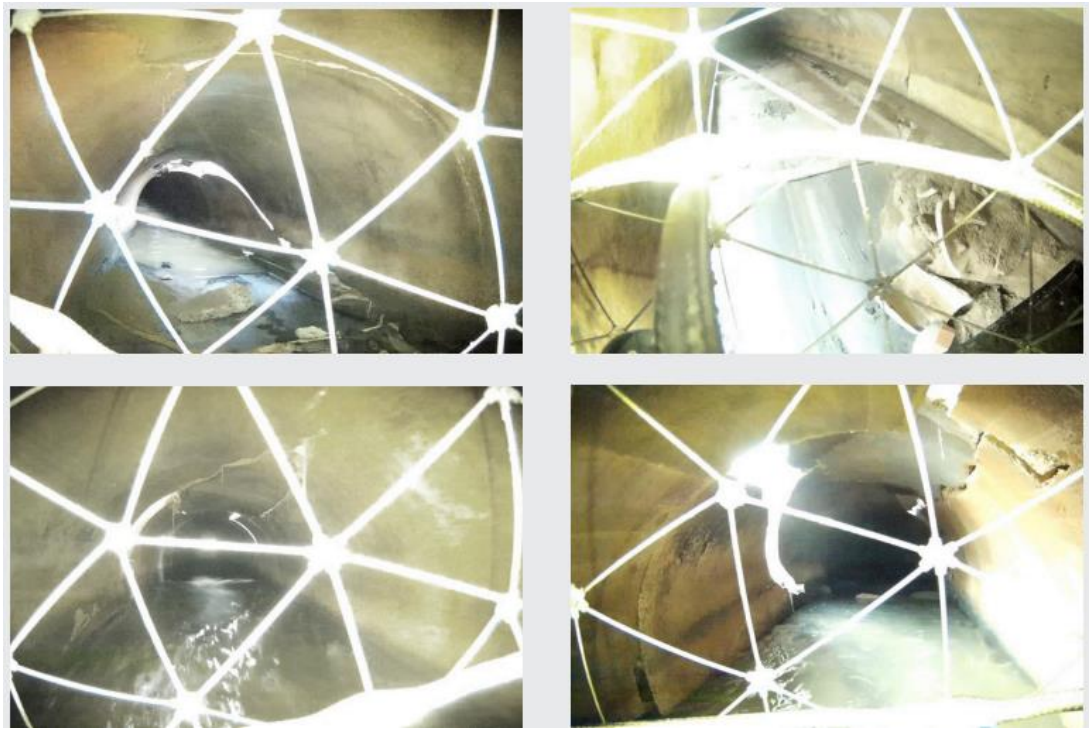
Elios collision-proof drone

D

RESULT

Showed the exact extent of the damage.

https://cdn2.hubspot.net/hubfs/2602167/Marketing%20Collaterals/Inspection%20of%20Wastewater%20Infrastructure%20with%20Flyability's%20Elios%20Solution.pdf



Mission pictures taken by Elios

https://cdn2.hubspot.net/hubfs/2602167/Marketing%20Collaterals/Inspection%20of%20Wastewater%20Infrastructure%20with%20Flyability's%20Elios%20Solution.pdf

Advantages

http://depts.washington.edu/pactrans/wp-content/uploads/2015/03/2015-S-OSU-82_Dan-Gillins_Cost-Effective-Bridge.pdf
https://www.heliguy.com/pages/drones-for-construction#drones-in-construction
https://guestwritershub.com/2021/01/10/the-pros-and-cons-of-using-drones-for-aerial-surveying/

Disadvantages

http://depts.washington.edu/pactrans/wp-content/uploads/2015/03/2015-S-OSU-82_Dan-Gillins_Cost-Effective-Bridge.pdf
https://www.heliguy.com/pages/drones-for-construction#drones-in-construction
https://guestwritershub.com/2021/01/10/the-pros-and-cons-of-using-drones-for-aerial-surveying/

DOT	Traffic Monitoring	Structural Inspection	Construction Site Inspection	Other Applications
Arkansas	X			
California				X
Connecticut		X		
Florida		X		
Georgia	X			
Michigan	X	X		X
Minnesota		X		
North Carolina				X
Ohio		X		X
Texas				X
Utah			X	
Washington	X			X
West Virginia	X		X	

