U.S. DEPARTMENT OF ENERGY

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Evolution of Commercial Building Design and Construction

National Energy Codes Conference Seminar Series

Building Technologies Office

Summer 2021

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- **9/23: Evolution of Commercial Building Design and Construction**
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Building Energy Codes
U.S. DEPARTMENT OF ENERGY

Welcome!

Charles E. Gulledge III, P.E., FASHRAE, HBDP, LEED AP
ASHRAE Presidential Member 2020-2021

Building Energy Codes
U.S. DEPARTMENT OF ENERGY

Evolution of Commercial Building Design and Construction

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The Bridge to Relevance
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CELEBRATING
125
YEARS

The Bridge to Relevance

My grandfather, an immigrant from Italy, was the consummate **Engineer**, **Machinist**, and **Farmer**. He taught me how things were **built**. He taught me how to **farm** the land and put **food** on the table.

Working beside my grandparents over many summers, provided a **bounty** of lessons. One of those was the natural progression of **WORK**; particularly Work on the land.

PLOW: Soil must be **prepared**, and **configured**.

PLANT: The seed we **sow**, turns into the crop that **grows**.

MAINTAIN: What we grow, needs **continuous attention**.

HARVEST: **Reap**, what you sow.

I learned, that you can't **cheat** the natural process. There is no **Harvest**; without **Plowing**, **Planting**, and **Maintaining**.

The Bridge to Relevance

Engineering & Construction (E&C), is a lot like Farming.

PLOW: Preparation, requires assembling the **correct team**.

PLANT: The outcome we desire, needs a **well-defined path**.

MAINTAIN: Continuous improvement is implemented, to **drive value**.

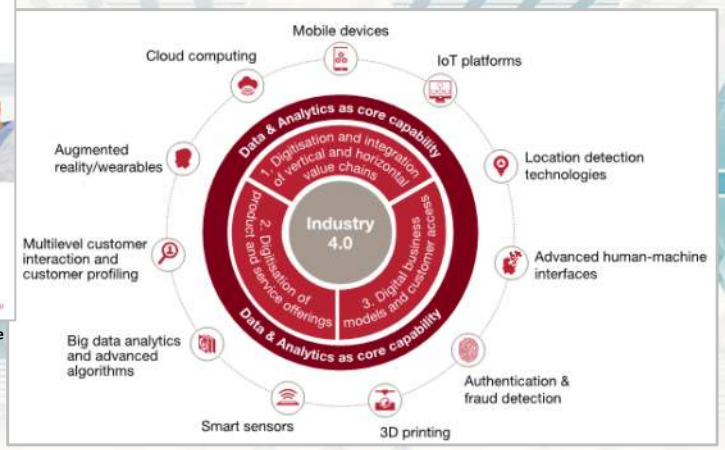
HARVEST: Built solutions that **exceed** expectations, are delivered.

Yes, the E&C process, is **no different** than nature's own. We can't **cheat** this natural **Flow!**

Why?

Industry 4.0: Building the Digital Enterprise Engineering and Construction Key Findings PwC

Industry 4.0 Framework and Contributing Digital Technologies



Let's pause for a moment, to ask - **WHY**?

Why should we care; about **Plowing**, **Planting**, and **Maintaining** within the Building ecosystem?

Here's Why! With the expansion of the Digital World, we can:

Differentiate ourselves, from the competition.

Identify ourselves, as the Innovators.

Improve our profit margins.

Attract, and **Retain**, a digitally savvy workforce.

Deliver Value.

Optimize building performance.

And **Mitigate** environmental footprint.

Our evolution to **Lean** and **Digital Maturity**, can **deliver** this Harvest, and **more!**


The Current State
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The Current State: Waste

"I have great respect for the past. If you don't know where you've come from, you don't know where you're going ..."
– Maya Angelou

Every journey, has a starting point.

Before **We** explore the **digital path**, let's reflect on our **current** industry state. Let's **start** by considering, how **POORLY** we have **managed** our crops. A busted F&B steam coil provides a good backdrop.

Why are we **STILL** burdened, with **marginal yields**?

The Current State: Waste

Plan Grid/FMI 2018 Industry Report:
Construction Disconnected
April 2018

"Cost of Non-Optimal Labor Activities: $177 Billion"

"Forecasted Cost of Rework: $65.2 Billion"

"Cost of Rework Caused by Poor Data and Communication: $31.3 Billion"

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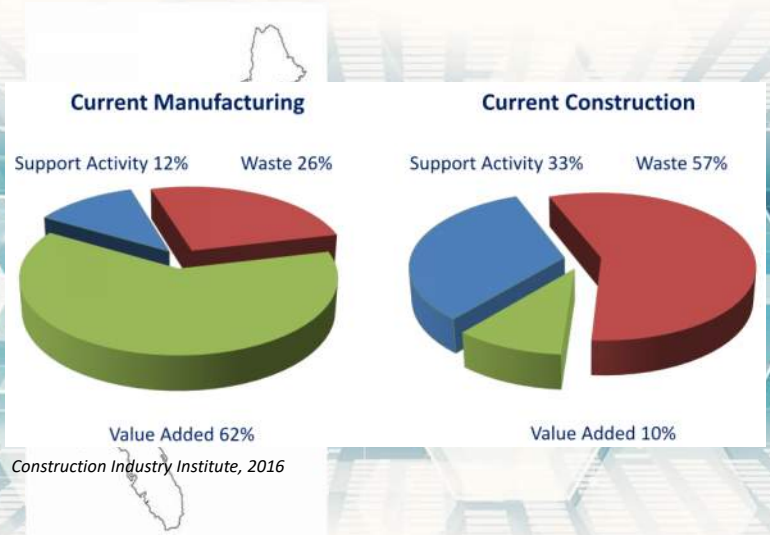
First, **Our current workflows, are ripe with Waste**!

It is estimated that in the US alone, **$177B** is **lost** annually, on non-productive labor activities. **Looking** for information, **Engaging** in conflict resolution, **Dealing** with mistakes, and **Performing** rework; **all impact the bottom line!**

$31B of this loss, is **directly** associated with, poor **data** and **communication**. **Poor**, in this context, is **Inaccurate**, **Inaccessible**, and **Incompatible**.

The Current State: Waste



Construction Industry Institute, 2016

Look at this from a comparison of Manufacturing vs Construction. Waste is **high**, Value is **low**.

Waste, in this solution delivery context, has a direct impact on building performance. When optimization is not achieved, performance waste is embodied in the shortcomings.

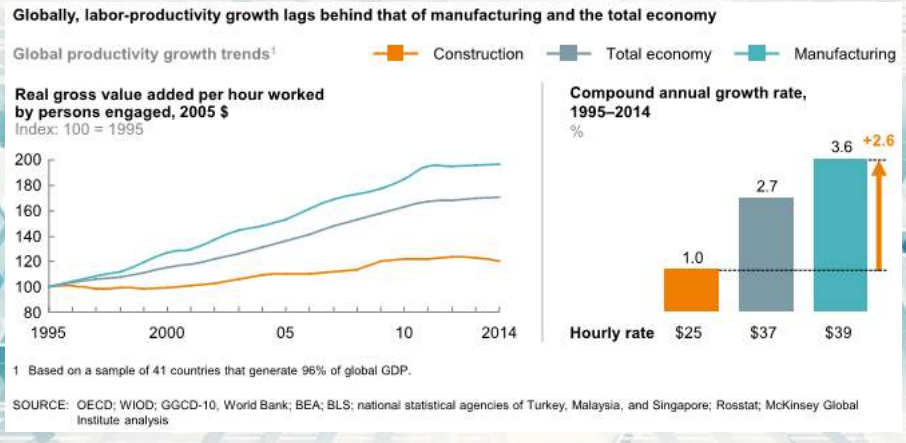
The Current State: Productivity

McKinsey Global Institute (MGI), *Reinventing Construction: A Route to Higher Productivity*, February 2107

Second, **E&C is a Flat ecosystem!** Data reflects, that we are **NOT** very Productive. Sadly, our annual productivity growth has only increased **1%**, over the past **two decades**.

