



JANUARY 2024

Artificial Intelligence and the Future of Engineering

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Chief Technology Officer

Thornton Tomasetti

OUR LOCATIONS



1,700

ENGINEERS,
ARCHITECTS,
SCIENTISTS
AND OTHER
PROFESSIONALS

150

COUNTRIES
WORKED IN

45+

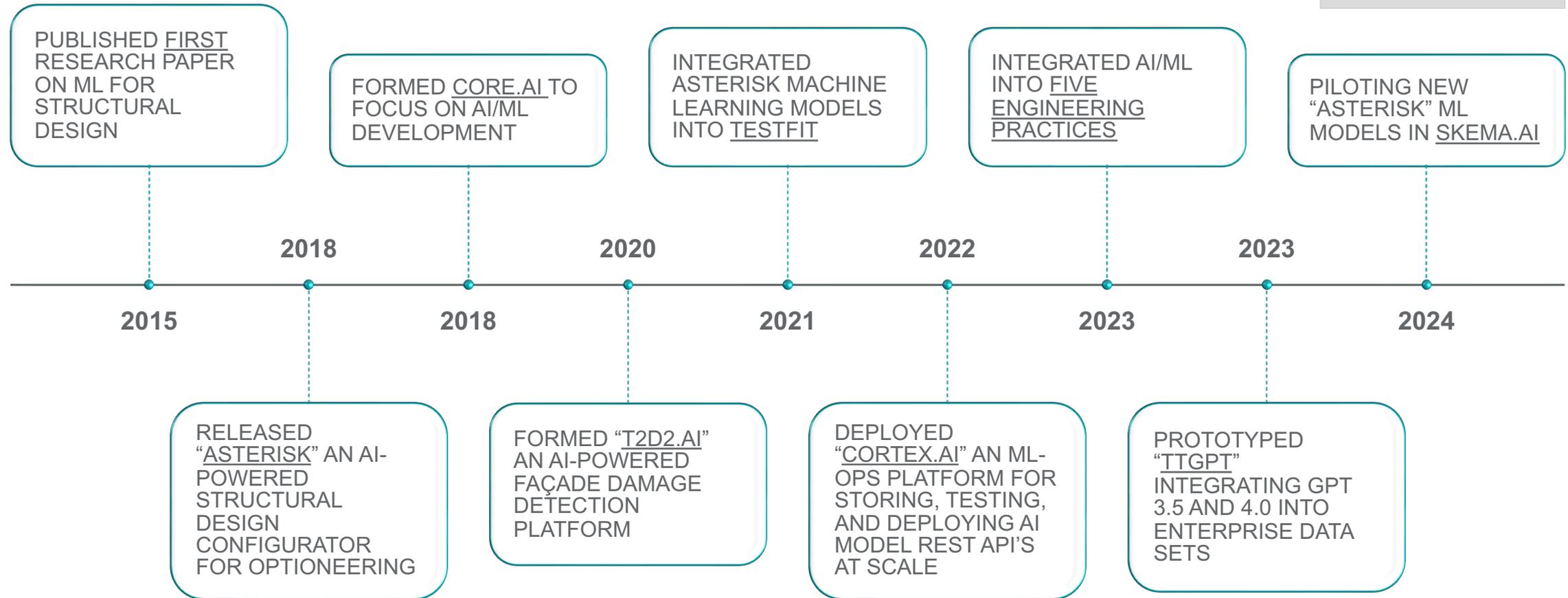
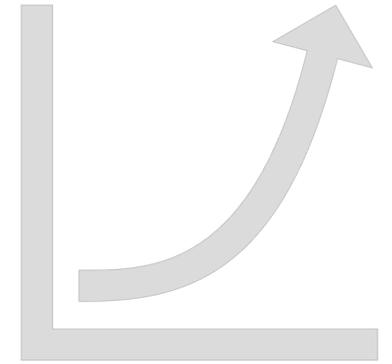
OFFICES

5

CONTINENTS

AI @ TT

FROM R&D TO PRACTICE



AGENDA

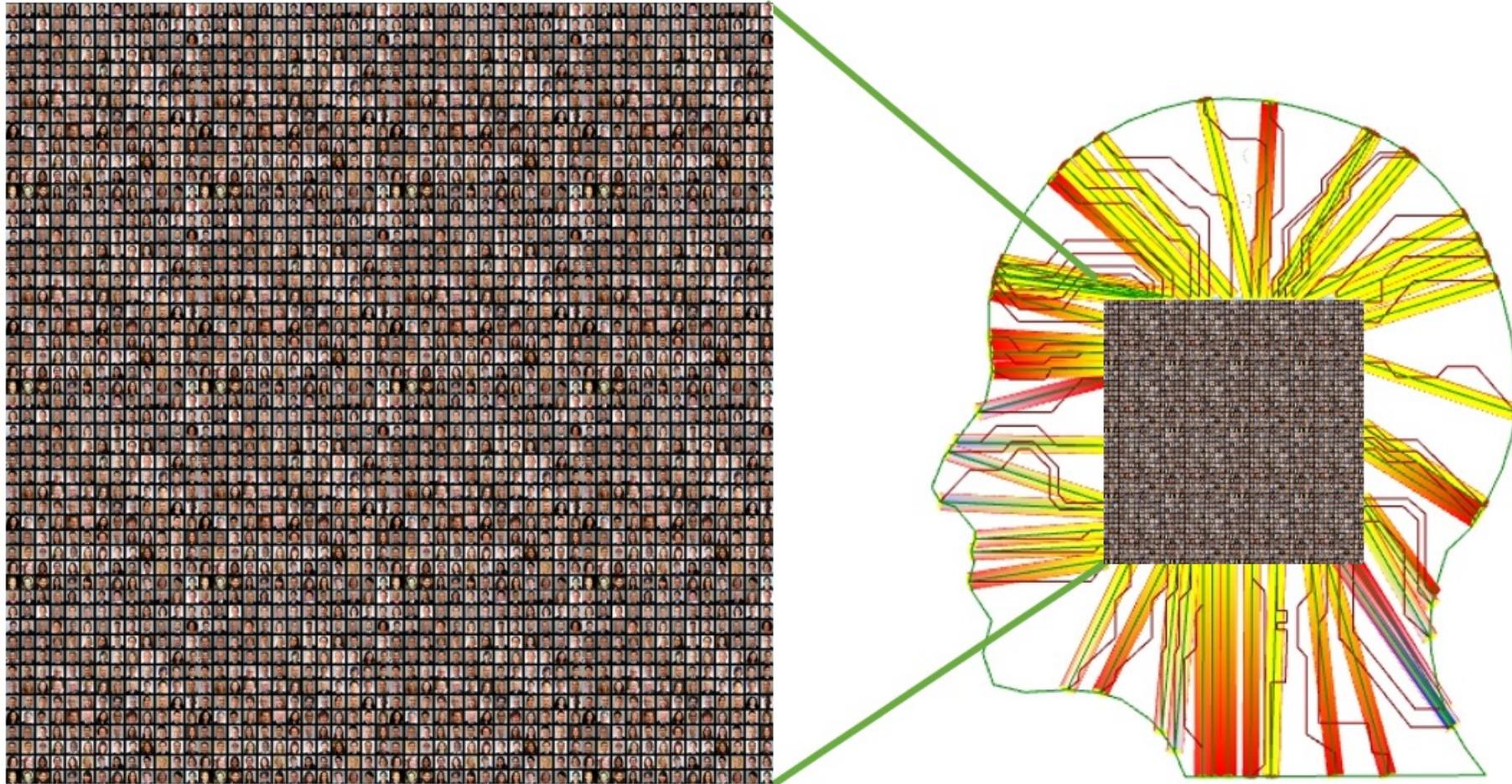
1. Define Artificial Intelligence and Machine Learning.
2. Explain how AI/ML can be used to improve their business functions.
3. Describe applications that have been developed at Thornton Tomasetti and how they can be used in projects.
4. Describe how Large Language Models (LLM's) can be used in everyday tasks to improve their learning and communications

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WHAT IF THE ENTIRETY OF THE FIRM'S KNOWLEDGE (PAST AND PRESENT) WAS ACCESSIBLE BY EVERY TT EMPLOYEE?



WHAT IS AI / ML?

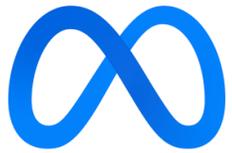


AI is everywhere



Google

amazon.com[®]

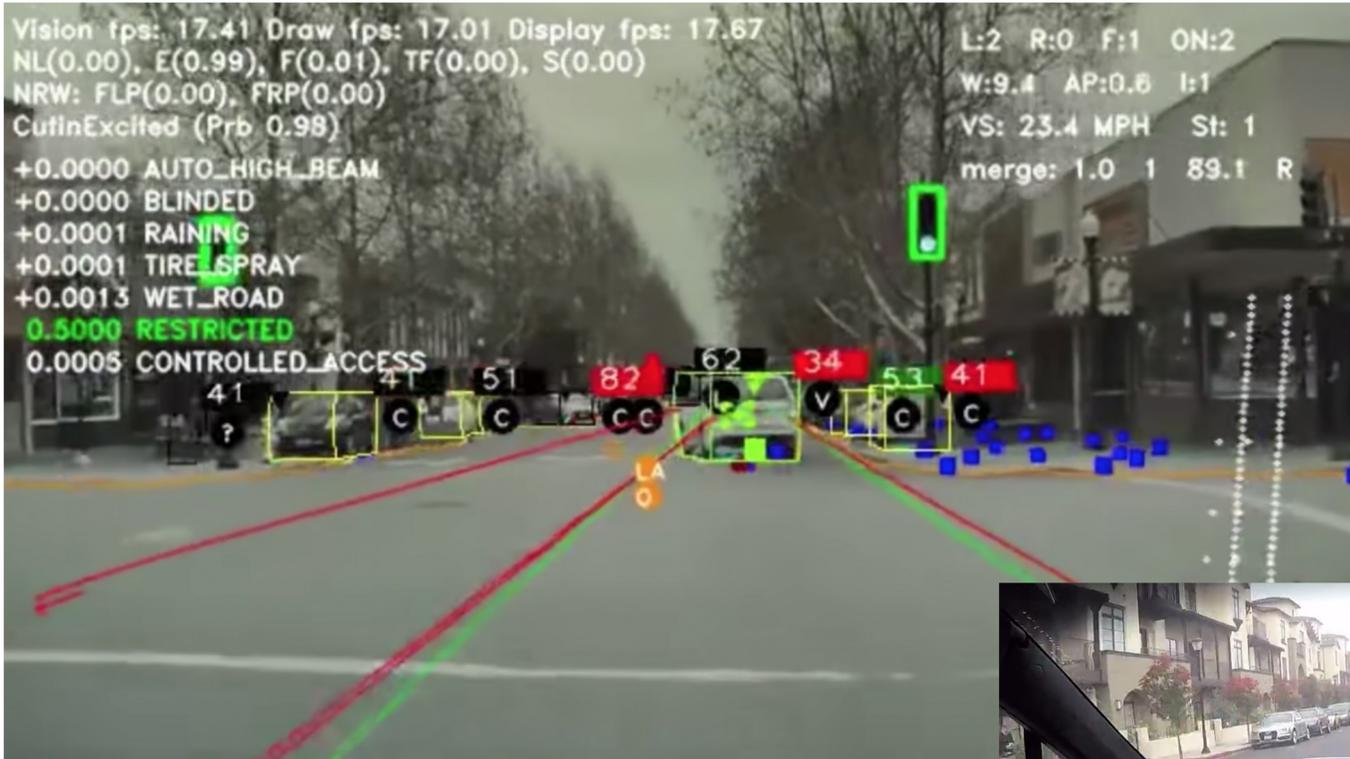


UBER

NETFLIX



AI in 2023



TESLA AUTOPILOT 2023



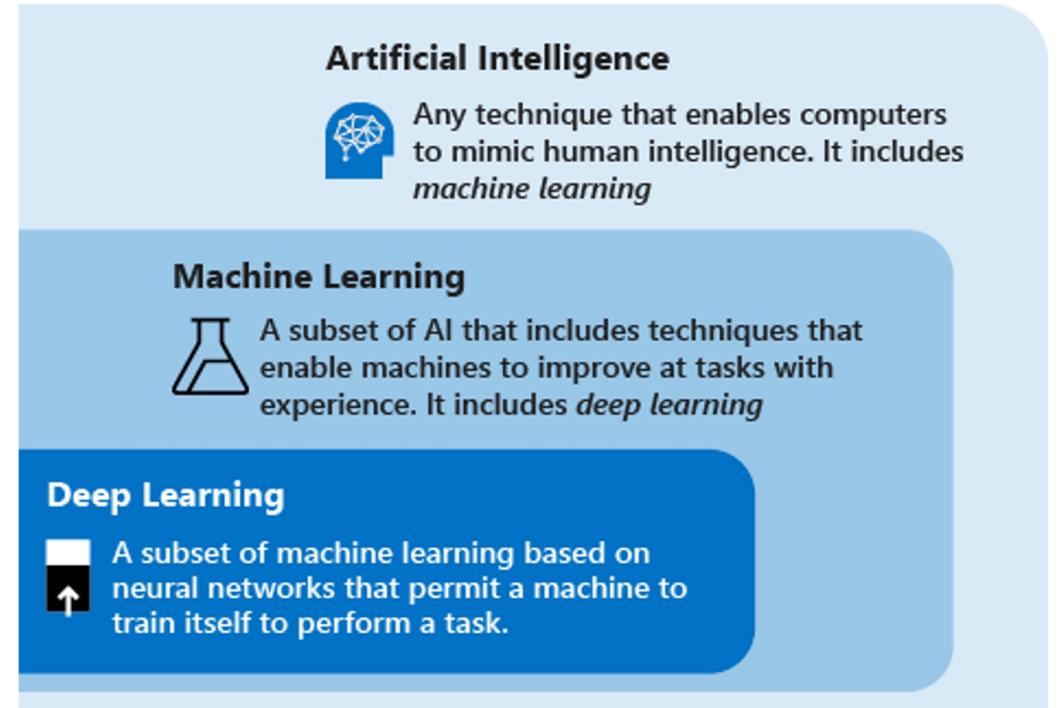
WHAT IS AI?