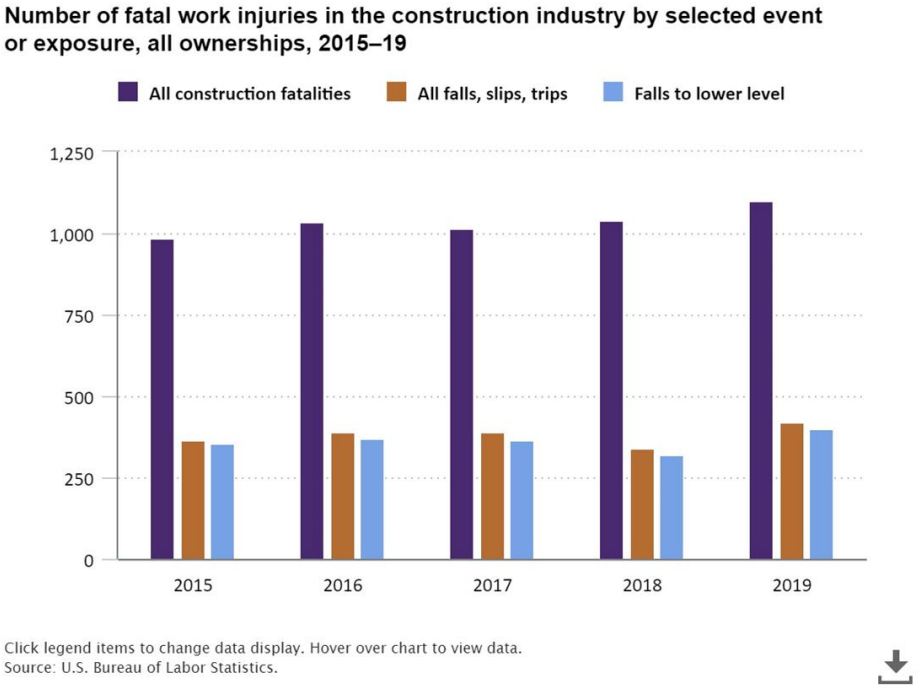
Example usage of UAS in various departments of transportation

http://depts.washington.edu/pactrans/wp-content/uploads/2015/03/2015-S-OSU-82_Dan-Gillins_Cost-Effective-Bridge.pdf

Robotics and AI in Safety

Construction Fatalities

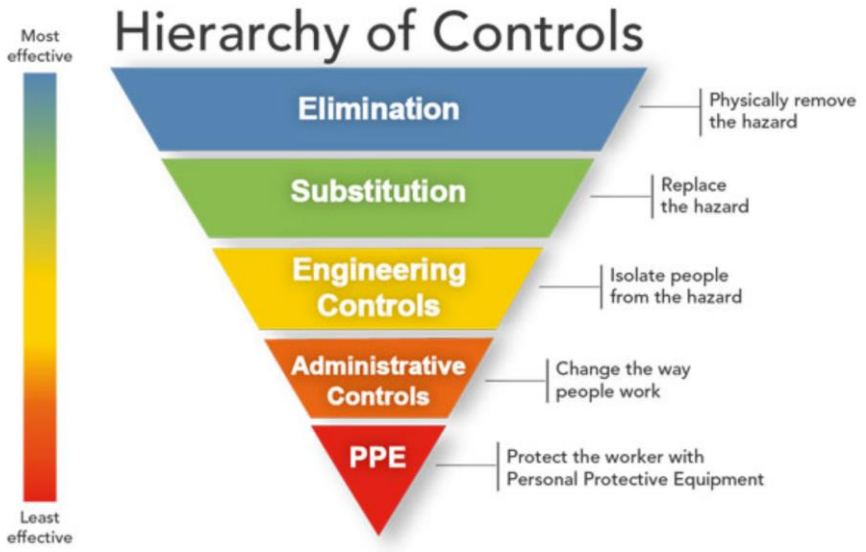
- According to the US Bureau of Labor Statistics, construction worker fatalities rose 5% in 2019, totaling 1,061 deaths



https://www.bls.gov/opub/ted/2021/fatal-and-nonfatal-falls-slips-and-trips-in-the-construction-industry.htm#:~:text=Bureau%20of%20Labor%20Statistics,-The%20Economics%20Daily&text=There%20were%201%2C102%20fatal%20injuries,the%20United%20States%20(5%2C333)