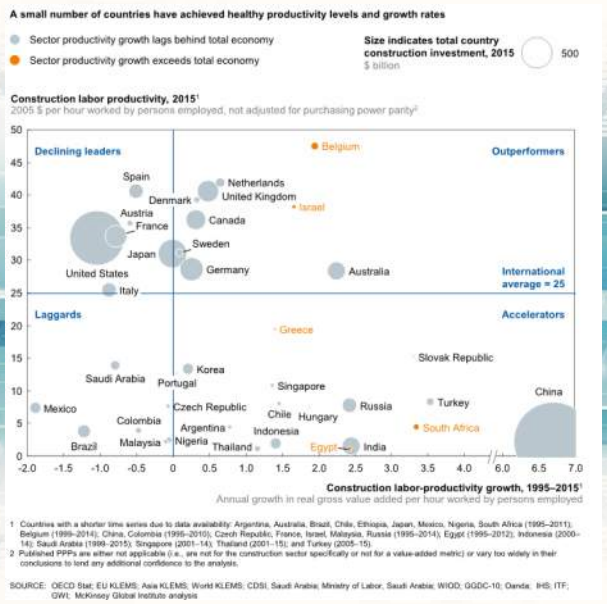
Stagnation is costly!

The Current State: Productivity



Look at these trend lines comparing Construction to the Total Economy, and Manufacturing. We are relatively **flat**!

The Current State: Productivity

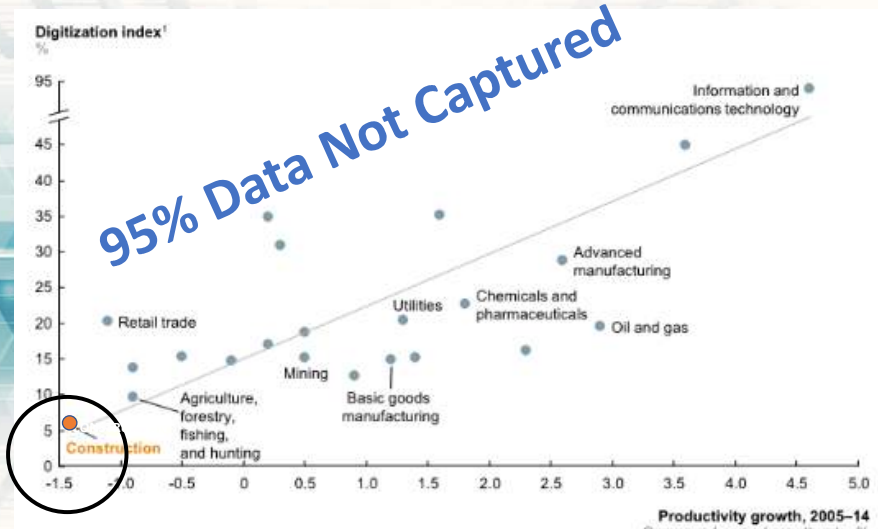


What if I presented this in a global manner? McKinsey shows us that the US Construction Market is a **Declining Leader**.

Look at this from another perspective. Stagnation also reveals a paucity of integrated high-performance solutions that are more sustainable, use less energy and optimize holistic building environmental footprint.

The Current State: Dark Data

McKinsey – Reinventing Construction:
A Route to Higher Productivity
February 2017



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Third, **Our ecosystem, remains one of the least Digitized sectors, in the world! Look** at **Us!** [**LOW** and **LEFT**].

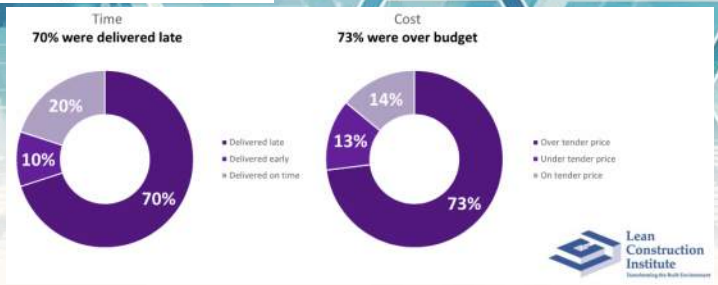
To **compound** this shortcoming, FMI suggests that up to **95%** of data, that **IS** captured, goes **unused**. We **allow** knowledge to go dark. **DARK** knowledge, becomes **LOST** knowledge!

This **LOST** knowledge is vital to building resource management!

The Current State: Dark Data

- Risk is high.
- 70% of projects are delivered late.
- 73% of projects are over budget.
- Rework and waste is high.
- Teamwork is unreliable.
- Customers are not satisfied.
- Profit margins are shrinking.

- Construction productivity is declining.
- Construction costs are skyrocketing.
- Injuries are too high.
- Traditional planning systems are unable to produce predictable workflows.
- Workflow reliability directly affects speed and cost of projects.



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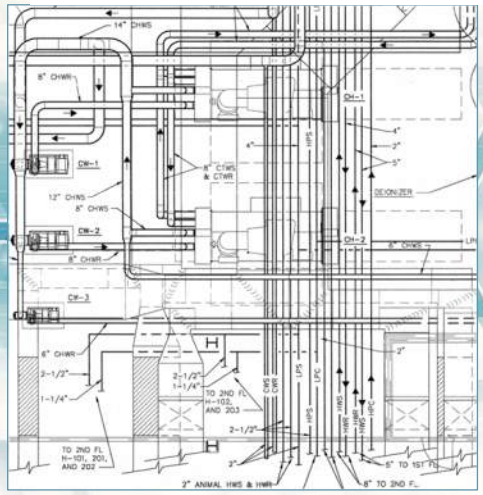
Fourth, our Logistics are poor. Our projects are late and over budget.

The Current State: The Analog Chain

The Dance of the Silos

Representational
HVAC – Piping



Finally, **we remain shackled, to the Analog Age!** Over many decades, we have perfected, the **Dance of the Silos**.

Risk and **Liability** keep us, from optimizing the whole. We **protect** our borders, from the **impact** of "OTHERS".

We have so many touch points! We **manually** collect, review, and transfer Data. We continuously **recreate** knowledge.

We **rarely** consider cost and schedule, as **INPUTS** to design. Rather, we **delete** scope, when bids are over budget.

We rely on paper for **everything**! Paper **consumes** time.