Mckinsey: What is AI?

Artificial intelligence is a machine's ability to perform the cognitive functions we usually associate with human minds.

IS ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING THE SAME THING?

“AI is a bigger concept to create intelligent machines that can simulate human thinking capability and behavior, whereas, machine learning is an application or subset of AI that allows machines to learn from data without being programmed explicitly.” *Javatpoint.com*



Microsoft.com

WHY USE AI?

Mckinsey: What is AI?

- More specifically, this group of leaders is more likely to link AI strategy to business outcomes and “industrialize” AI operations by designing modular data architecture that can quickly accommodate new applications.

AI IS THE NEW EXCEL ¹⁰

Andrew Ng, DeepLearning.AI, Coursera, Google Brain and Stanford University

AI IS "REAL" INTELLIGENCE

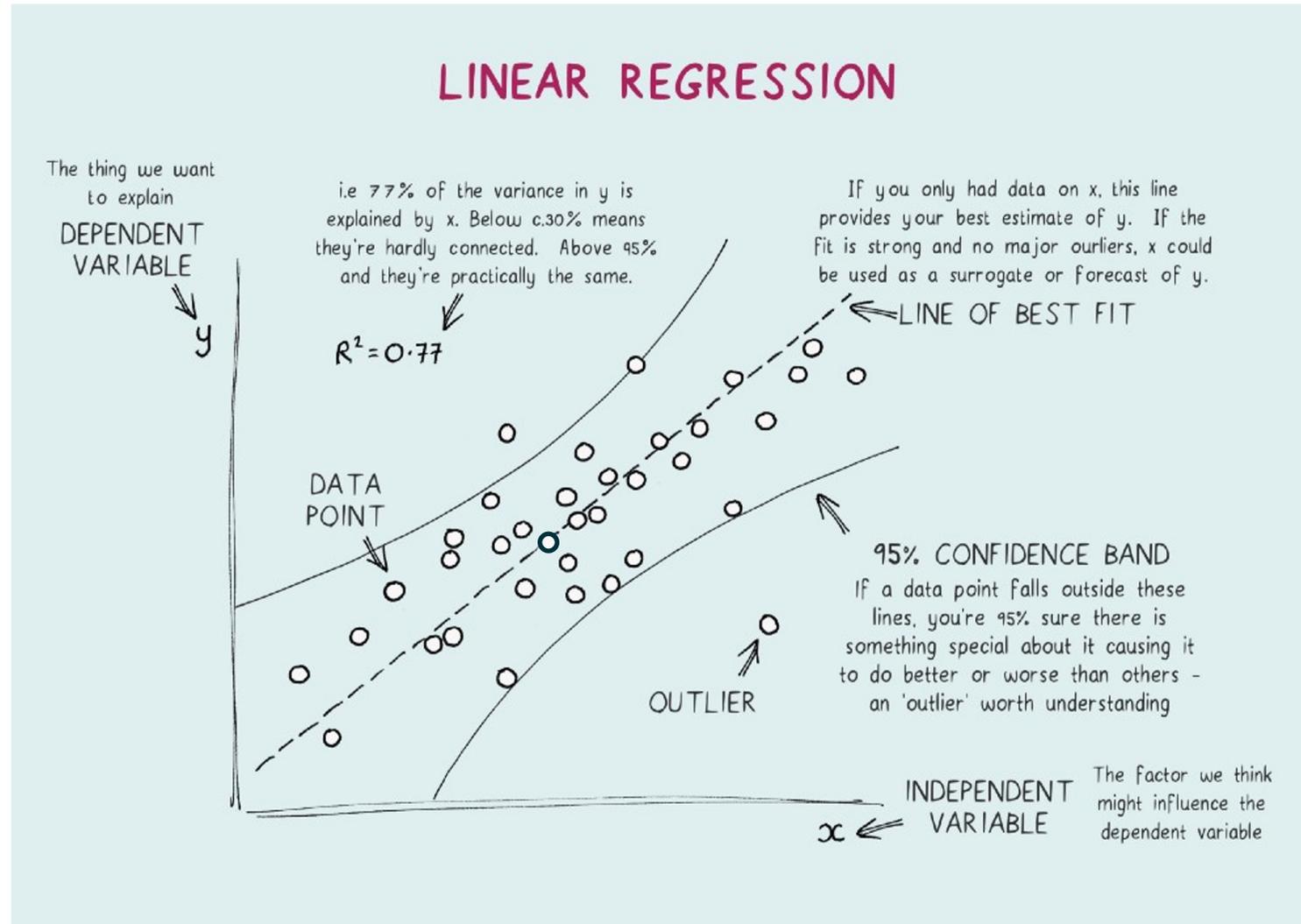


Image by Dan White 1000 on Shutterstock

[Towardsdatascience.com](https://towardsdatascience.com)

AI/ML: INGREDIENTS



DOMAIN EXPERTISE



MINED DATA SETS



“SYNTHETIC” DATA SETS



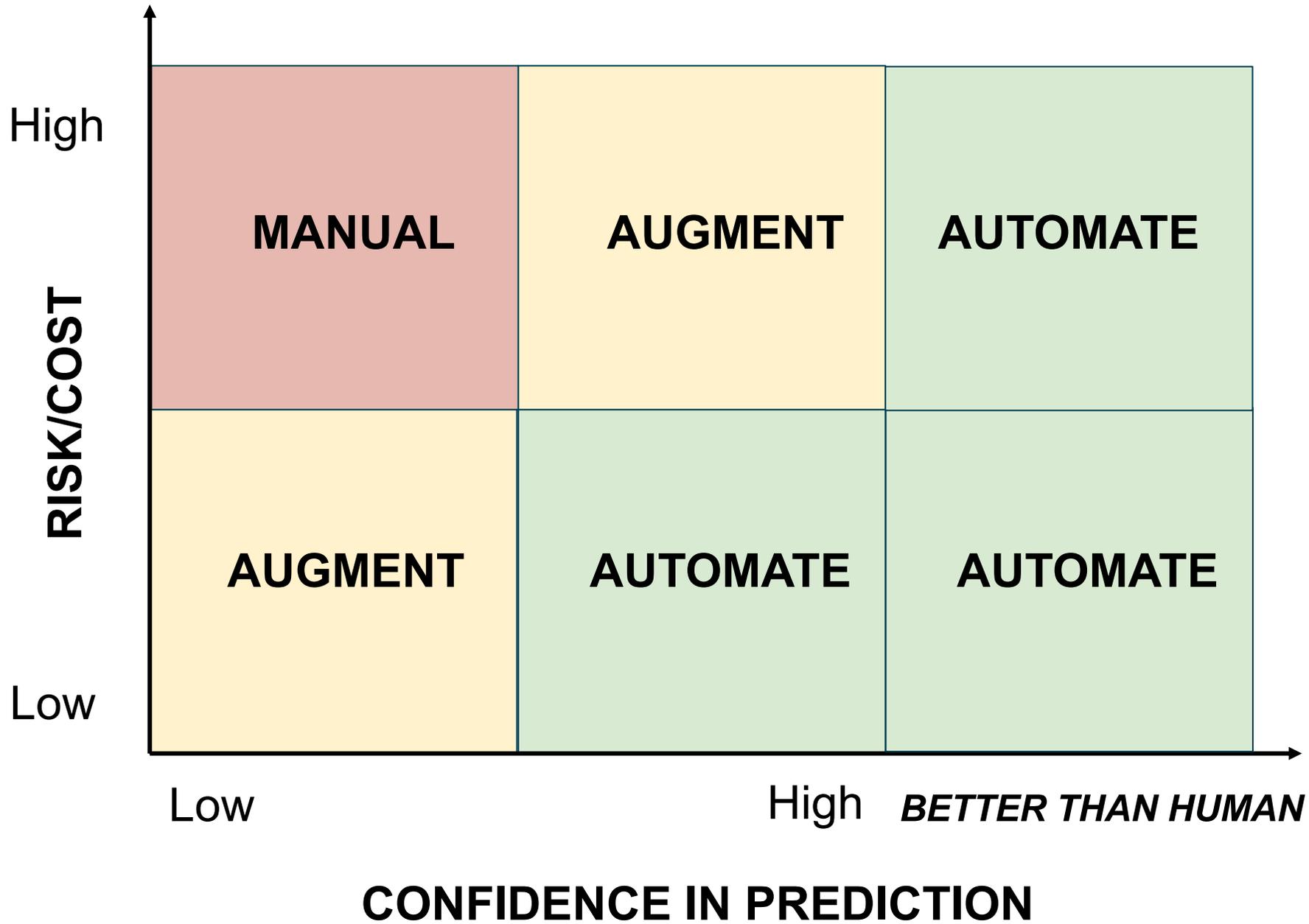
SOFTWARE DEVELOPMENT



ML OPS

DATA

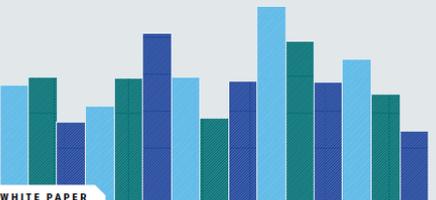




Why should engineers be aware of it's potential



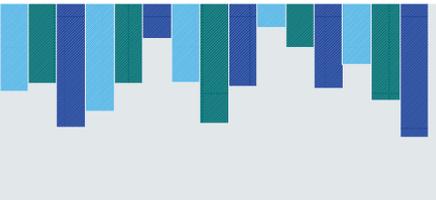
AI IN AEC AND TT + AI

WHITE PAPER

Leveraging Artificial Intelligence and Automation for Return on Investment in Innovation

Architecture, Engineering, and Construction Sector

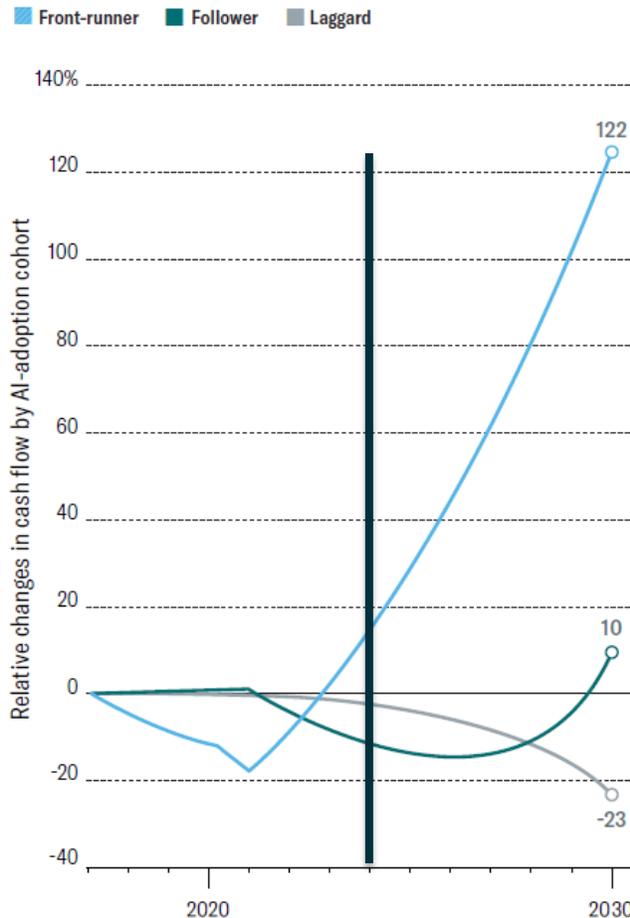


Sponsored by



Advantages Accrue to Early Adopters

By 2030, front-runners in adopting artificial intelligence could double their cash flow



Source: McKinsey & Co., September 2018

McKinsey analysts found front-runners in artificial intelligence (AI) adoption could double their cash flow (economic benefit captured minus associated investment and transition costs) by 2030, with a 122% cumulative change.