Hierarchy of Controls

- **Framework according to the National Institute for Occupational Safety and Health**



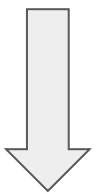
https://www.cdc.gov/niosh/topics/hierarchy/default.html

Example of hierarchy

Type of Control	Example of fall prevention
Elimination	Complete work at ground level instead of working at heights
Substitution	Use a lift to get into a position to work at heights instead of physically climbing
Engineering Control	Provide a safe working platform, scaffold, install guard rails, edge protection, catch-nets
Administrative Control	Employee training, alarms, job rotation, warnings, signage, permit to work systems
PPE	Wearing safety harness, inertia reel, high visibility vest, hard hats and safety shoes

Challenges implementing hierarchy

Unidentified Hazards

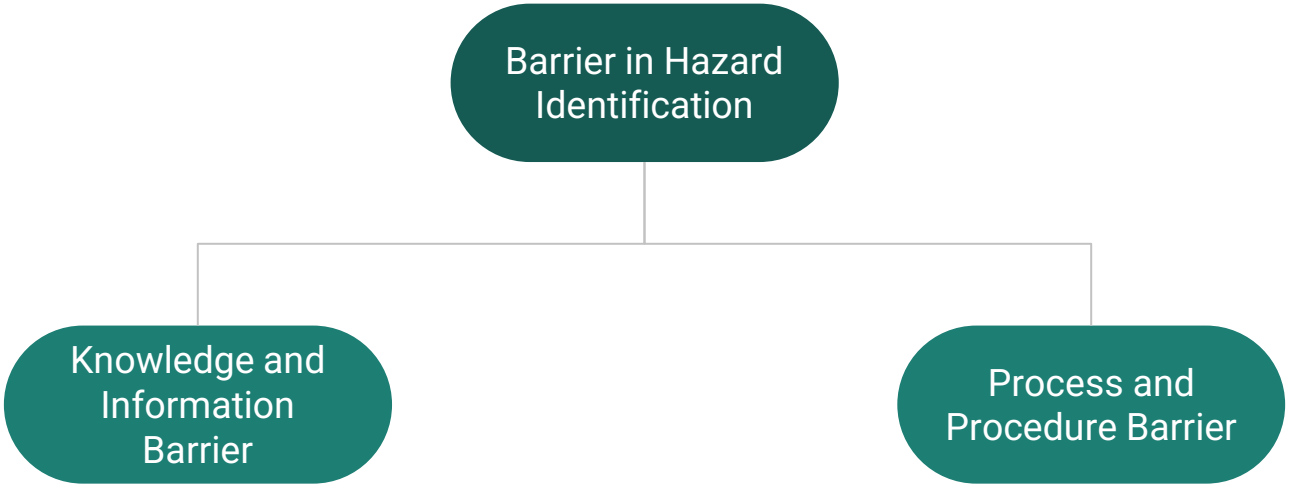


Uncontrollable Situation

- Lack of information sharing across projects
- Lack of resources on smaller projects
- Lack of current industry publications for reference
- Lack of full-time safety department, subjective nature of hazard identification and risk assessment
- Lack of standardized approach and unidentified structures for tasks and hazards