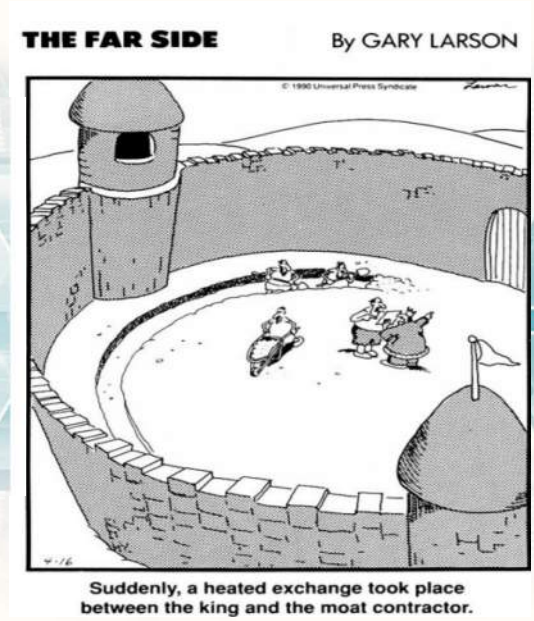
We focus on the silos of prescriptive normative **minimum**. The whole is not optimized!

We **attempt** to build something; looking across **static** drawings, of **variable** quality, from **multiple** players. Work results get executed by, **Who** arrives **First**.

This, is the world, **We** know. We **excel** at **Fragmentation**, and the **Weeds of Waste!**

What Do Owners Want?

"When it is obvious that the goals cannot be reached, don't adjust the goals, adjust the action steps" - Confucius



Let's look at our current state, from another **perspective**. What do **Owners**, want **Their Harvest** to be? They want **US** to do the following:

Resolve issues **virtually**, before they become **physical**.

Reduce the level of **unknowns**, eliminate the **need** for RFIs.

Provide better, cost/schedule **certainty**.

Improve closeout, deliver a **complete** knowledge base.

Develop holistic, optimized solutions that minimize environmental footprint.

Deliver something that **WORKS**.

These are **NOT**, onerous expectations. Somehow, our industry has managed to **lose track**, of the Harvest. How do **WE** change course, and **alter**, these **Conditions of Satisfaction**?


Project Delivery
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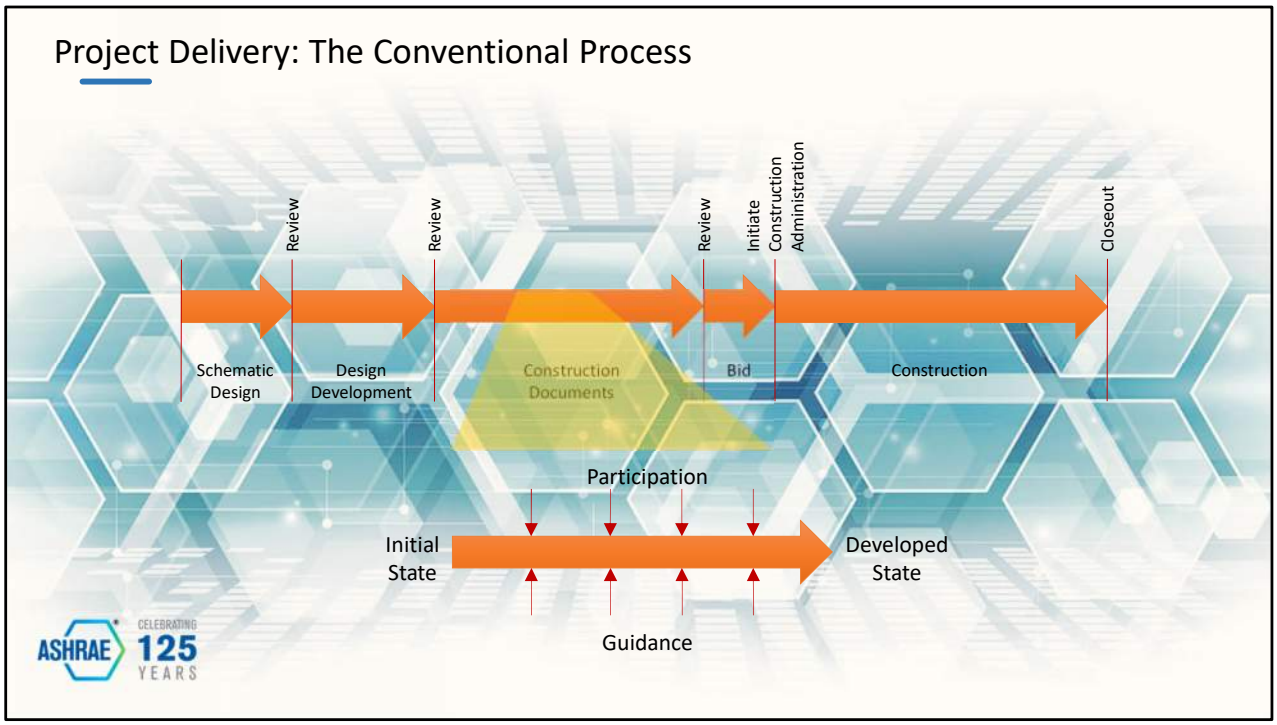
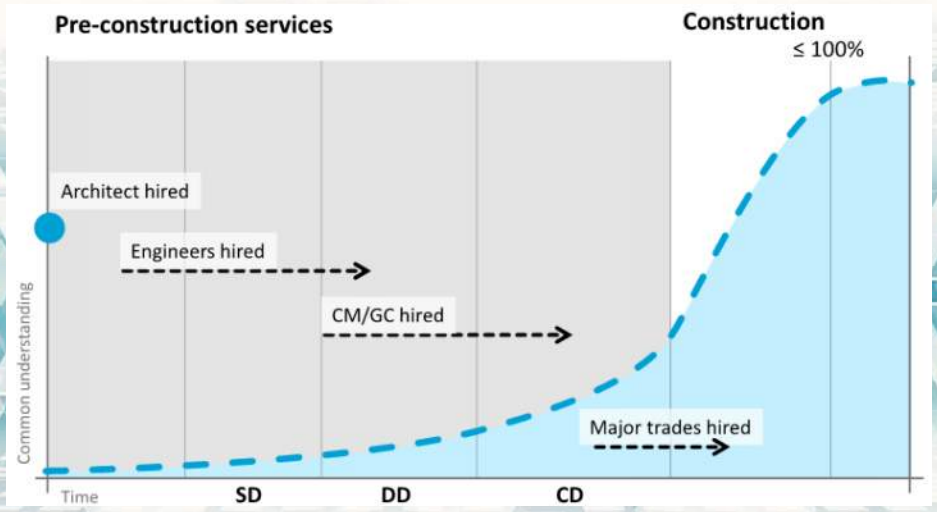
YEARS