“Notes from the AI frontier: Modeling the impact of AI on the world economy,” McKinsey & Co., September 2018

Nonadopters [of artificial intelligence] “might experience around a 20% decline in their cash flow from today’s levels,” according to a 2018 McKinsey & Co. report.

AI/ML SOLVES BUSINESS PROBLEMS (NOW)

AEC PROBLEM STATEMENT	AI/ML SOLUTIONS
TALENT SHORTAGE	AI IS FAST! DO MORE WITH LESS
SCOPE CREEP	AI/ML SOLUTIONS SOLVE 50-100X
STEEP LEARNING CURVE IN ENGINEERING	SHORT CIRCUITS TRADITIONAL LEARNING BY MAKING "MISTAKES"
KNOWLEDGE IS SILOED IN OFFICES/PEOPLE	AGGREGATES KNOWLEDGE

WHY ADOPT AI?



VS



“AGILE COMPANIES WILL TAKE ADVANTAGE OF AI AND BOOST THEIR POSITION. COMPANIES LESS SO WILL PERISH,” THE CEO TOLD GRADUATING STUDENTS AT THE NATIONAL TAIWAN UNIVERSITY IN TAIPEI.

“WHILE SOME WORRY THAT AI MAY TAKE THEIR JOBS, SOMEONE WHO'S EXPERT WITH AI WILL.”

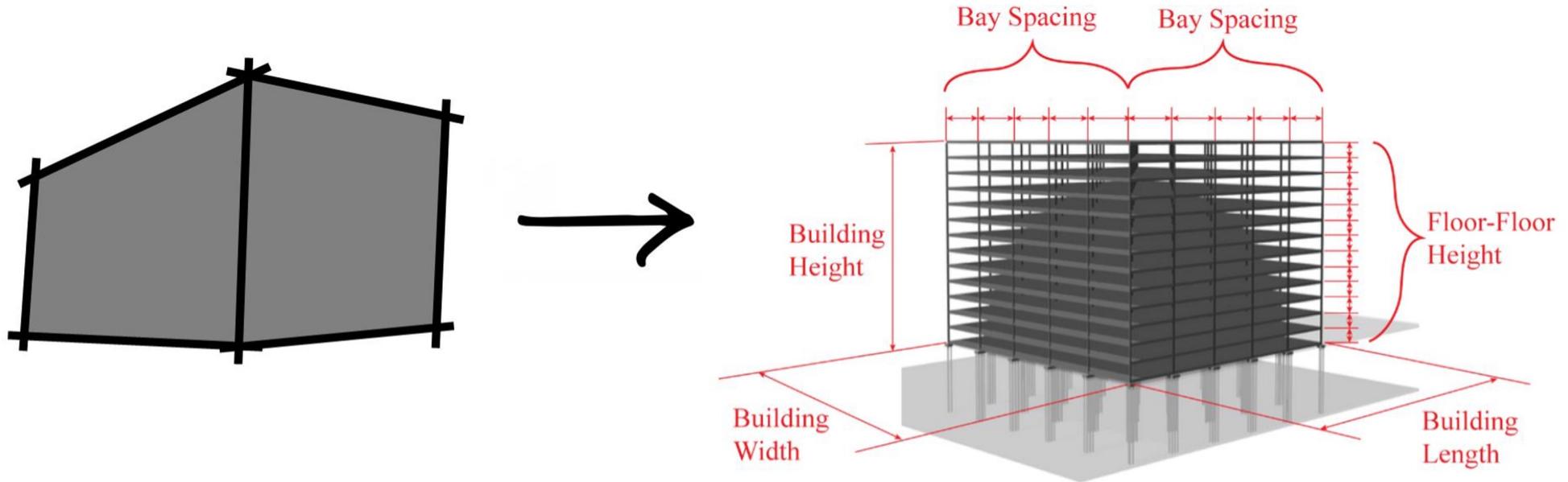
Jensen Huang, Nvidia

**AI/ML IS THE MOST IMPACTFUL
TECHNOLOGY TO TRANSFORM
AEC / ENGINEERING IN ITS HISTORY**

CORE.AI APPLICATIONS



AI R&D in 2015 (Ref. IASS “Performance Measures from Architectural Massing Using Machine Learning)



Input Parameters

Geometry
Structural System
Materials

Structural Calculation

Column Size
Beam Framing Size/Spacing
Slab Thickness
Rebar Layout
...

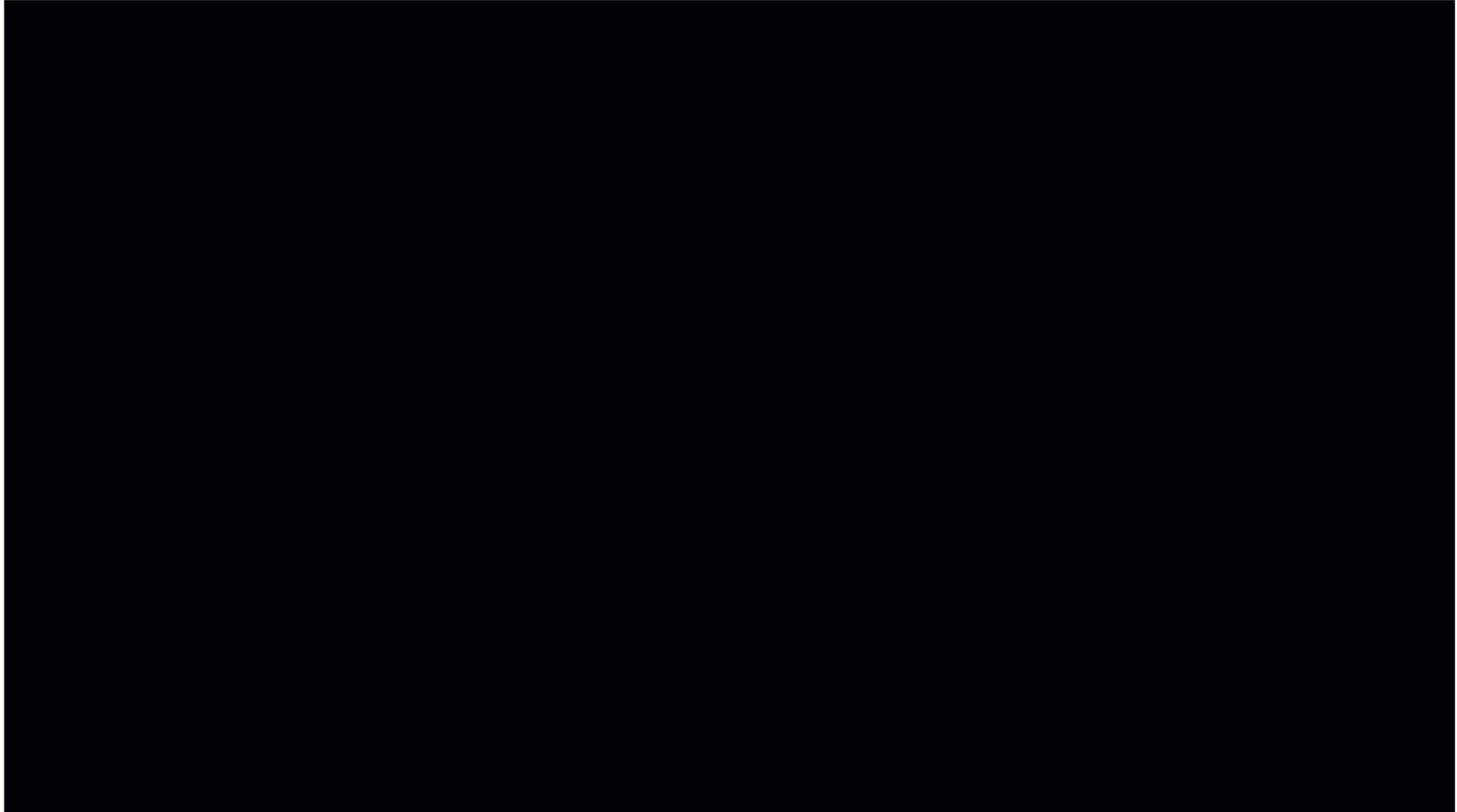
Quantity Takeoff

Volume of Steel
Volume of Concrete

Embodied Energy Calculation

$$\begin{aligned} (V_Steel)(\rho)(EE/kg) &= EE_Steel \\ (V_Concrete)(\rho)(EE/kg) &= + EE_Concrete \\ &= \frac{\quad}{Total\ EE} \end{aligned}$$

AI R&D - Synthetic Data Creation 2015



AI R&D

Brute Force Method: If each design iteration takes 5 minutes, calculating all of the possible combinations would take 95 years!!

Proceedings of the International Association for Shell and Spatial Structures (IASS) Symposium 2015, Amsterdam
Future Visions

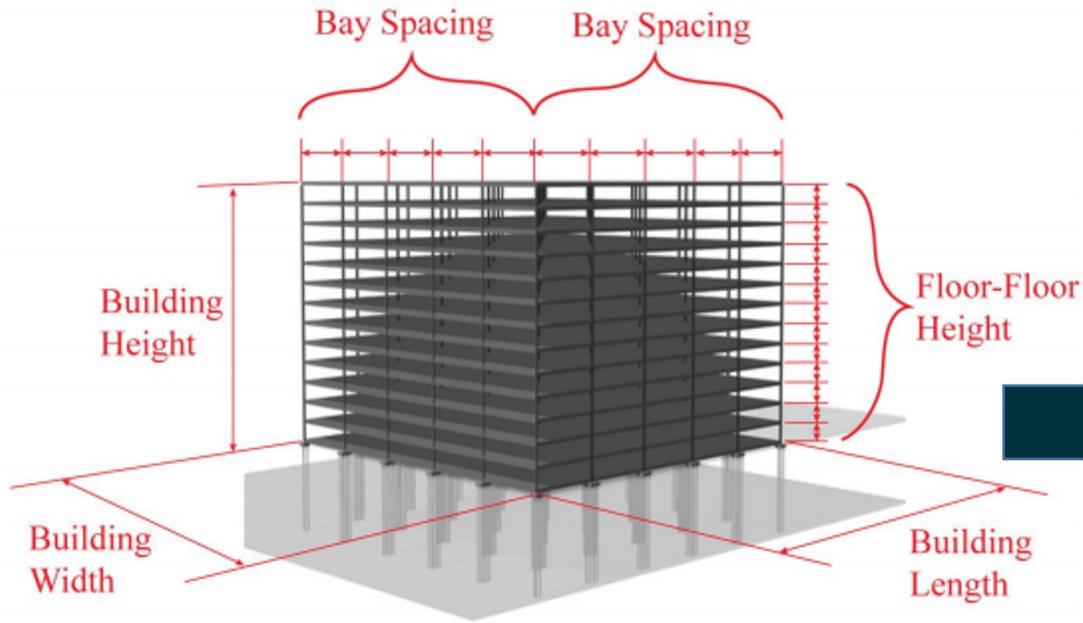
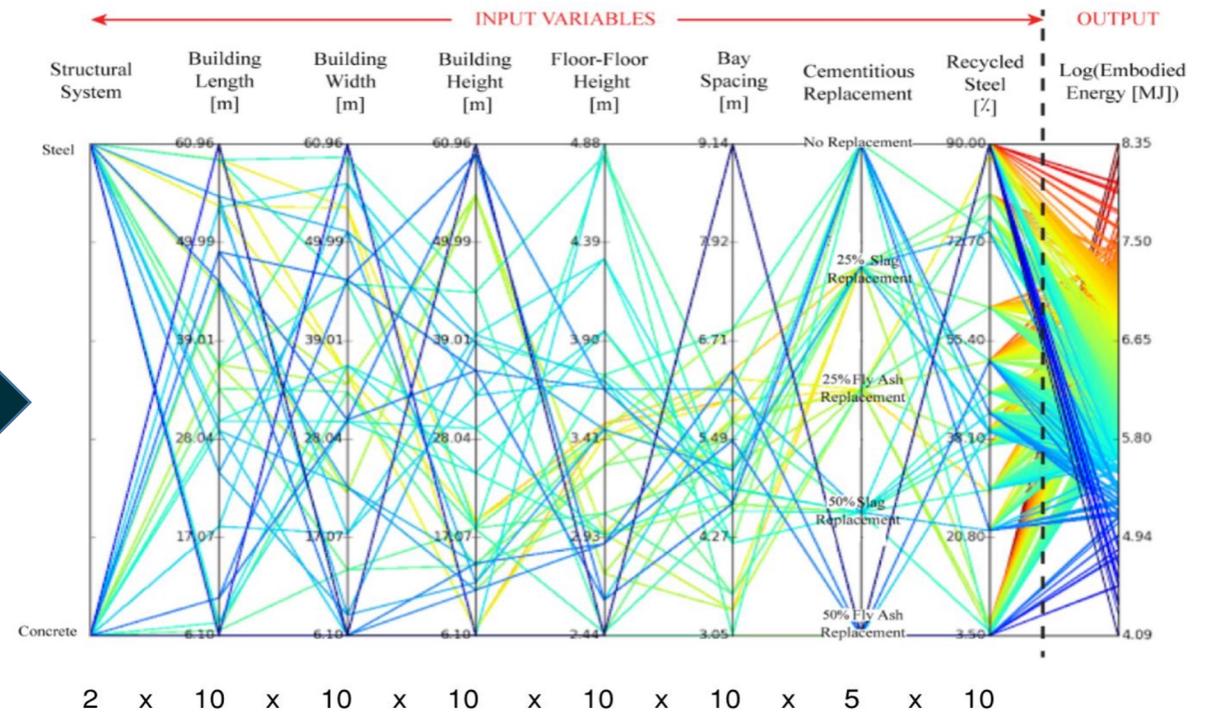