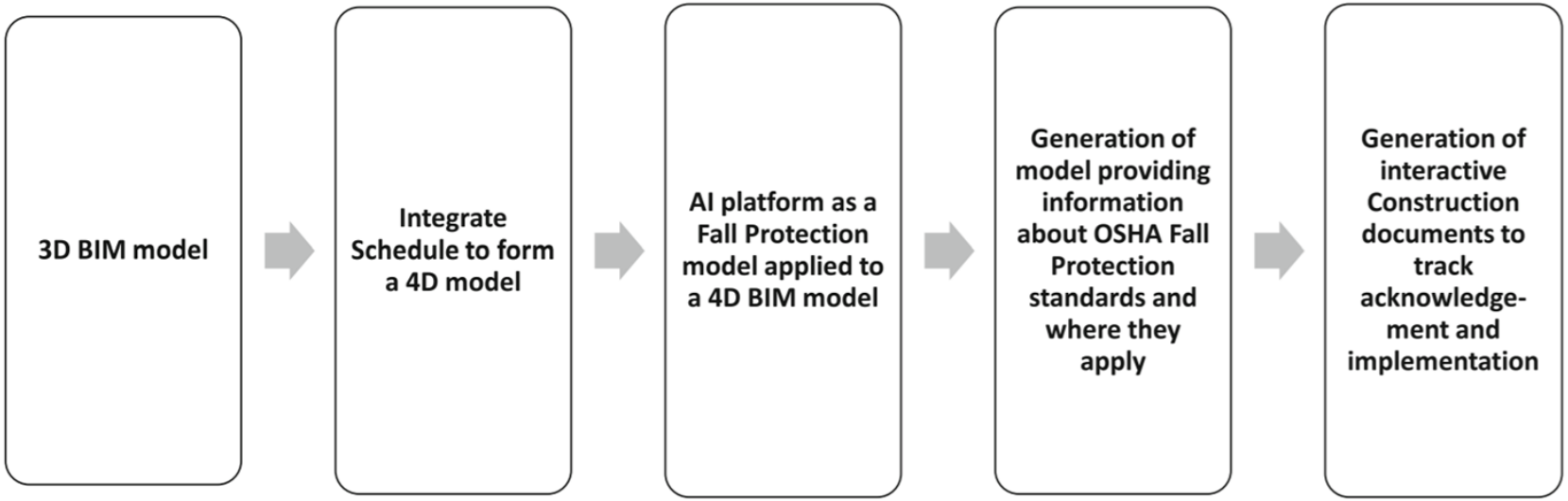
Artificial Intelligence for Construction Safety: Mitigation of the Risk of Fall: Proceedings of the 2018 Intelligent Systems Conference (IntelliSys) Volume 2

Hazard Identification



Whirlwind Team.: BIM for Construction Site Safety: how to Identify and Prevent Hazards. Retrieved 10 Jan 2018, from https://www.whirlwindsteel.com/blog/bim-for-constructionsite-safety-how-to-identify-and-prevent-hazards (2016, April 20)

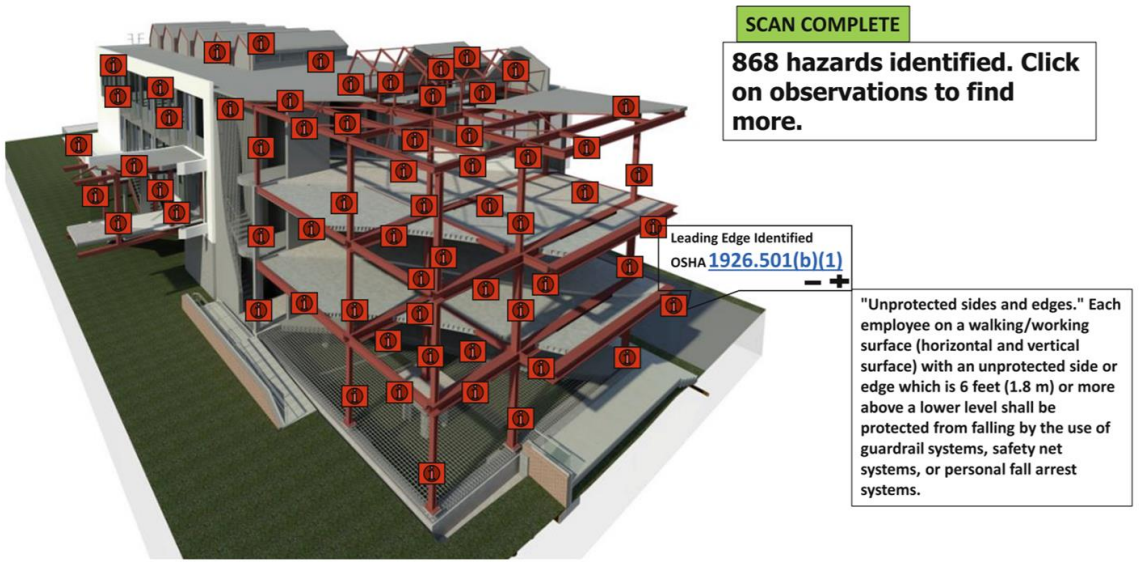
Framework of AI platform



Artificial Intelligence for Construction Safety: Mitigation of the Risk of Fall: Proceedings of the 2018 Intelligent Systems Conference (IntelliSys) Volume 2