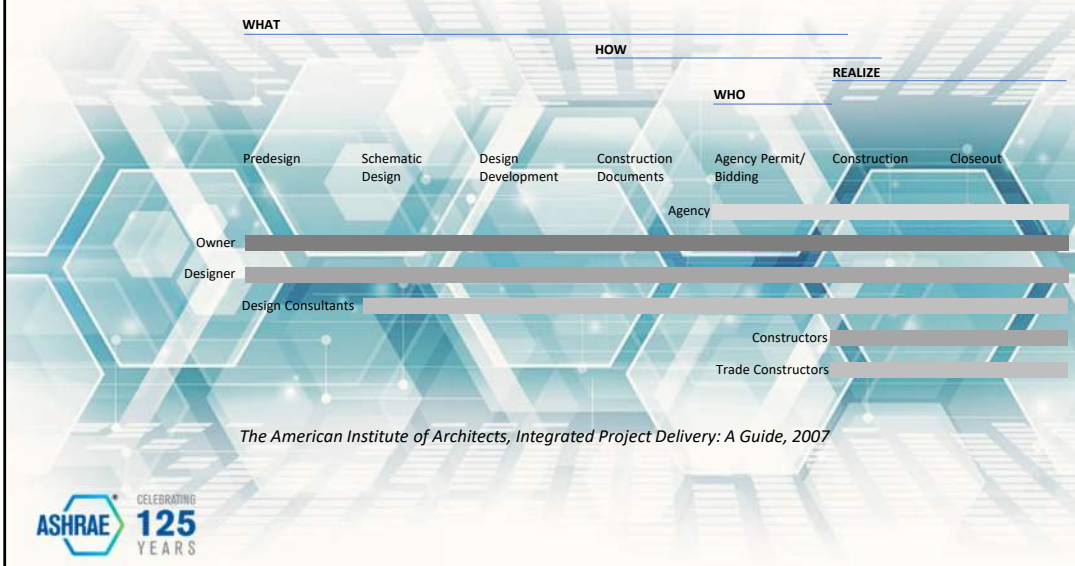
Before we outline the future path, let's reflect on our processes.
The Conventional Delivery Process (CDP) is characterized as a linear process of sequential response by all project team members. The project builds on previous decisions, regardless of whether or not optimal foundation work is established for the next layer of development. In effect, CDP is similar to making **sausage**.

Project Delivery: The Conventional Process



Look at this sequential linearity from a "**Common Understanding**" perspective.

Project Delivery: The Conventional Process



The American Institute of Architects, Integrated Project Delivery: A Guide, 2007

AIA captures this in a graphic set that sequences **What-How-Who-Realize**.

Project Delivery: The Conventional Process

Command & Control

Transactional

CPM Scheduling

Lean Construction Institute, Transforming Design and Construction, 2016

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Conventional, is all about Command and Control, Transactions, and Start-to-Finish thought.

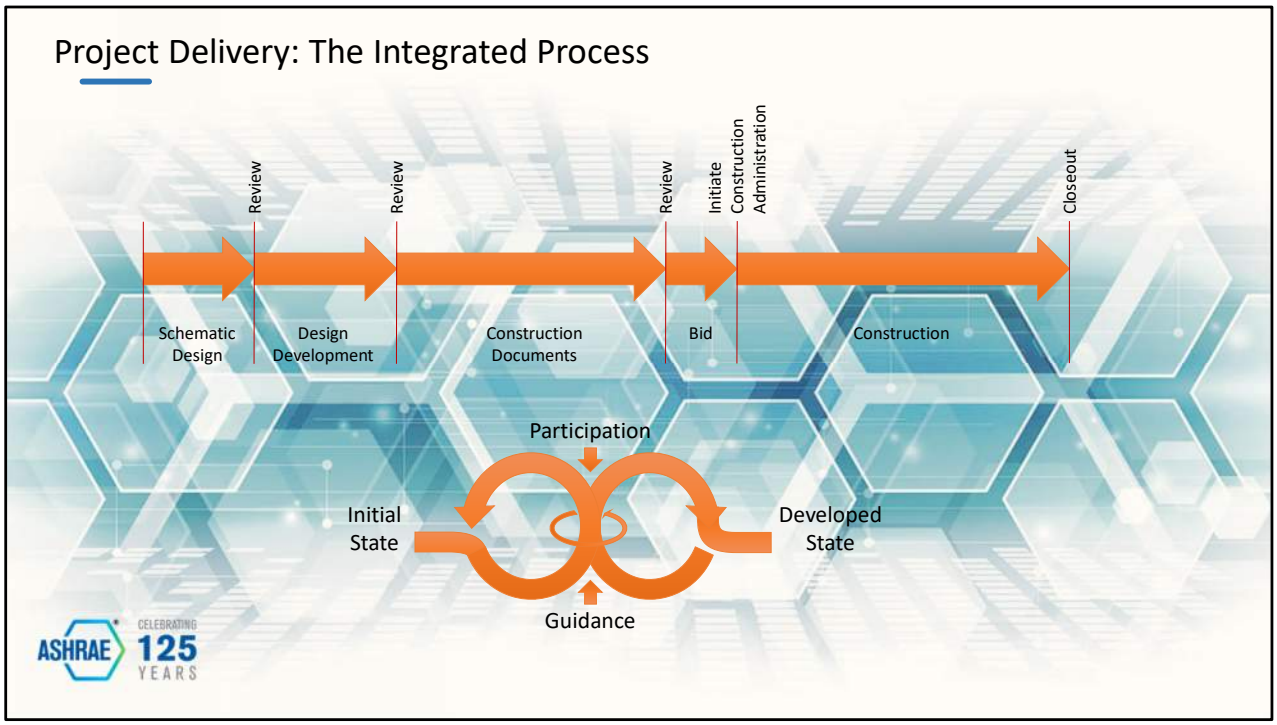
Project Delivery: The Conventional Process

The Dance of the Silos

"We've done it for years. Trust us."

Individual risk and liability concerns foster a work environment that does not empower project participants to collaborate. Instead of optimizing interdependencies, we protect against interdependent shortcomings.

The sequential nature of CDP precludes collaborative input and hampers optimized development of the project.

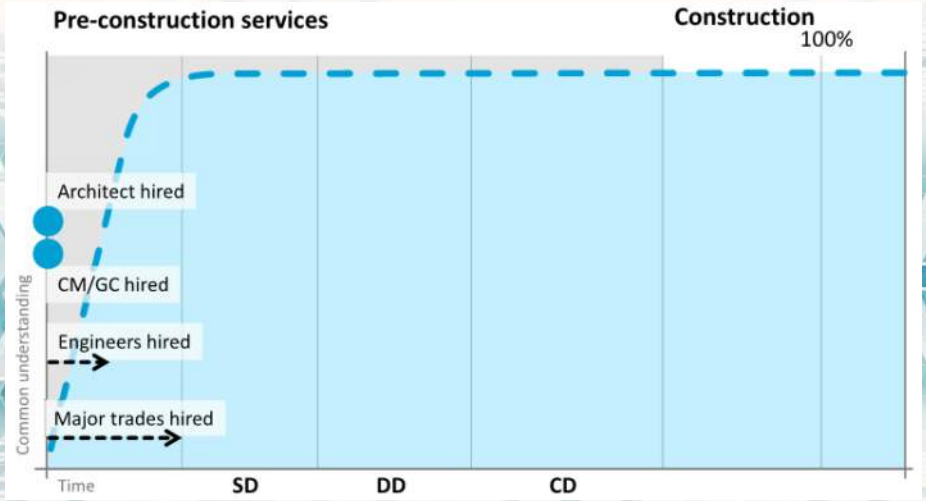


Like CDP, the Integrated Delivery Process (IDP) follows a semi-linear phase progression. Instead of building on sequential response decisions though, workflow is altered to include iterative loops.

Previous decisions are challenged, in an effort to find optimized solutions that fit within the project guidance.