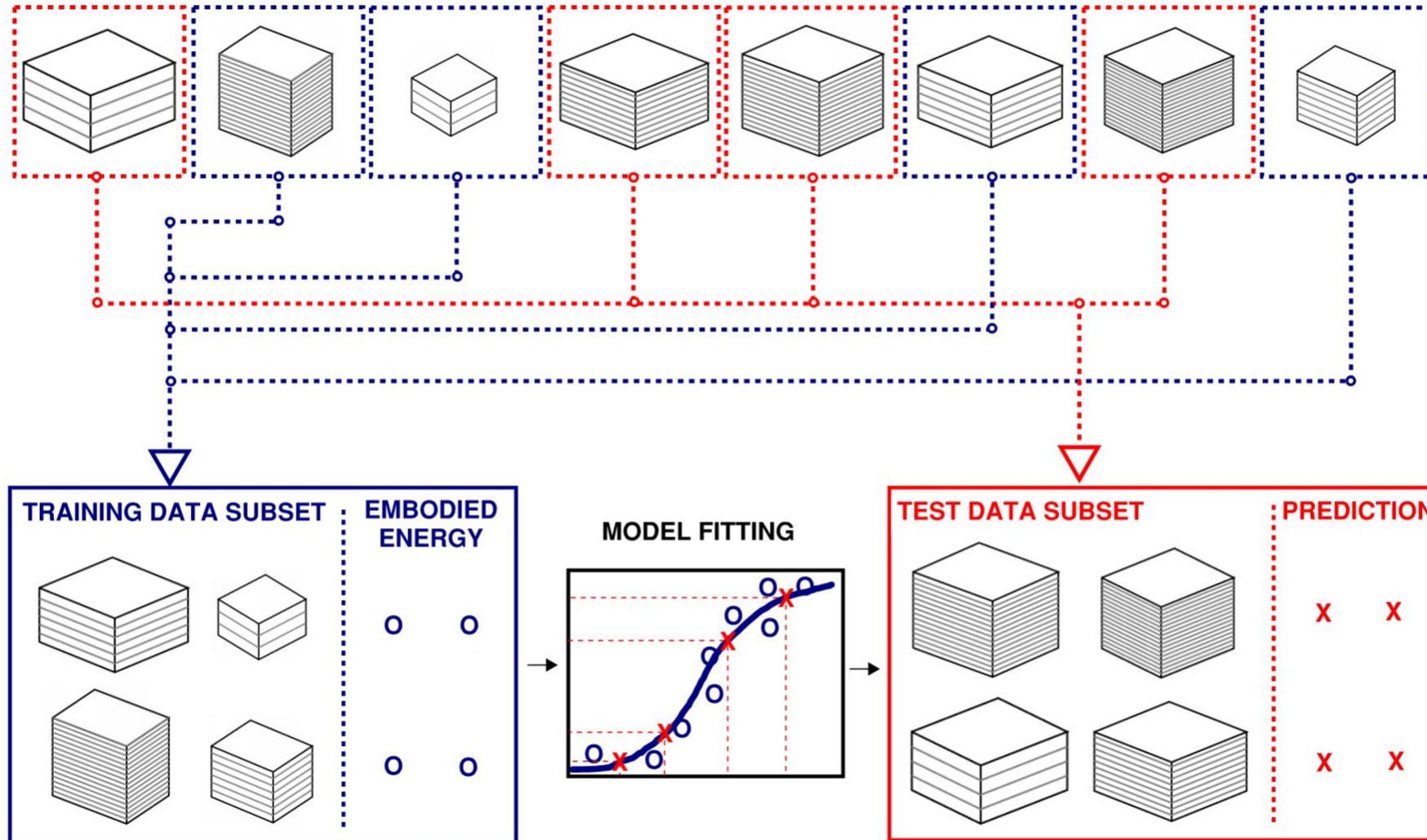
Figure 1: Geometric input parameters for embodied energy calculation.



= 10,000,000 Possible Combinations

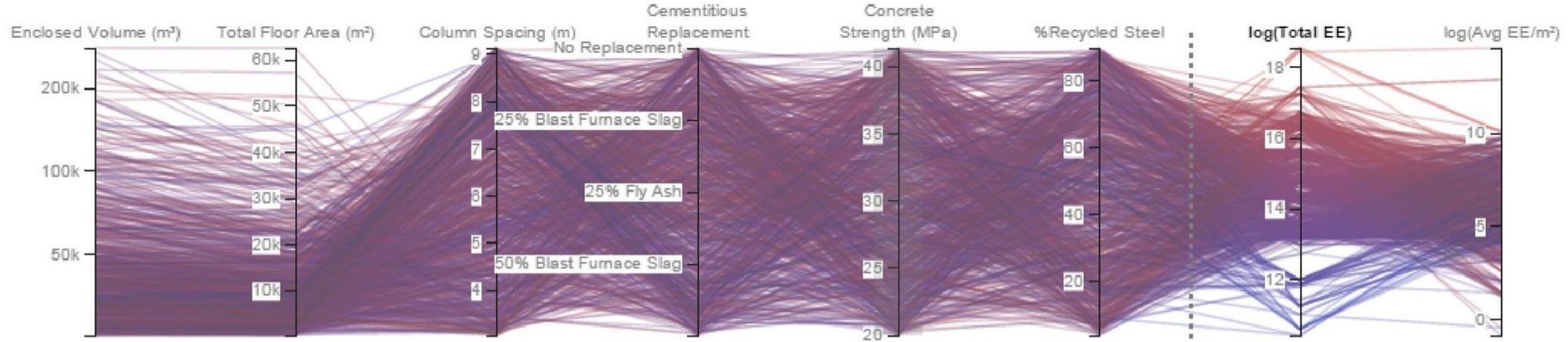
AI R&D

COLLECTION OF BUILDING DESIGNS (PARAMETER COMBINATIONS)



AI R&D

BUILDING DESIGN CHARACTERISTICS (PARAMETERS)

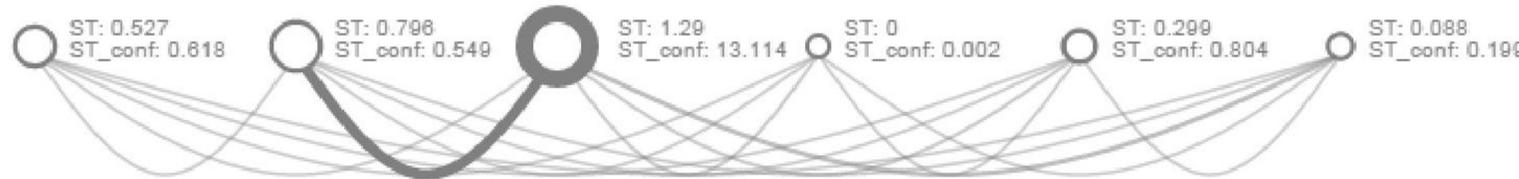


EMBODIED ENERGY

TOTAL SENSITIVITY ANALYSIS

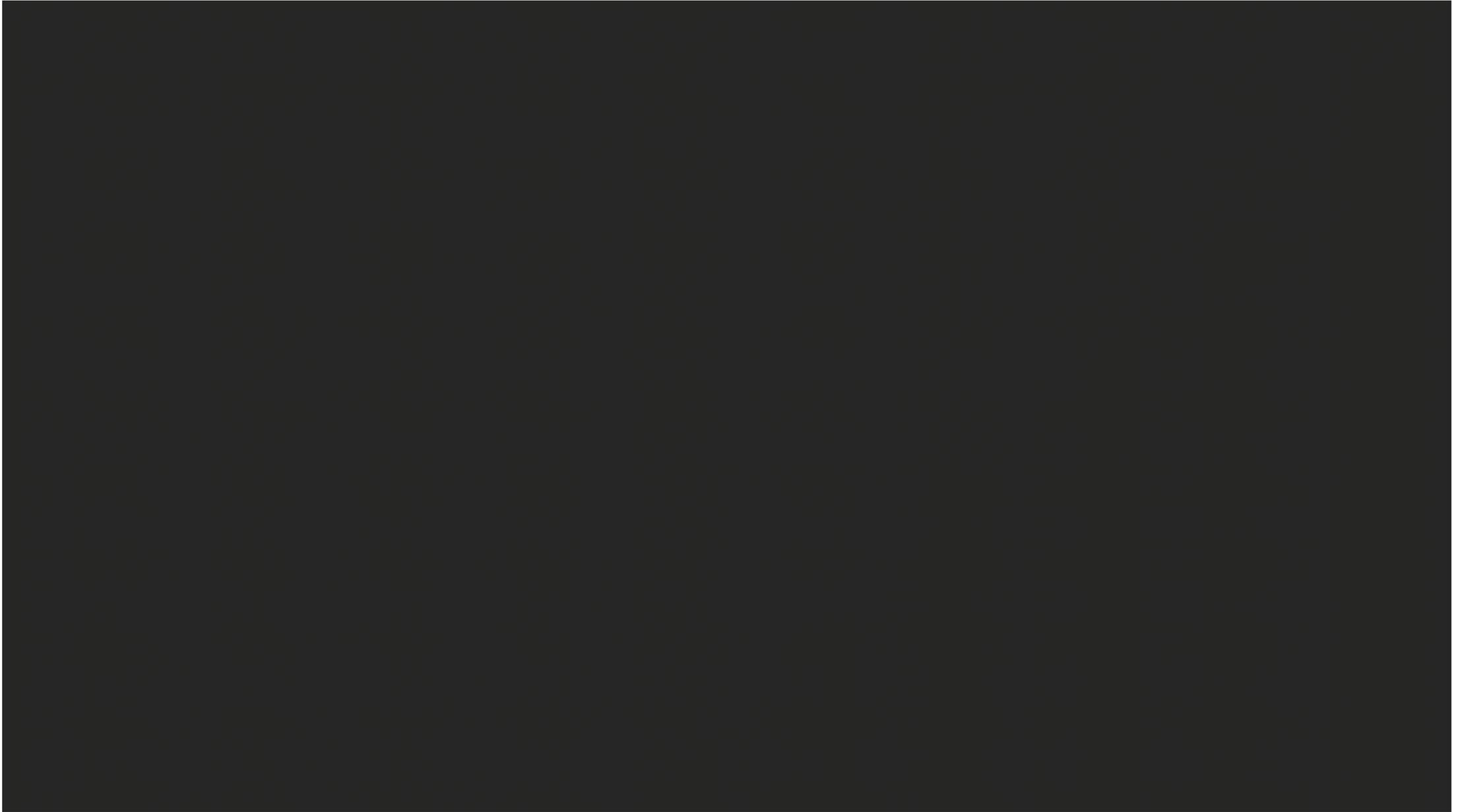


AVERAGE SENSITIVITY ANALYSIS



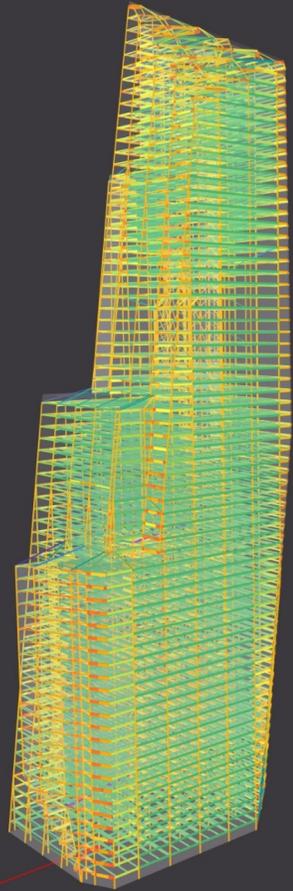
Decision Tree Algorithm:
Training on 5000 samples:
~15 min.
Emulating the embodied energy of 10,000,000 parameter combinations:
~45 min.
Sensitivity Analysis:
~5 min.