Expected Outcome of Programme

BIM
+
AI



Artificial Intelligence for Construction Safety: Mitigation of the Risk of Fall: Proceedings of the 2018 Intelligent Systems Conference (IntelliSys) Volume 2

Documents Generated

Sl No	Hazards Identified	Risk	Area	Acknowledged by	OSHA Standards applicable	Measures taken	Close-out
1	Leading edge	Fall	Level-1, S1	Suprintendent	1926.501(b)(1)	Guardrails of height 1.2m, with intermedita rails at 1.2m and toe board of 200mm provided	04-06-2017
2	Work at height	Fall	Level-1, Column C1		1926.502(a)(1)		
3	Work at height	Fall	Level-1, Column C2		1926.502(a)(1)		
4	Work at height	Fall	Level-1, Column C3		1926.502(a)(1)		
5	Leading edge	Fall	Level-1, S2		1926.501(b)(1)		
6	Work at height	Fall	Level-1, Column C4		1926.502(a)(1)		
7	Work at height	Fall	Level-1, Column C5		1926.502(a)(1)		
8	Work at height	Fall	Level-1, Column C6		1926.502(a)(1)		
9	Work at height	Fall	Level-1, Column C7		1926.502(a)(1)		
10	Work at height	Fall	Level-1, Column C8		1926.502(a)(1)		
11	Work at height	Fall	Level-1, Column C9		1926.502(a)(1)		
12	Work at height	Fall	Level-1, Column C10		1926.502(a)(1)		
13	Leading edge	Fall	Level-1, S3		1926.502(a)(1)		
14	Slab opening	Fall	Level-1, S1		1926.501(b)(4)(i)		
15	Slab Opening	Fall	Level-1, S1		1926.501(b)(4)(i)		

Ways to use BIM coordination to promote safety

Barista, D.: BIM for Safety: how to Use BIM/VDC Tools to Prevent Injuries on the Job Site. Retrieved 10 Jan 2018, from https://www.bdcnetwork.com/bim-safety-how-use-bimvdctools-prevent-injuries-job-site (2015, February 8)

Example

Turner Construction uses Solibri Model Checker

Barista, D.: BIM for Safety: how to Use BIM/VDC Tools to Prevent Injuries on the Job Site. Retrieved 10 Jan 2018, from https://www.bdcnetwork.com/bim-safety-how-use-bimvdctools-prevent-injuries-job-site (2015, February 8)

Common Safety Check at Turner

- Material storage locations, and their proximity to fire hydrants and adjacent structures
- Design criteria for the ramps on the site, including slope, landing distances at the top and bottom, and entrance and exit locations
- Location, size, and timeline of temporary job site hazards—floor penetrations, perimeter protection areas, etc.—and the materials required for protection
- Requirements for erosion and sedimentation control
- Equipment and egress requirements by phase
- Pedestrian protection measures

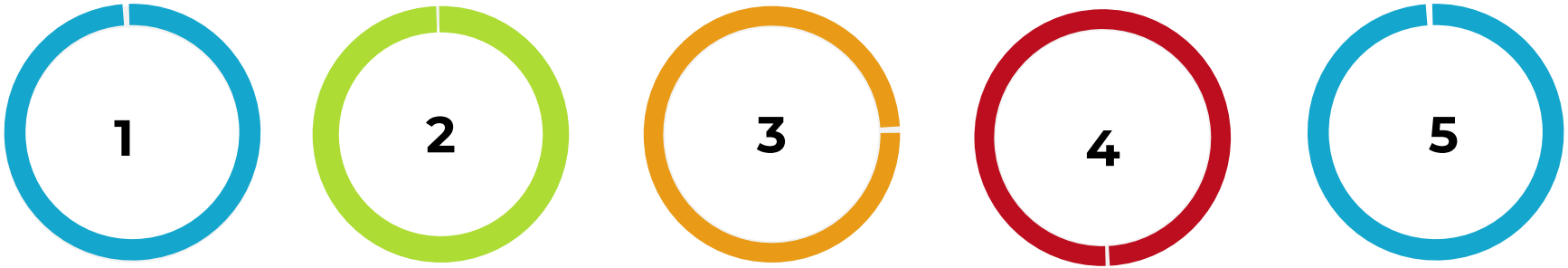
Barista, D.: BIM for Safety: how to Use BIM/VDC Tools to Prevent Injuries on the Job Site.
Retrieved 10 Jan 2018, from https://www.bdcnetwork.com/bim-safety-how-use-bimvdctools-prevent-injuries-job-site (2015, February 8)