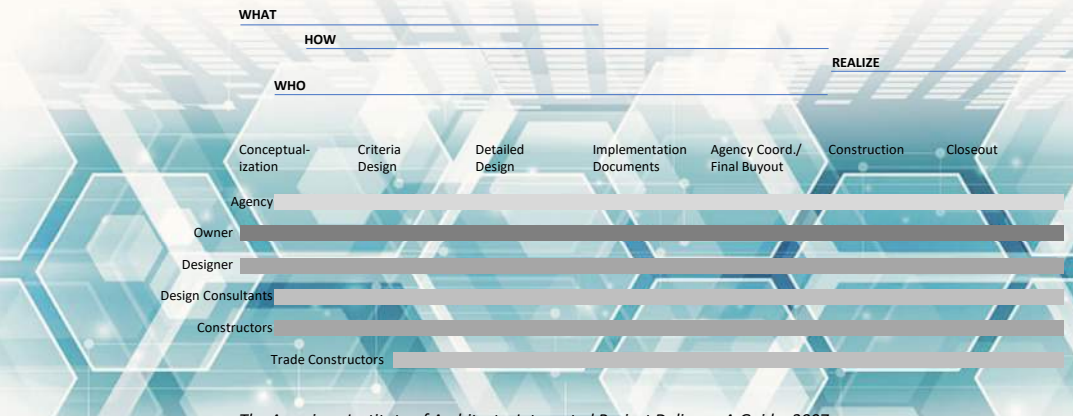
Instead of making sausage in isolation, we seek continuous improvement by making **pretzels**.

Project Delivery: The Integrated Process



Look at how "**Common Understanding**" changes when all stakeholders are engaged at inception.

Project Delivery: The Integrated Process



The American Institute of Architects, Integrated Project Delivery: A Guide, 2007

AIA captures this in an altered graphic set. **What-How-Who-Realize** now morphs to **What-Who-How-Realize**

The vital element of IDP is implementation of the collaborative Team concept; with more inclusive roles, and altered participation timing.

Project Delivery: The Integrated Process

Relational **Collaboration**

Lean – Eliminate Waste

Lean Construction Institute, Transforming Design and Construction, 2016

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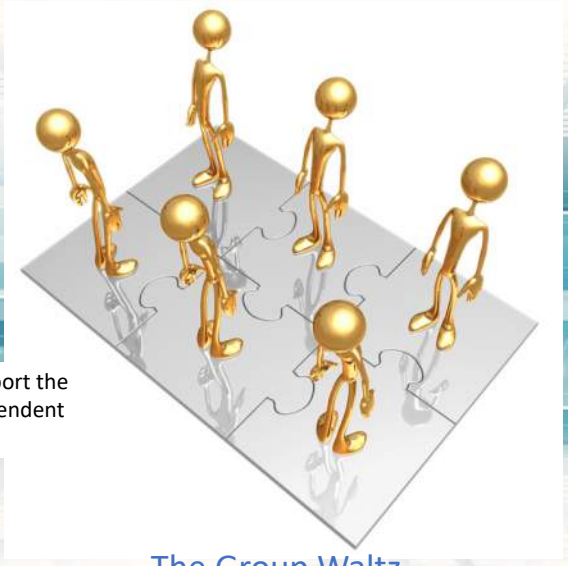
Command and Control yields to Relational.

Transactional is replaced by Collaboration.

Start-to-Finish mindset evolves to Lean and the pursuit of Value.

Project Delivery: The Integrated Process

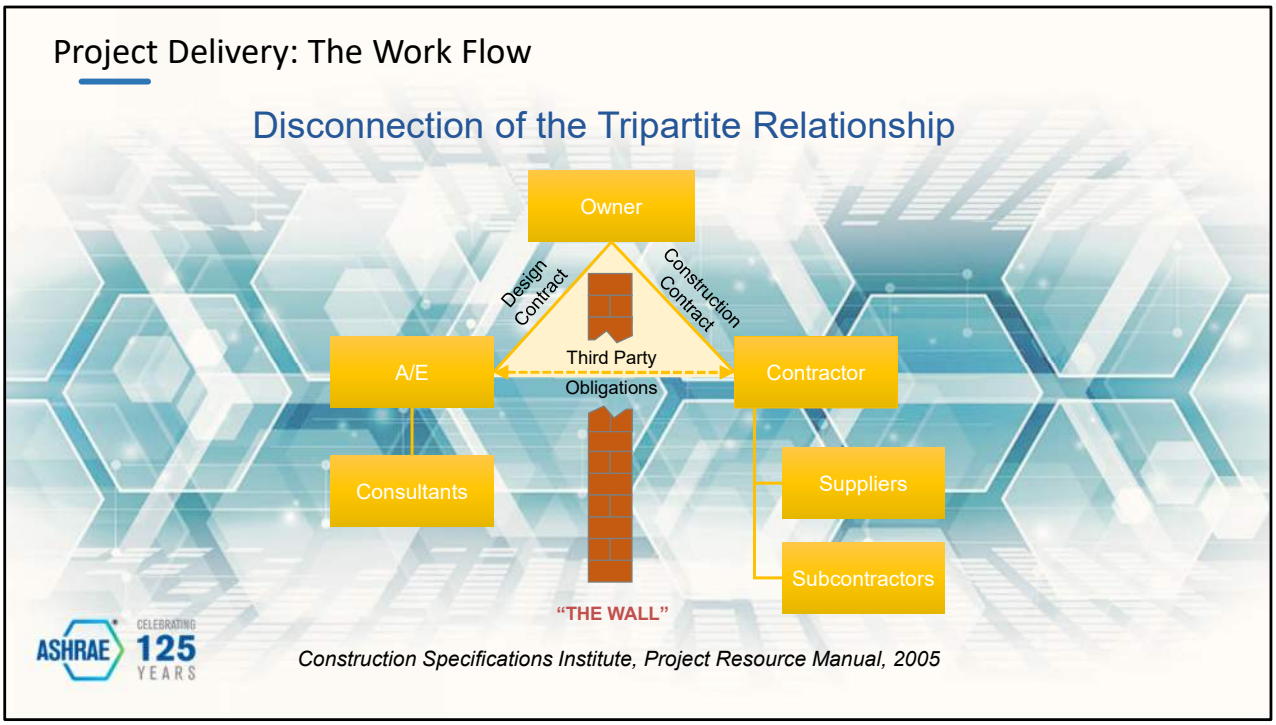


"My actions support the holistic, interdependent solution …"

The Group Waltz

Collaboration fosters solution delivery of integrated systems that, in **aggregate**, form a holistic building. Perspective shifts from isolated stakeholder interests; to one of optimized interdependencies, and group accountability.