Asterisk App - 2017 (Qualitative Structural Optioneering)

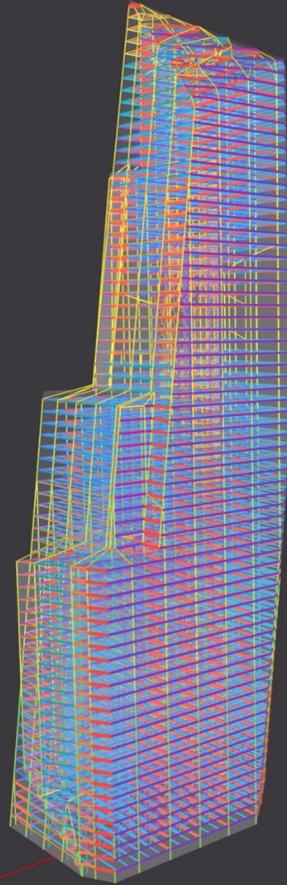


Analysis

Select Analysis Types

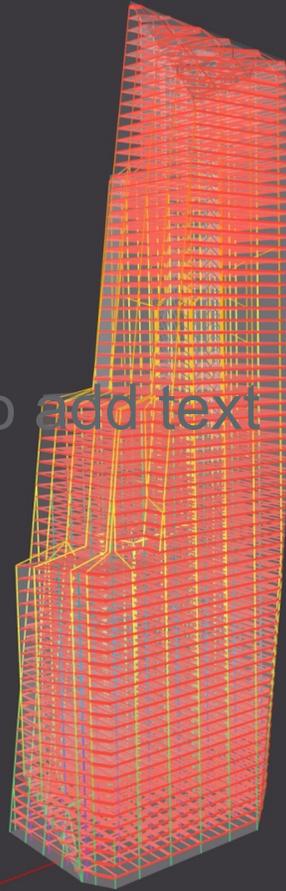


Length

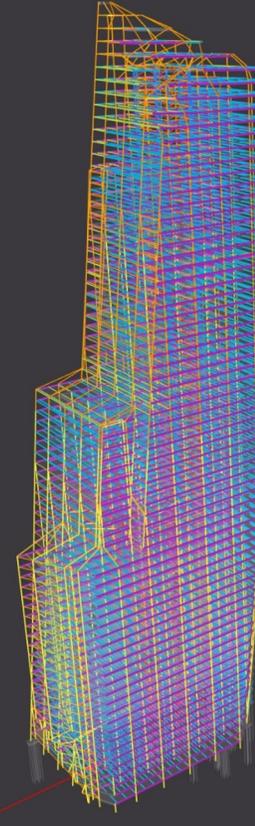


Profile

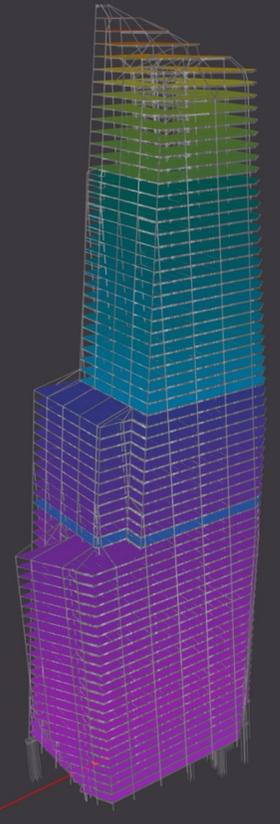
Click to add text



Trib Area



Depth



Floor Area

ASTERISK IN TESTFIT



CORE | **Thornton Tomasetti**

Automated Column Sizing TestFit 2.14

CAUTION: SYNTHETIC DATA GENERATION IS TIME CONSUMING AND NEEDS PRE-OPTIMIZATION USING DOMAIN KNOWLEDGE, DATA SCIENCE TECHNIQUES AND PRACTICALITY

Composite Beam Design Synthetic Data Set

	Beam Span (Ft)	Metal Deck Height (in)	Concrete Topping (in)	Concrete Compressive Strength (ksi)	CDL (klf)	DL (klf)	SDL (klf)	LL (klf)
Start	5	2	1	2	0.5	0.5	0.05	0.5
End	60	3	6	5	1.5	2	1.1	4
Increment	0.25	1	0.25	0.5	0.05	0.05	0.05	0.05
Number	221	2	21	7	21	31	22	71

Total Number of Records = 66,069,591,588

ML TRUSS DESIGNER

Truss-ML-V0 (Alpha)

Inputs

Span Length [ft]	50	<input type="range"/>	200	150
L span / height	5	<input type="range"/>	20	15
Dead load [psf]	10	<input type="range"/>	100	15
Live load [psf]	10	<input type="range"/>	100	40
Trib width [ft]	6	<input type="range"/>	40	30
Override clustering				<input checked="" type="checkbox"/>

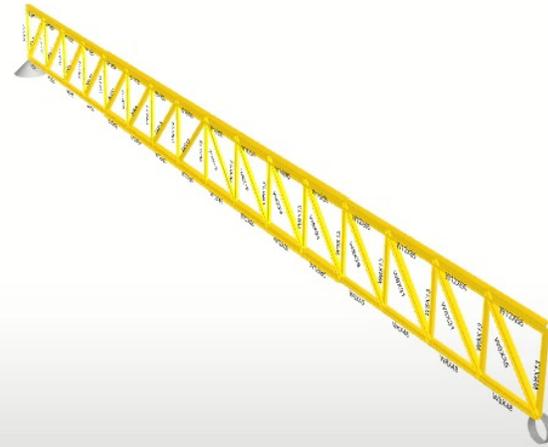
Outputs

Summary

```
{ 0; } "16 panels @ 9.4ft"  
" Truss height = 10.0 ft"  
" Total steel weight: 15.5 tonne (7.6 psf)"  
" EC: kg CO2/m2: 55.1 "
```

Mesh

MESH



ML Validation

In [21]: `1 W_sec = 'W14X145'`
`2 truss_deisgner.data_bc_compact[40.0].loc[truss_deisgner.data_bc_compact[40.0]['W_`

Out[21]:

	W_sec	Lb	Cb	phi_Mn	phi_Pnt	phi_Pnc	phi_Vn	KLr
2489704	W14X145	40.0	1.0	9305.427	1921.5	663.21	301.92	120.603

In [19]: `1 truss_deisgner.force_dict_LC[2003]['G2']`

Out[19]: `array([5.85864427e+02, 4.11313619e+00, -1.84121052e+02, -5.85864427e+02, -6.25969524e-01, 7.52813738e+02])`

In [20]: `1 truss_deisgner.truss.element_dict[2003]`

Out[20]: `{'node_L': 60,`
`'node_R': 80,`
`'type': 't_chord',`
`'sec': 'W14X145',`
`'alpha': 0.0,`
`'length': 20.0,`
`'DCR_accept': 0.96,`
`'A': 0,`
`'qu_LP': {'VL': 0.0, 'L': 0.0, 'D': 0.012108217592592594},`
`'qu_LC': {'G1': 0.01695150462962963, 'G2': 0.014529861111111111},`
`'Ag': 42.7,`
`'LC_crit_force_cluster': 'G2',`
`'LC_crit_force_ele': 'G2',`
`'DCR_elastic': 0.9552885090685003}`

Steel Stress Check Data AISC 360-16

File

Length: 240. Y Mid: 0. Shape: W14X145 Frame Type: SMF
 Loc : 240. Z Mid: 240. Class: Compact Princpl Rot: 0. degrees Units: Kip, in, F

Provision: LRFD Analysis: Direct Analysis
 D/C Limit=0.95 2nd Order: General 2nd Order Reduction: Tau-b Fixed
 AlphaPr/Py=0.274 AlphaPr/Pe=0.697 Tau_b=1. EA factor=0.8 EI factor=0.8

PhiB=0.9 PhiC=0.9 PhiTY=0.9 PhiTF=0.75
 PhiS=0.9 PhiS-RI=1. PhiST=0.9

A=42.7 I33=1710. r33=6.328 S33=231.081 Av3=28.158
 J=15.2 I22=677. r22=3.982 S22=87.355 Av2=10.064
 E=29000. Fy=50. Ry=1.1 z33=260. Cw=31812.924
 RLLF=1. Fu=65. z22=133.

STRESS CHECK FORCES & MOMENTS (Combo DSTI2)

Location	Pu	Mu33	Mu22	Vu2	Vu3	Tu
240.	-585.864	752.814	0.	-0.626	0.	0.

PMM DEMAND/CAPACITY RATIO (H1.3b,H1-2)
 D/C Ratio: 0.941 = 0.934 + 0.007 + 0.
 = (Pr/Pcy)*(1.5 - 0.5*(Pr/Pcy)) + (Mr33/(Cb*Mc33))^2 + (Mr22/Mc22)

COMPACTNESS

Slenderness	Lambda	Lambda_p	Lambda_r	Lambda_s	Compactness
Major/Flange	7.11	9.152	24.083		Compact
/Web	16.794	90.553	137.274	232.	Compact
Minor/Flange	7.11	9.152	24.083		Compact
/Web	16.794	90.553	137.274	232.	Compact
Axial/Flange	7.11		13.487		Compact
/Web	16.794		35.884		Compact

AXIAL FORCE & BIAXIAL MOMENT DESIGN (H1.3b,H1-2)

Factor	L	K1	K2	B1	B2	Cm
Major Bending	2.	1.	1.	1.	1.	1.
Minor Bending	2.	1.	1.	1.	1.	1.

	Ltcb	Kltb	Cb
LTB	2.	1.	1.

	Pu	phi*Pnc	phi*Pnt
Axial	Force	Capacity	Capacity
	-585.864	663.814	1921.5

	Mu	phi*Mn	phi*Mn	phi*Mn
Major Moment	Moment	Capacity	No LTB	Cb=1
	752.814	9304.019	11700.	9304.019
Minor Moment	0.	5985.		

SHEAR CHECK

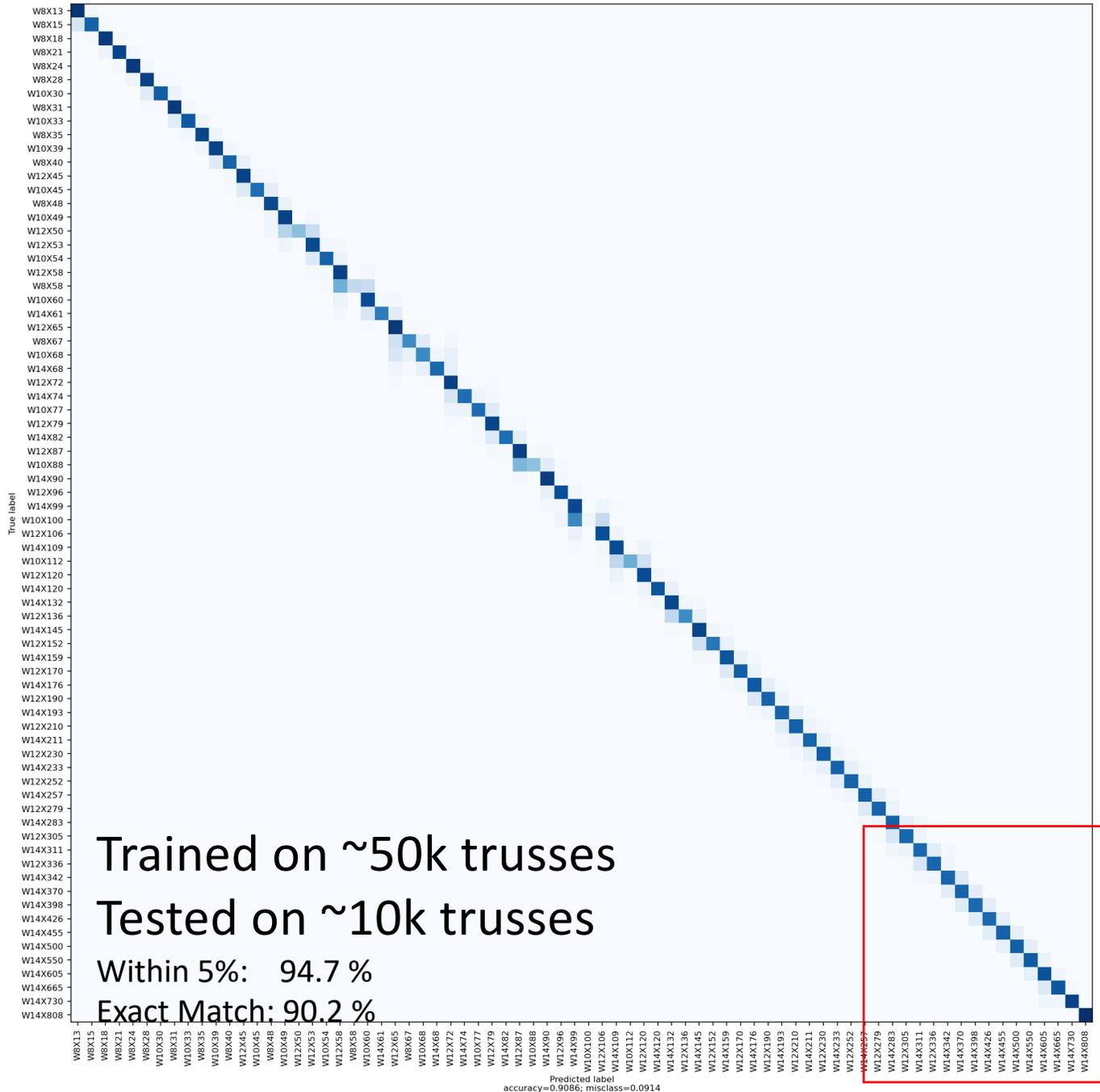
	Vu	phi*Vn	Stress	Status
Major Shear	Force	Capacity	Ratio	Check
	0.626	301.92	0.002	OK
Minor Shear	0.	912.33	0.	OK