Limitations

- AI + BIM has not been explored.
- Extensive effort is required to prepare this program.
- Acceptance from construction industry.

Robotics & AI in Project Management

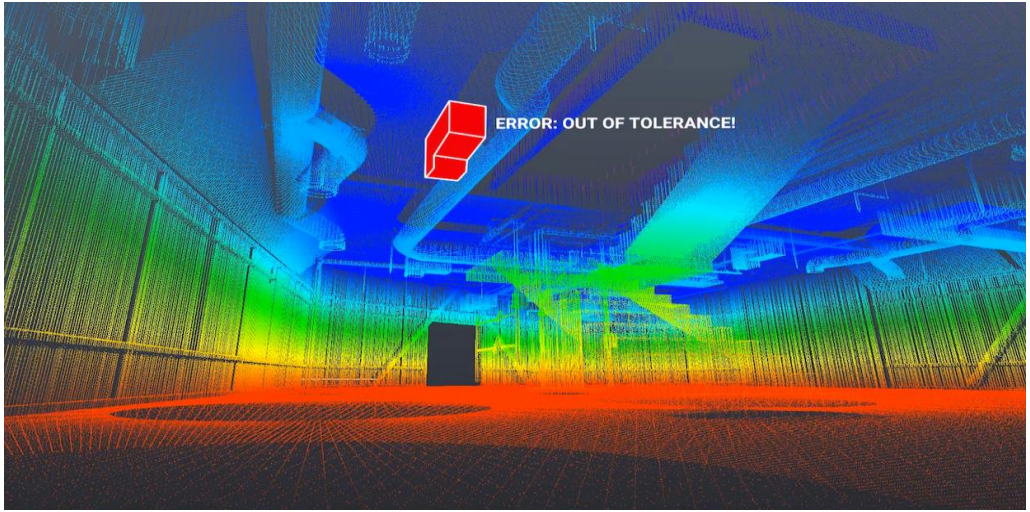
Need for Robots in Project management and Scheduling

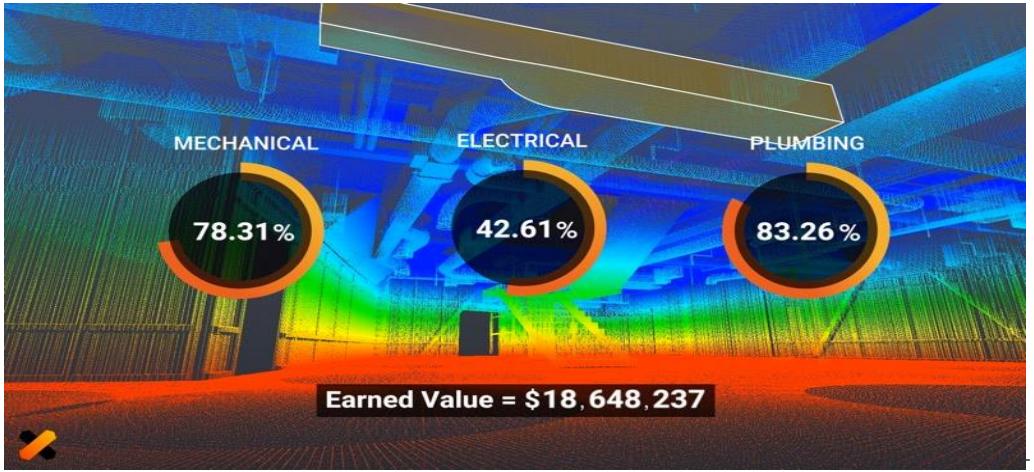


1. To Avoid Human Errors
2. Cost overruns and schedule delays
3. Cloud Based Platform to store data
4. Useful in regions where there is less manpower
5. Fast and Easy and Reliable

How Does It Work?