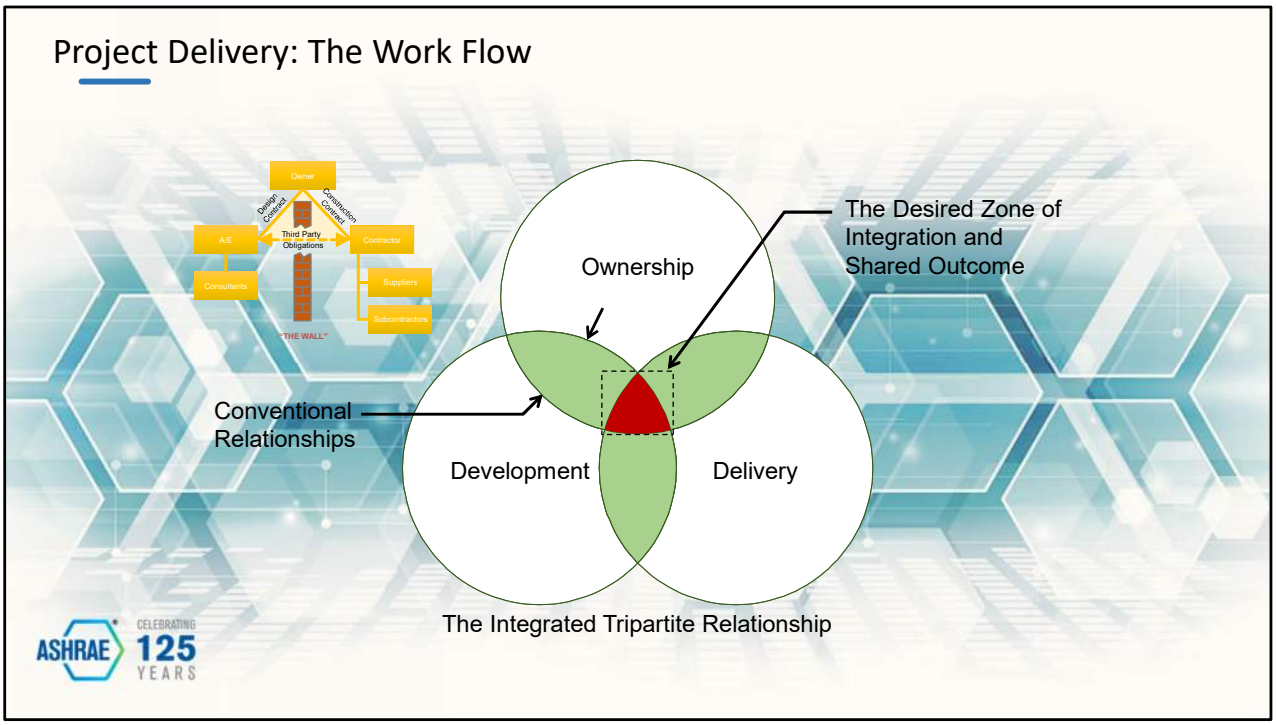
Project Delivery: The Work Flow



CDP can promote a less than desirable dynamic referred to as delivery in isolation. Isolation refers to the potential for work to proceed without collaborative knowledge of what the other stakeholders are doing.

This phenomenon is demonstrated by our adherence to linear hierarchy role management. We see our first example of linearity in the basic tripartite relationship between the Owner, Contractor, and Designer. A contractual disconnect exists between the design and construction paths when employing a Design-Bid-Build model. In effect, we create a collaborative development wall from the outset between design and construction interests.

Project Delivery: The Work Flow



IDP shifts the structure and mindset of the conventional tripartite relationship pyramid to one of shared outcome.

Conceptually, the overlap of the tripartite interests represents the zone of integration.

Silos and hierarchy yield to collaborative intelligence.

Project Delivery: The Work Flow

Traditional Project Delivery		Integrated Project Delivery
Fragmented, assembled on "just-as-needed" or "minimum-necessary" basis, strongly hierarchical, controlled	teams	An integrated team entity composed key project stakeholders, assembled early in the process, open, collaborative
Linear, distinct, segregated; knowledge gathered "just-as-needed"; information hoarded; silos of knowledge and expertise	process	Concurrent and multi-level; early contributions of knowledge and expertise; information openly shared; stakeholder trust and respect
Individually managed, transferred to the greatest extent possible	risk	Collectively managed, appropriately shared
Individually pursued; minimum effort for maximum return; (usually) first-cost based	compensation/ reward	Team success tied to project success; value-based
Paper-based, 2 dimensional; analog	communicatitons/ technology	Digitally based, virtual; Building Information Modeling (3, 4 and 5 dimensional)
Encourage unilateral effort; allocate and transfer risk; no sharing	agreements	Encourage, foster, promote and support multi-lateral open sharing and collaboration; risk sharing

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The American Institute of Architects, Integrated Project Delivery: A Guide, 2007

AIA summarizes the CDP vs IDP paths for us in simple terms.


The Future of Work
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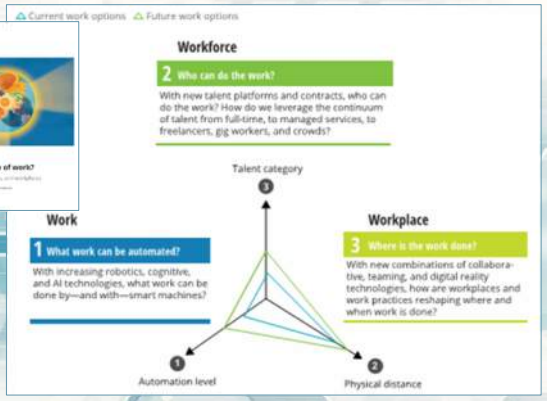
125
YEARS

The Future of Work

A NEW VISION OF (HUMAN) WORK

What is work? Deloitte Review Issue 24, Deloitte Insights, January 2019

THE FUTURE OF WORK ENCOMPASSES CHANGES IN WORK, THE WORFORCE, AND THE WORKPLACE



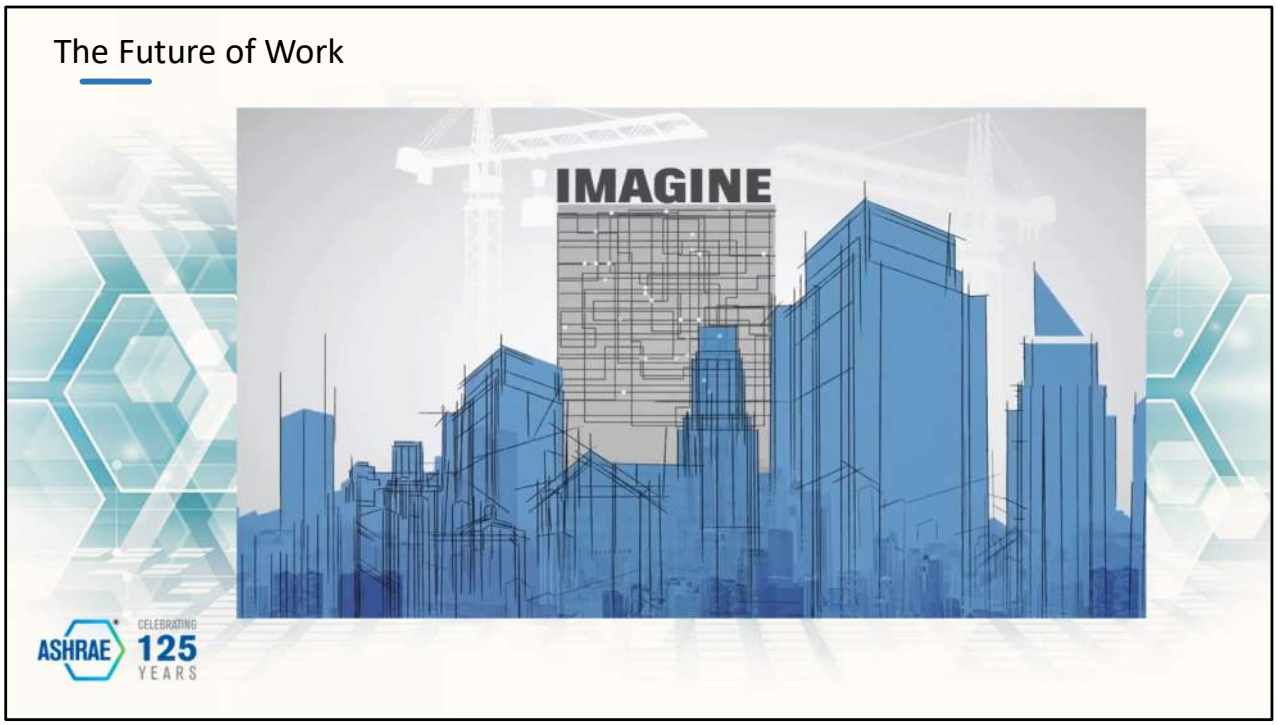
What is the future of work? Deloitte Insights, 2019

Improving our Harvest, begins with altering our view, on the **execution** of Work.