CONNECTION SHEAR FORCES FOR BEAMS

	VMajor	VMajor
Major (V2)	Left	Right
	4.113	0.816

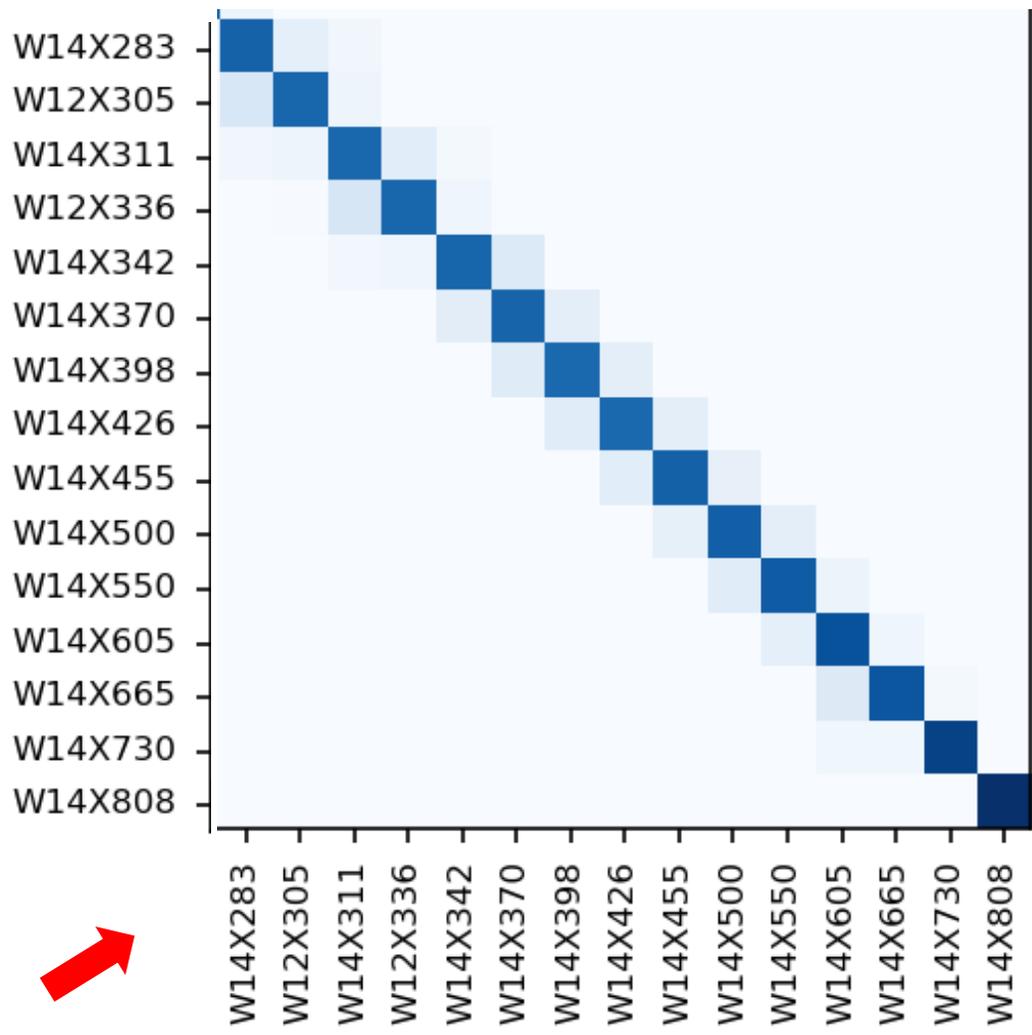


Confusion matrix



Trained on ~50k trusses
Tested on ~10k trusses
Within 5%: 94.7 %
Exact Match: 90.2 %

accuracy=0.9086; misclass=0.0914



Kaseya Center

Miami Florida



<https://www.thorntontomasetti.com/project/kaseya-center>

Next Gen. SE ML apps

Truss Designer V2

CORE.AI Foundation Model:

Small
 Large

Select steel grade:

A992

Target DCR

0.90

0.10 1.20

Temperature change ΔT (°F)

30

-50 50

TP-1

W14

TP-2

W14

TP-3

W14

TP-4

W14

TP-5

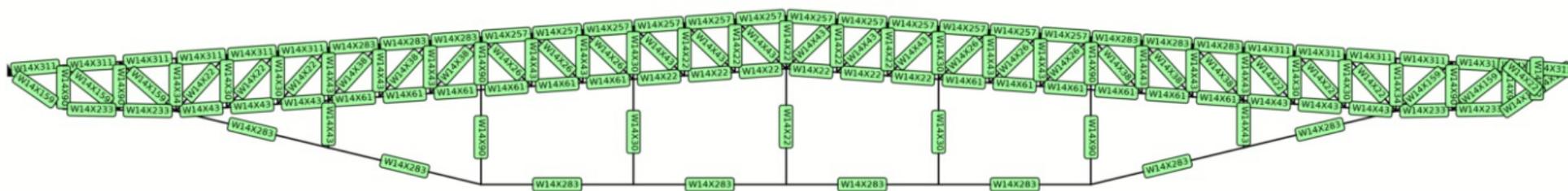
W14

Mid span deflections:

Dead: 7.75 in

Live: 4.48 in, L/360: 12.25 in

Dead+Live: 12.23 in, L/240: 18.38 in



Section design comparison:

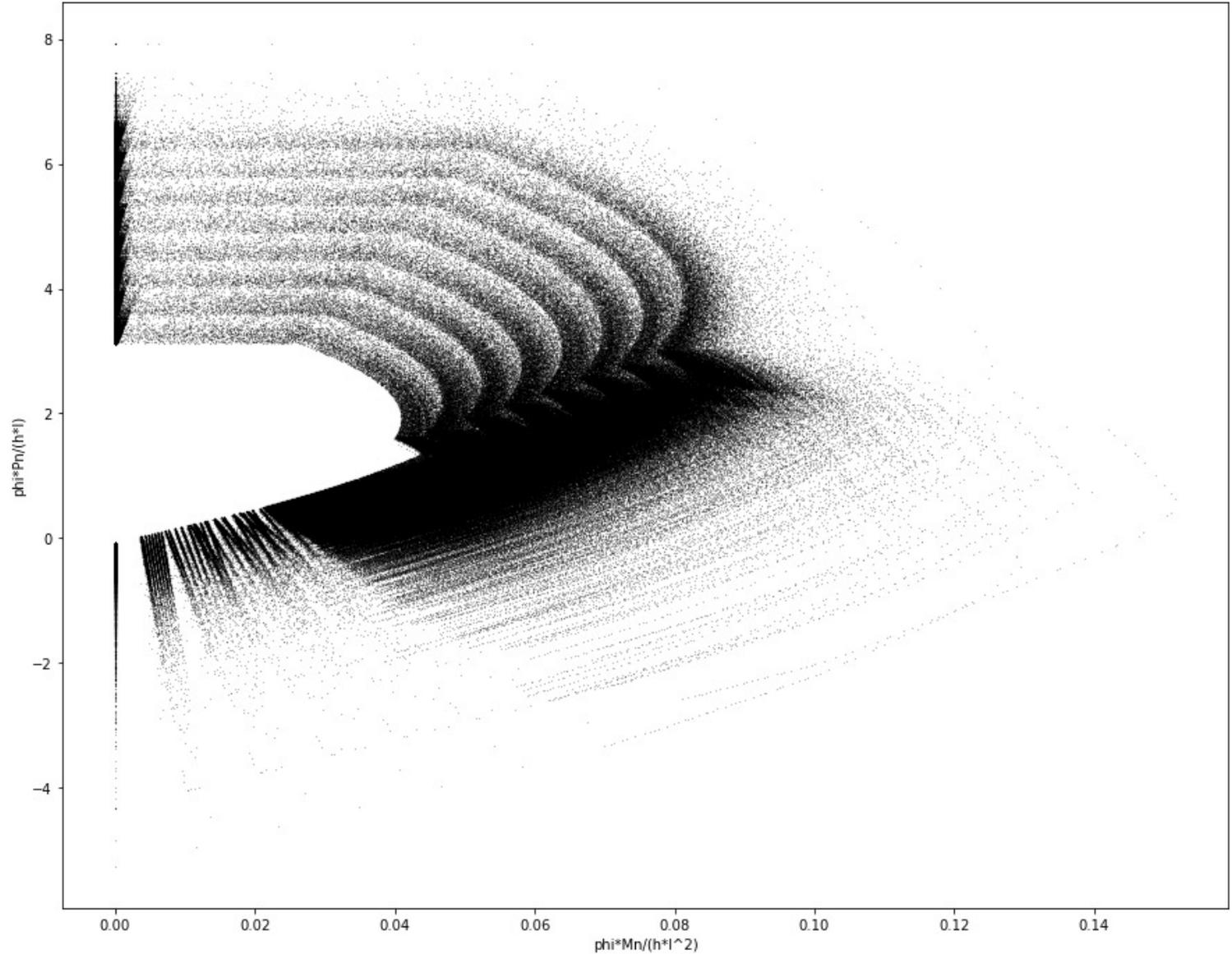
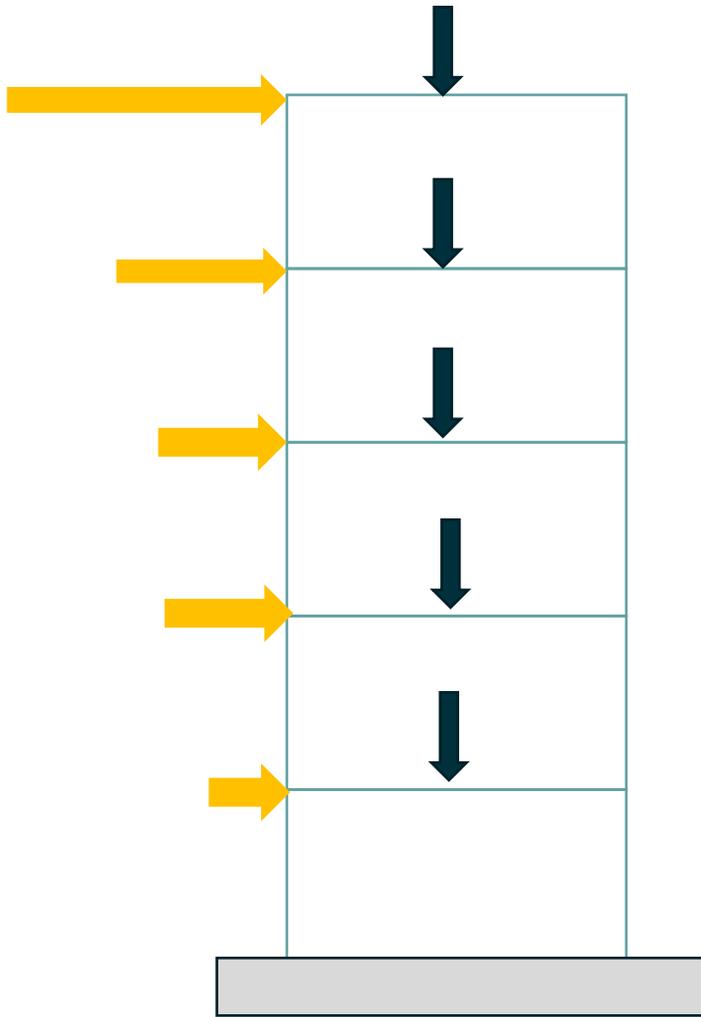
Steel tonnage:

Benchmark: 140.02 ton

AI: 133.27 ton (Difference: -4.8%)

	Cluster	AI Section	RISA Section	AI Weight (ton)	RISA Weight (ton)
0	TP-1	W14X311	W14X311	12.41	12.41
1	TP-2	W14X311	W14X311	11.22	11.22
2	TP-3	W14X283	W14X311	10.23	11.22
3	TP-4	W14X257	W14X311	9.28	11.22
4	TP-5	W14X257	W14X311	9.28	11.22
5	BP-2	W14X43	W14X61	1.55	2.20
6	BP-3	W14X61	W14X61	2.20	2.20
7	BP-4	W14X61	W14X61	2.20	2.20
8	BP-5	W14X22	W14X61	0.80	2.20