- Autonomous devices to scan every inch of a site on a daily basis with LIDAR and HD cameras.
- Proprietary AI algorithm processes the visual data, inspects installation quality, and quantifies
- Cloud-based dashboard ingests data on person-hours spent on the job, compares it to progress measured by AI and predicts a project's cost-at-completion and completion date based on current productivity





Types of Equipment

Company Producing: Doxel

Company Producing: BuildBot and Doxel

Expected Outcome of Programme

BIM
+
AI

About Doxel

- Doxel is an artificial intelligence startup founded in 2016 by Saurabh Ladha (CEO) and Robin Singh (CTO). It is developing an AI-Powered Project Controls solution for the construction sector.
- Doxel is the only solution on the market that can take video footage of a job site, 3D blueprints, a project budget, and a project timeline and tell clients exactly how much progress has been made on their job site today and how much progress will be made in the future in real time.
- The business uses a variety of ML models of varying complexity, ranging from simple heuristics to Graph Neural Networks (GNN), which are specifically designed to compare mesh and point cloud data.

Case Study 1

ABOUT

Kaiser Permanente Viewridge Medical Office, San Diego, California

AIM

Integrating all modules of project planning on one platform

TECHNOLOGY

Doxel AI

RESULT

- 38% increase in labor productivity
- 11% Under Budget
- 96% Accuracy
- 6x more lead time

Advantages


COST SAVINGS
REDUCED RISK
TIME SAVING
ACCURACY
Integrated Platform

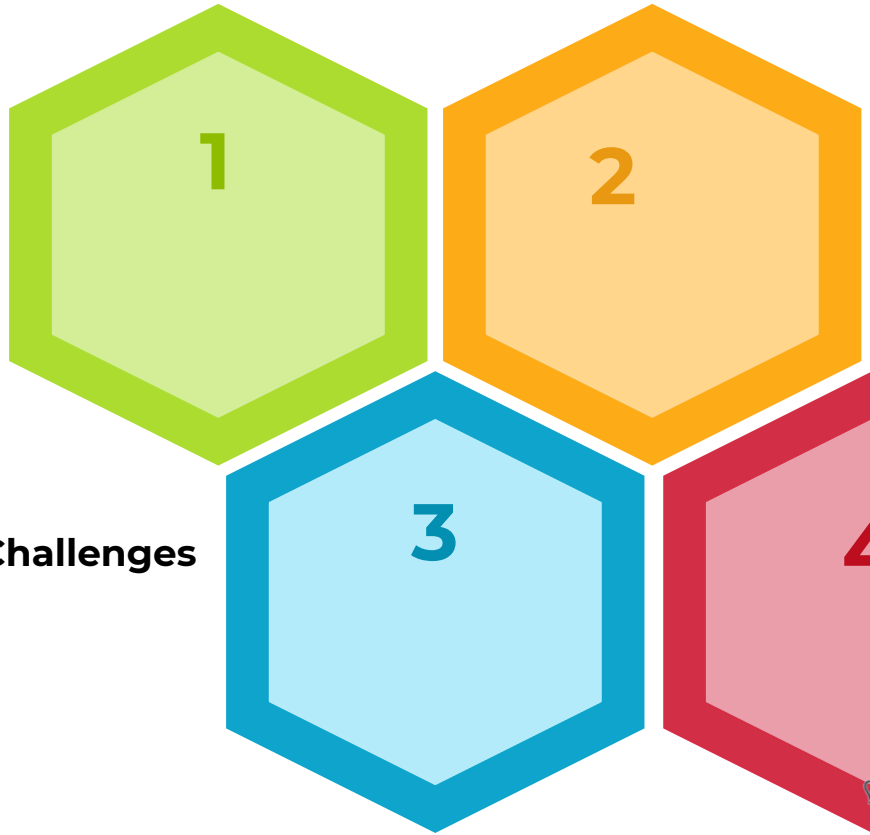
Disadvantages

Cost of Product

Accessibility to the product

Repair and Maintenance

Future Research Agenda



SWOT Analysis

Competitors and Market Analysis

Challenges

How to Improve


Thank You