For many of us, **Work** is a place to go perform tasks. We go to work, work on a project, finish work for the day, and go home.

Our path to fragmentation, began many decades ago, when the Assembly Line **siloed** Work. The progression thru Industry 2.0 and 3.0, refined **Work Tasks**. Over time, we have systematically **built**, our own **silos!**

What is the Work that **really**, needs to be done? What if **Work**, itself, was **redefined**? What if we **shifted**, from **Tasks**, to higher value **Activities**? **Prepare yourself**, a **new** vision of Human engagement, awaits **Work**, **Workforce**, and **Workplace!**



Imagine a world, where we **break down** Work silos, and become one **integrated** force:

Collaboration, will **engage** all stakeholders, at inception; to **find** Value.

Digital intelligence, will **amplify**, Human intelligence. We will be **relieved**, of the exhaustive, and repetitive. We will become, more analytical, and strategic.

Building Performance will **evolve** to real-time management. Static points in time will fade away.

Projects will **move**, from **disconnected** paper, to **connected** platforms. We will **evolve**, from intent to build, to building virtually.

The Cloud, will **facilitate** contribution; from **anywhere** in the world, at **any** time, by **anybody**.

Digital precision will **challenge**, where physical work occurs. "**In the field**", will no longer, be the **only** place, for work results to play out.

In **3 Steps**, we **can make this**, our new, **Reality!**


Lean Collaboration
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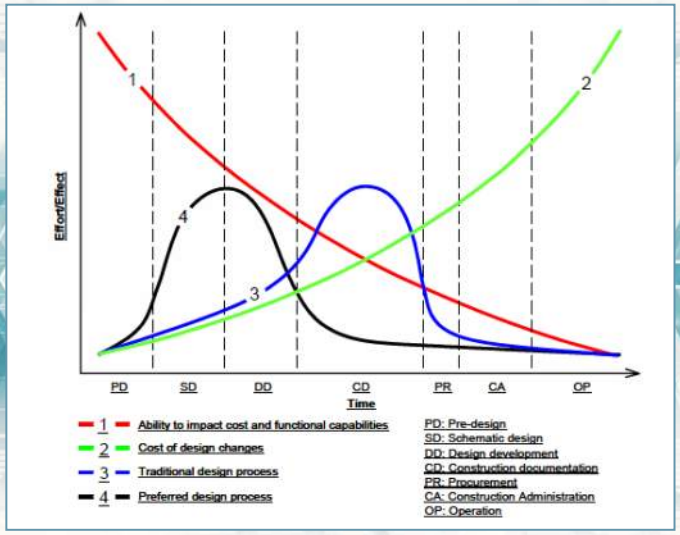
CELEBRATING
125
YEARS

Lean Collaboration



The Construction Users Roundtable (CURT), WP-1202: Collaboration, Integrated Information, and the Project Lifecycle in Building Design, Construction and Operation, 2004

Step 1, of Our **transformation**, requires proper **Preparation**, via **Lean Collaboration**.

Preparation, must **always** keep **Value Discovery**, in focus. **Beneficial Impact**, is **best** realized, when captured **early**. Effort, that occurs **later** in development, has **minimal opportunity**, to impact Value; changes become **expensive**.

Lean processes, create better customer, **experiences**. **Our** ecosystem, needs to adopt a **lesson**, from Manufacturing: "**That which does not add value, is waste!**"

But, how do we **uncover** value? **Six** principles of Lean, **illuminate** our path.

Lean Collaboration

It's All About People

Traditional Culture	Lean Culture
Function Silos	Interdisciplinary Teams
Managers Direct	Managers Teach/Enable
Benchmark to justify not improving	Seek perfection - the absence of waste
Blame People	Blame the Process - Root Cause analysis
Rewards: Individuals	Rewards: Group Sharing
Supplier is Enemy	Supplier is Ally
Guard Information	Share Information
Volume Lowers Cost	Removing Waste Lowers Cost
Internal Focus	Customer Focus
Expert Driven, Periodic Improvement	Process Driven, Continuous Improvement
Efficiency	Value

ASHRAE CELEBRATING 125 YEARS

Respect For People, is the **core** fundamental. **We**, must **evolve**, to:

Value stakeholders, and their **knowledge**.

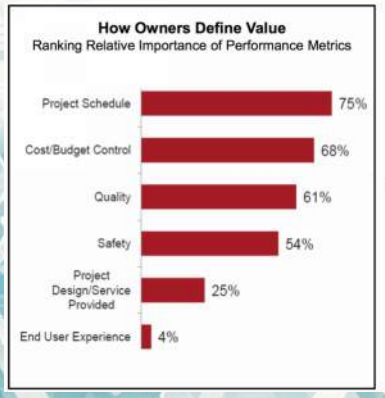
Solve the **issues**, stop blaming the participants.

And, Honor our **commitments** to Team.

Lean Collaboration

Look, beyond the Borders, to **Optimize the Whole**.

Lean Collaboration



Source: McGraw-Hill (2014)

Value is in the eye of the beholder….

Define, what Customer **Value** means.

What, do They want?

How, do They want it?

And, **What**, are They willing to pay, to get it?

Lean Collaboration

Map, the value stream, to identify, and remove **Waste**.

Execution, of Lean IPD, requires new **perspective**. Consider,

There is **ONE** narrative.

Risk and Reward, are **shared**.

Decisions, are **Value** based.

In all phases; **nothing** is done, until it **should** be done. And **yes**, design, is **NO** exception.

I will **never forget** my first visit, to the "**Big Room**". My comfort zone, was **attacked**. My understanding of order, was **threatened**. **I was in a New World**.

Project Success, wasn't **pre-scripted**. **Humans**, reached across **Borders**, to **define**, what the **Harvest**, should be.

"WE", became the operative word. How are **WE**, going to deliver this, as a **Team**?