80,000,000 shear walls



SHEAR WALL

Swarm *alpha*



Shear Wall ML Optimizer-V1-Lite

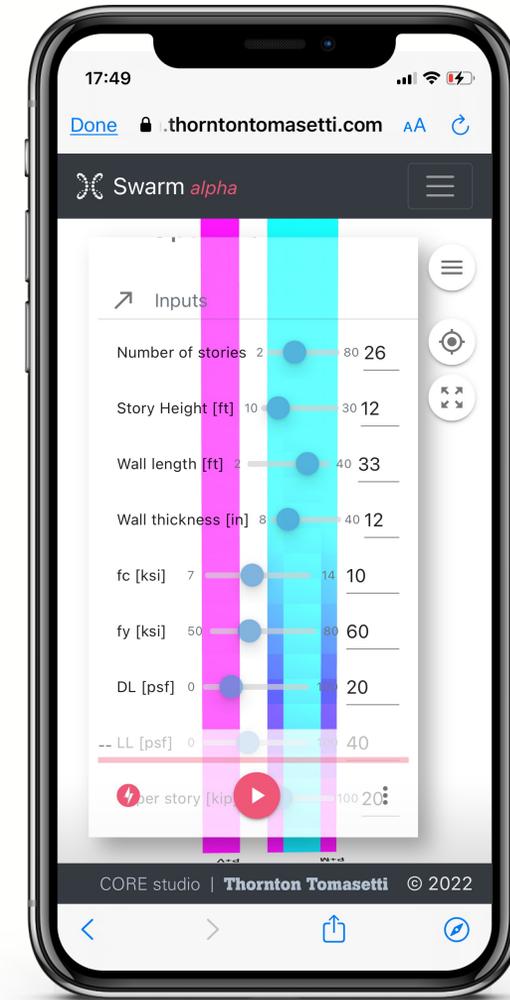
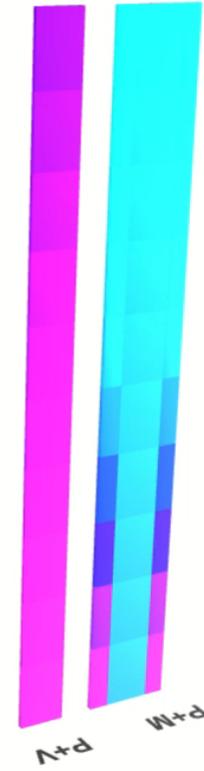
Inputs

Number of stories	2	<input type="range"/>	80	10
Story Height [ft]	10	<input type="range"/>	30	12
Wall length [ft]	2	<input type="range"/>	40	15
DL [psf]	0	<input type="range"/>	100	20
LL [psf]	0	<input type="range"/>	100	40
W per story [kip]	0	<input type="range"/>	100	20
Trib Area [sf]	0	<input type="range"/>	1000	400
Use Boundary element		<input checked="" type="checkbox"/>		
Consider wall's self-weight		<input checked="" type="checkbox"/>		

Numeric slider for single values

Outputs

List of assumptions
"1) $f_y = 60$ ksi (Grade 60)"
"2) $f_c =$ "
"3) Boundary element length ratio (if any) = 25%"



CHEVRON BRACED FRAME (DRIFT < H/400) + VIRTUAL WORK

× CBF ML-V2

↗ Inputs

Story Number	1	<input type="range"/>	10	5
Bay Width(ft)	10	<input type="range"/>	40	20
Tributary Width(ft)	9	<input type="range"/>	30	9
Story Height(ft)	9	<input type="range"/>	15	15
Dead Load(psf)	70	<input type="range"/>	100	100
Live Load(psf)	40	<input type="range"/>	100	100

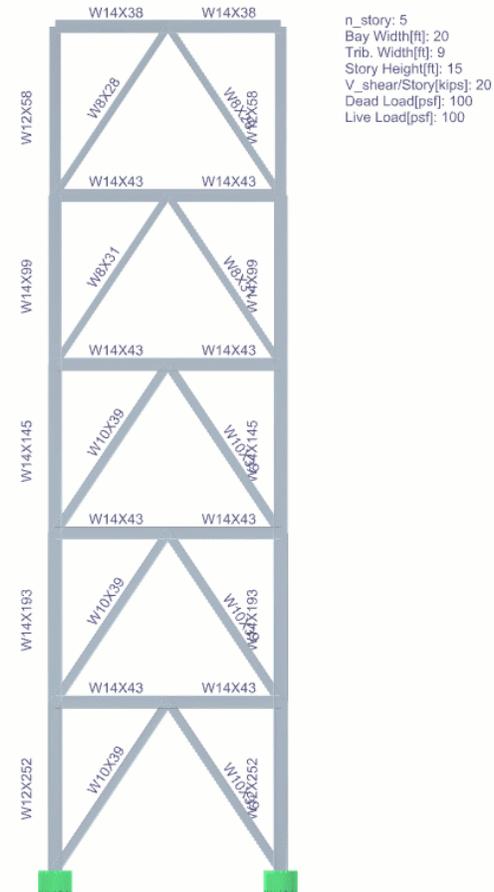
ML Endpoint Type something here
<https://18f9-38-104-71-142.ngrok.io/>

Wind Base Shear/Story(Kips) 10 90 20

↙ Outputs

Mesh-text	MESH
Support	MESH
Mesh	MESH

🔴 ⏪ ⏩ ⋮



ML STEEL FLOOR DESIGNER

Swarm *alpha*

SteelFraming

Inputs

X Bay Num	3	5	4
X Bay Span(ft)	15	65	25
Y Bay Num	3	5	5
Y Bay Span(ft)	15	65	25
Beam Spacing(ft)	9	12	10
Dead Load(psf)	20	100	75
Live Load(psf)	40	100	50

ML Endpoint
Type something here
<https://2f11-72-229-2-72.ngrok.io/>

Outputs

Mesh: MESH

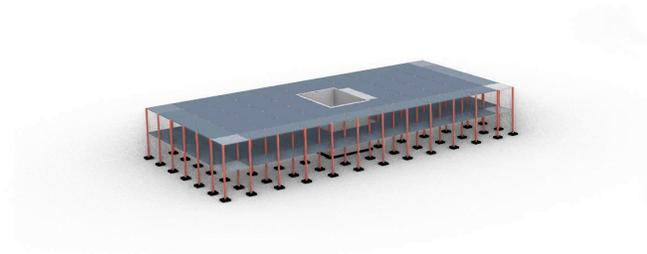
Mesh-text: MESH

Xspan(ft): 25
Yspan(ft): 25
Live Load(psf): 75
numbayX: 4
numbayY: 5

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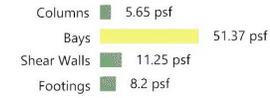
ASTERISK 2.0

Developed to match the pace of conceptual design, Asterisk leverages machine learning for rapid assessment and delivery of structural solutions.



Concrete

Tonnage:

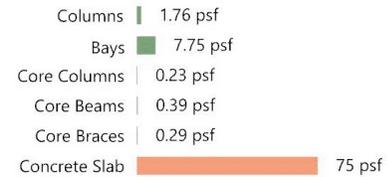


Embodied Carbon:

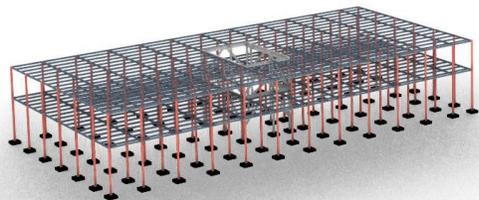
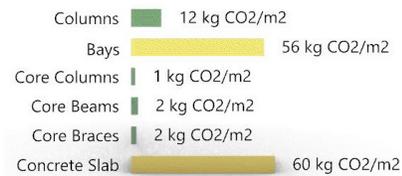


Steel

Tonnage:

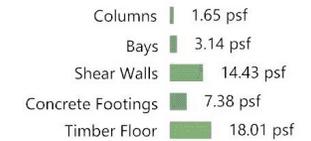


Embodied Carbon

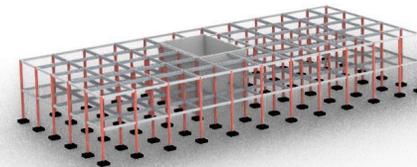


Timber

Tonnage:



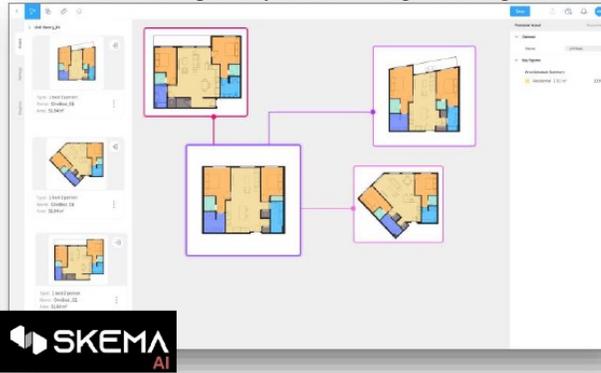
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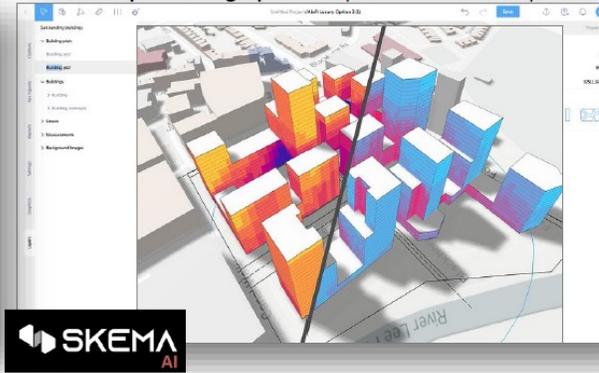
ASTERISK 2.0 IN SKEMA

Skema Unlocks a Firm's Existing BIM Investments

Machine Learning Core | Reuse Existing BIM Design Assets



Conceptual Design | Aided by Simulation & Analysis



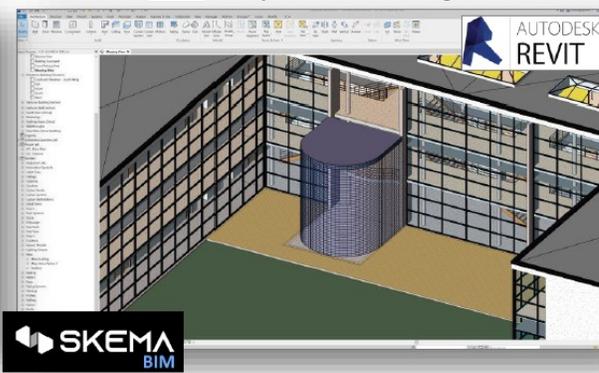
Block and Stacking | AI Generative Design



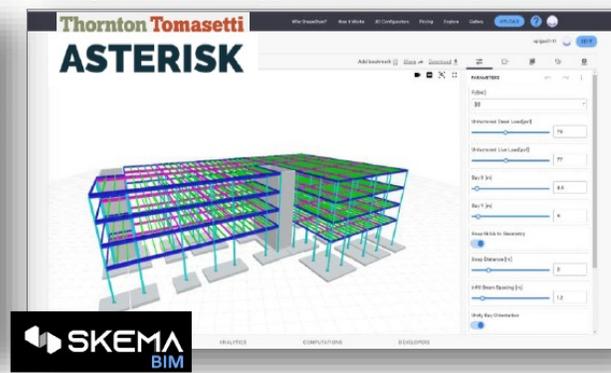
BIM LOD350 | Reusing BIM Expertise in Creating Models



Works WITH Revit | Accelerate Existing Workflows



High Interoperability | For Structures, MEP, and others



Loading. Terrain creation...

values

sum(Unit Area)

Column Labels

Drag here to set column labels

CORE.AI USE CASES TO DATE

- STRUCTURAL ML
- COMPUTER VISION
- SIGNAL PROCESSING
- GENERATIVE AI
- AUTOTAGGING DOCUMENTS
- DATA MINING AND INSIGHTS
- NATURAL LANGUAGE PROCESSING
- GPT (GENERATIVE PRETRAINED TRANSFORMERS) – LLM'S

COMPUTER VISION / AUTOMATED DETECTION AND REPORTING



The future
of inspection



LARGE LANGUAGE MODELS

- Understand human language
- Trained on massive datasets
- Bigger = more accurate
- Common in virtual assistants



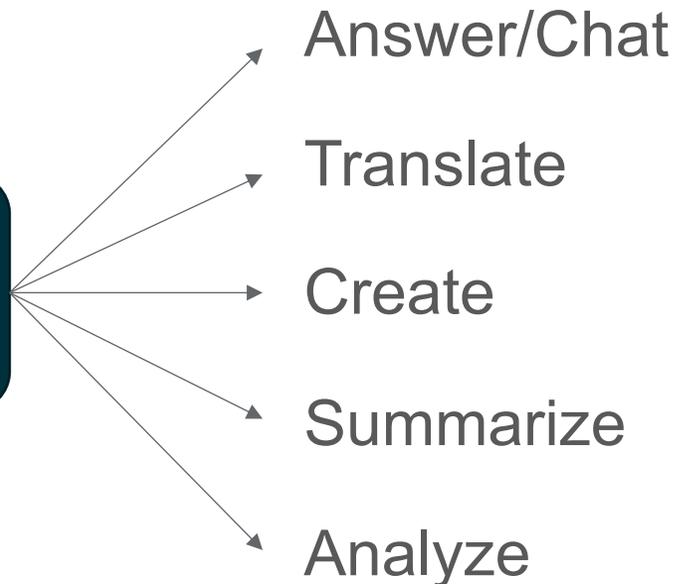
Hey
Google...



Open web datasets



Large Language
Model



TTGPT x + localhost:8501

TTGPT

Choose a model: ⓘ

GPT-3.5

GPT-4

Use old spark database ⓘ

Input: ⓘ

Text

Speech

Total cost of this conversation: \$0.00000

Clear Conversation

Please clear the conversation and start a new one after changing the sidebar settings.

Hi there! I am TTbot. How can I help you?

How to reduce drift in steel moment frames?

To reduce drift in steel moment frames, you can consider the following approaches:

1. Use stiffer connections: Designing connections with higher stiffness can help reduce drift in steel moment frames. This can be achieved by using fully rigid connections or by increasing the stiffness of the existing connections.
2. Increase member sizes: Upsizing the members in the moment frame can help increase the stiffness of the frame and reduce drift.
3. Add bracing: Introducing bracing to the moment frame can help increase the lateral stiffness of the structure and reduce drift.
4. Use a different lateral system: If drift is a significant concern, consider using a different lateral system, such as a braced frame or a shear wall system, which typically have higher stiffness and lower drift.
5. Optimize the structural layout: Re-evaluating the structural layout and making adjustments to the arrangement of moment frames can help reduce drift.

It is important to note that the specific approach to reducing drift in steel moment frames will depend on the project's unique requirements and constraints. Consulting with experienced structural engineers and using advanced analysis tools can help determine the most effective solution for your project.

You:

MARKETING

TTGPT

Marketing bot 🗨️

Choose a model: ?

GPT-3.5

GPT-4.0

GPT-3.5-16k

Choose a search method: ?

BM25

Semantic Search

Retrieve and Rerank ?

Filter documents without proper nouns ?

Document similarity threshold ?

0.00 0.95 1.00

Total cost of this conversation: \$0.00000

Clear Conversation

User Feedback

Please feel free to provide your feedback at any point during a conversation.

Feedback:



Hi there! How can I help you?

You:

Send

HOWEVER, AI HAS LIMITATIONS

- Memory
- Reasoning
- AI Search Relevance
- Hallucination

AI HAS LIMITATIONS (MORE DATA THE MORE ACCURACY)



Hi there! I am TTbot. How can I help you?



Ray Daddazio is the President of Thornton Tomasetti, a company that merged with Weidlinger Associates in 2015. He has been honored with several awards for his contributions to the field of engineering, including the Keystone Award from the Beverly Willis Architectural Foundation and the Melvin L. Baron Award for outstanding contributions to the field. He is also a champion of gender diversity in the building industry. Additionally, he has given speeches and shared his thoughts and experiences with graduating civil engineering students at Columbia University.



Who is Ray Daddazio?



I'm sorry, I couldn't find any relevant information about Doc Holliday in the provided documents.



Ray Daddazio is a Senior Consultant at Thornton Tomasetti (TT). He has held various leadership roles, including president of Thornton Tomasetti and president and CEO of Weidlinger Associates, which merged with Thornton Tomasetti in 2015. Ray has been honored with awards such as the Keystone Award by the Beverly Willis Architectural Foundation for his dedication to gender diversity and the Service to Humanity Award by the March of Dimes Greater New York Transportation & Construction Breakfast. He has also been a guest of honor at Columbia University, sharing his thoughts and experiences with graduating civil engineering students. In 2022, Ray received the Melvin L. Baron Award for outstanding contributions to the field of shock and vibration.



Who is Doc Holliday?



Who is Ray Daddazio?

GPT 3.5

GPT 4.0

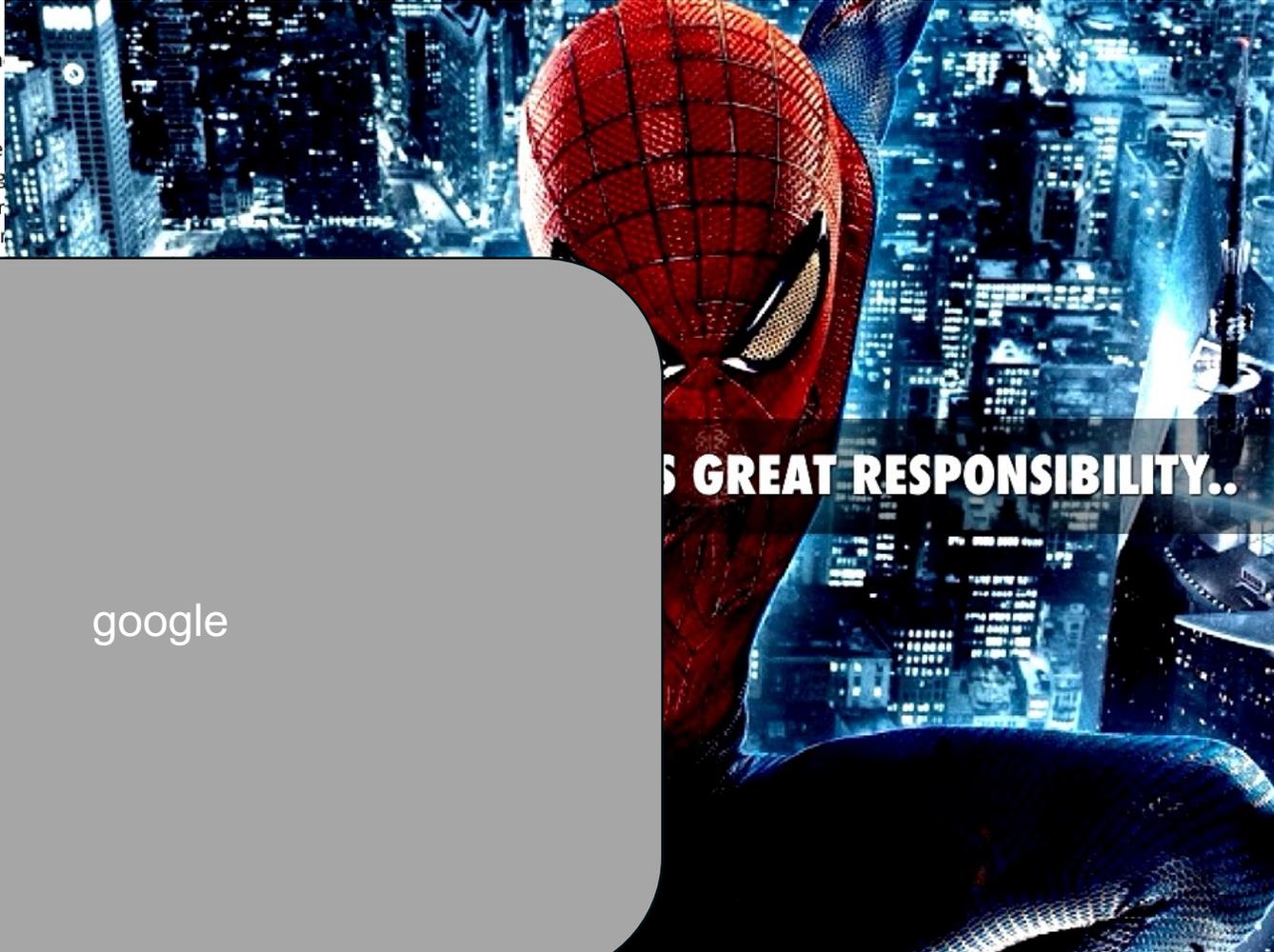
WHEN TO USE AI/ML (COMING SOON)

- FOR SEARCHING PAST PROJECT DATA
- SEARCHING FOR TECHNICAL INFORMATION ON SPARK
- HEADSTART FOR REPORTS/TEXT
- DESKTOP STUDIES
- SD AND DD
- CD'S (FOR RAPID QA/QC)
- CD'S FOR SPOT CHECKS
- CA (TBD)
- LEARNING "SOLVED" SOLUTIONS
- DATA INSIGHTS AND TRENDS
- PREDICTIVE ANALYSIS

RESPONSIBLE AI

Thornton Tomasetti AI Guiding Principles

Artificial Intelligence and machine learning have been in practice for several years, enhancing various aspects of a project. The recent rise of large language models has led to new guiding principles to encourage their responsible use.



google

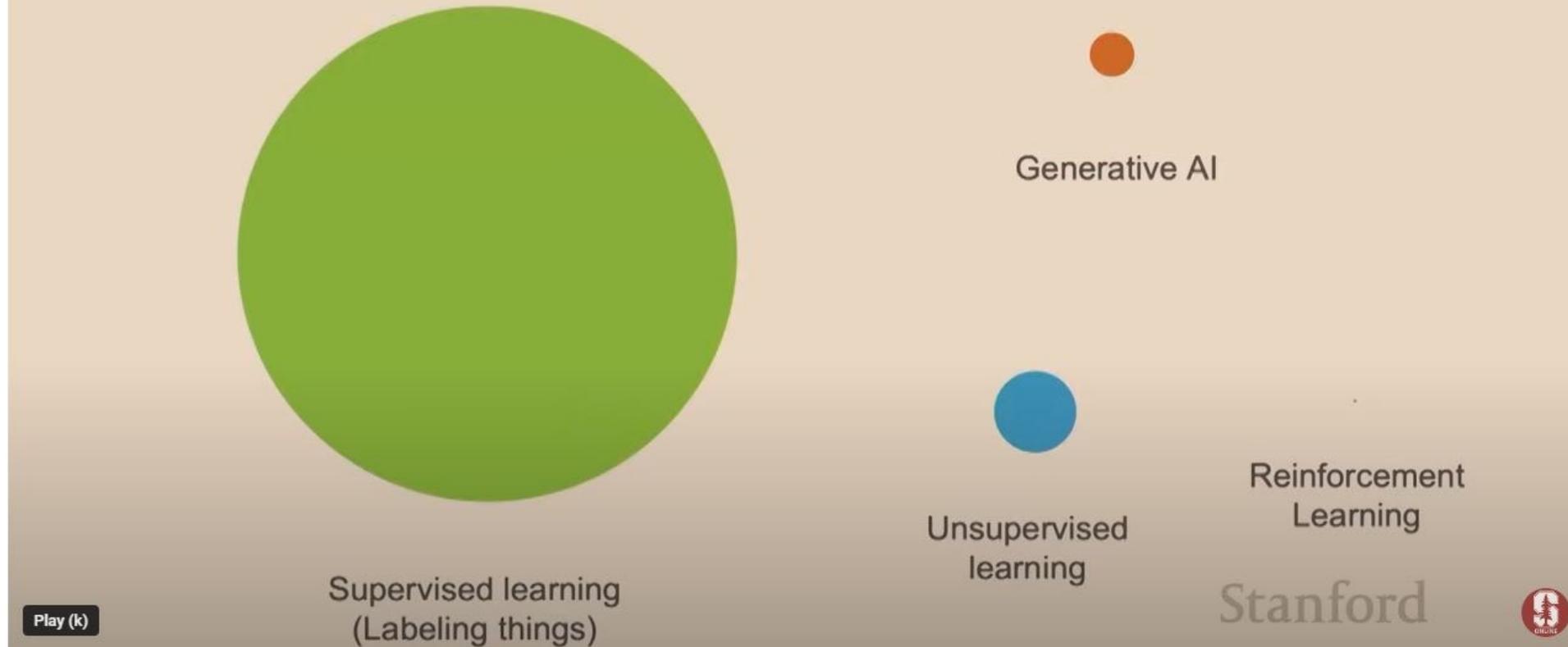
and Rob Otani

by Emerging Technology
e:

Kenneth Zammit, Scott
Pinto, Bill Dwyer,
La Warren, Najib Abboud,

AI STRATEGY

Value from AI technologies: Today → 3 years



Andrew Ng

ONGOING AI / ML WORK

- STRUCTURAL ML
- COMPUTER VISION
- SIGNAL PROCESSING
- GENERATIVE AI
- AUTOTAGGING DOCUMENTS
- DATA MINING AND INSIGHTS
- NATURAL LANGUAGE PROCESSING
- GPT (GENERATIVE PRETRAINED TRANSFORMERS)

SPARK GPT INTEGRATION –
COLIN MCLEOD

MARKGPT – MIKI WATANABE /
OMID SAJEDI

AI STRATEGY

CONTINUOUS RESEARCH AND DEVELOPMENT



AWARENESS, EDUCATION, TRAINING

DELIBERATE BUT STEADY ROLLOUT (BEST PRACTICES)

FIND NEW OPPORTUNITIES ACROSS ALL PRACTICES AND DEPARTMENTS

CONTINUOUS IMPROVEMENTS

THANK YOU



ROtani@ThorntonTomasetti.com