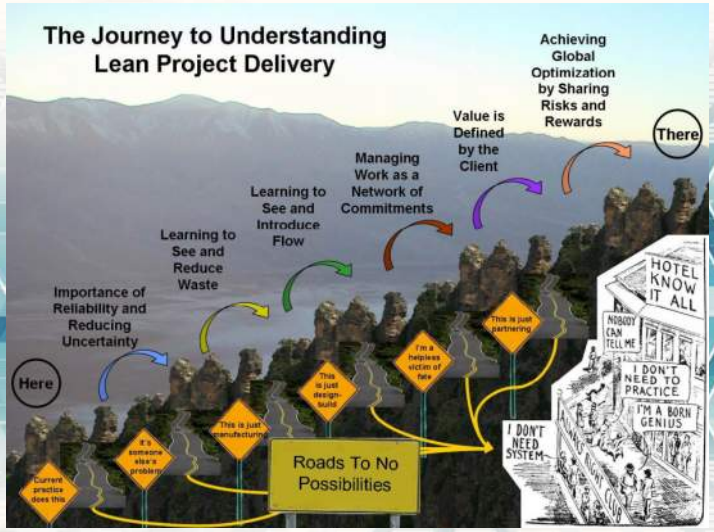
Flow, was **no longer** associated, with fluid transport. **How could this be?** Flow, had a far more, **important** role to play. **And just for good measure**; Flow, didn't start at the head waters, and move outbound; **not at all**. Flow, started at the vision of a built solution; and **backed up,** to **understand** the path, that **needed** to be traveled. A path that **revealed**:

HOW, the project would be, **delivered**.

WHAT, the order of events, **needed** to be.

And **WHO**, owned the **commitments**, along the path.

Lean Collaboration



Lean Construction Institute, Introduction to Lean Design, 2008

And finally, **Demonstrate Continuous Improvement**, along the path.


The Digital Landscape
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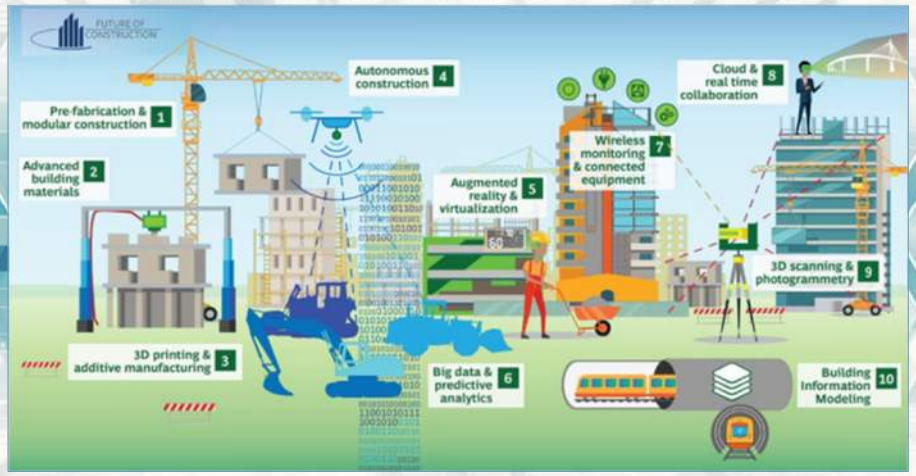
The Digital Landscape

DIGITAL TECHNOLOGIES THAT CAN IMPROVE PRODUCTIVITY

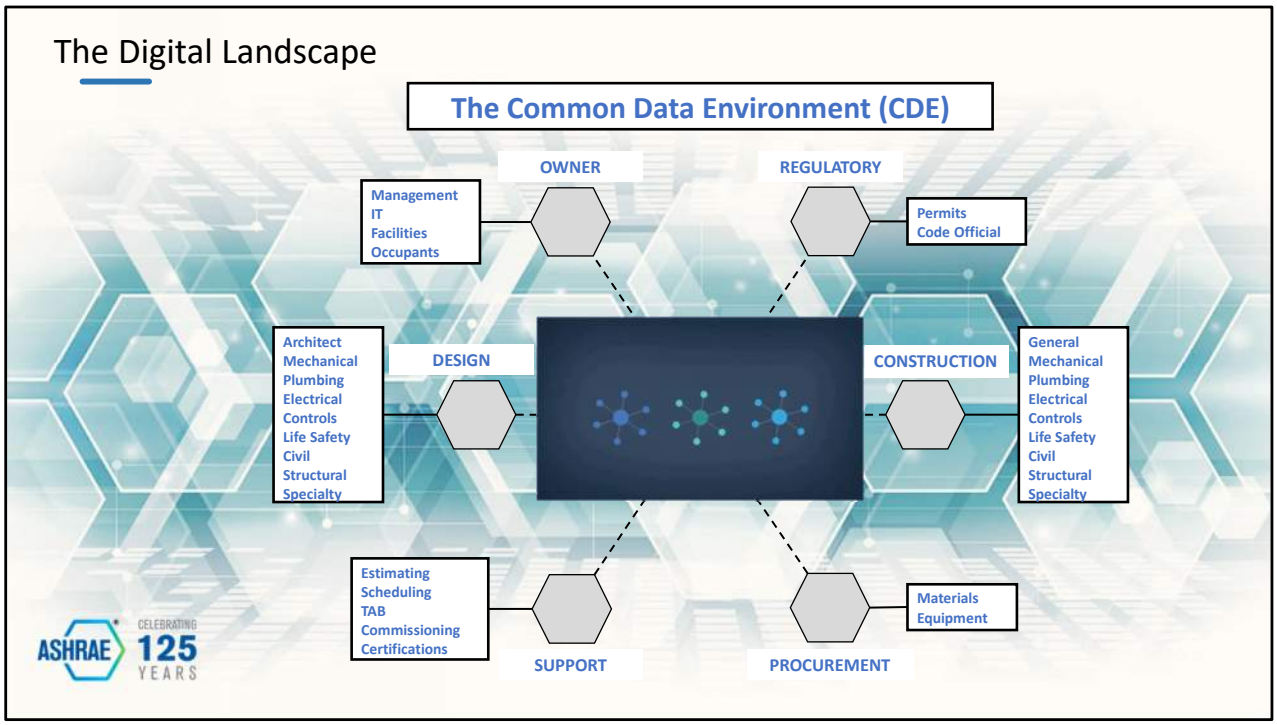


Shaping the Future of Construction: An Action Plan to Accelerate BIM Adoption, The World Economic Forum, February 2018

Proper **Preparation**, will **reveal** all aspects, of **Planting** the correct crop. How we **Maintain** that crop, defines how **bountiful**, our Harvest will be. **Step 2, requires embracing, Digital Technology!**

Transformation, is not simply associated with adopting new technology though. **Knowledge**, needs to be **captured**, and **linked**.

Let's explore critical aspects, of **managing** this process, and what **opportunities**, the Digital Landscape offers.



Digital Technology, is creating **vast** amounts of Data. **We are literally SWIMMING in it!**

We, must figure out a way, to **connect** all of this knowledge. The evolution of the **Common Data Environment (CDE)**, is warranted, to **manage** information; a **Single-Source**, **Single-Truth**, **Lighthouse**. The CDE platform, sets the table, for **all portable Project knowledge**!

Connected knowledge affords interconnection; which paves the way for grid-interactive buildings and resilient communities.

The Digital Landscape – Virtual Design and Construction

Virtual Design and Construction, or **VDC**, is a process that moves us, from static drawings, to 7D BIM models. We are making the transition, from **STATIC Geometry**, to **DYNAMIC Information**. Remember when we shifted, from paper to CAD? Well, the shift from CAD to Digital Models, **will be just as Disruptive!**

Intelligent Objects, contain **Knowledge**. **Changing** an object anywhere, becomes an **integrated change**, everywhere.

Our use, of a 7D platform will:

Verify Constructability.

Reveal Time.

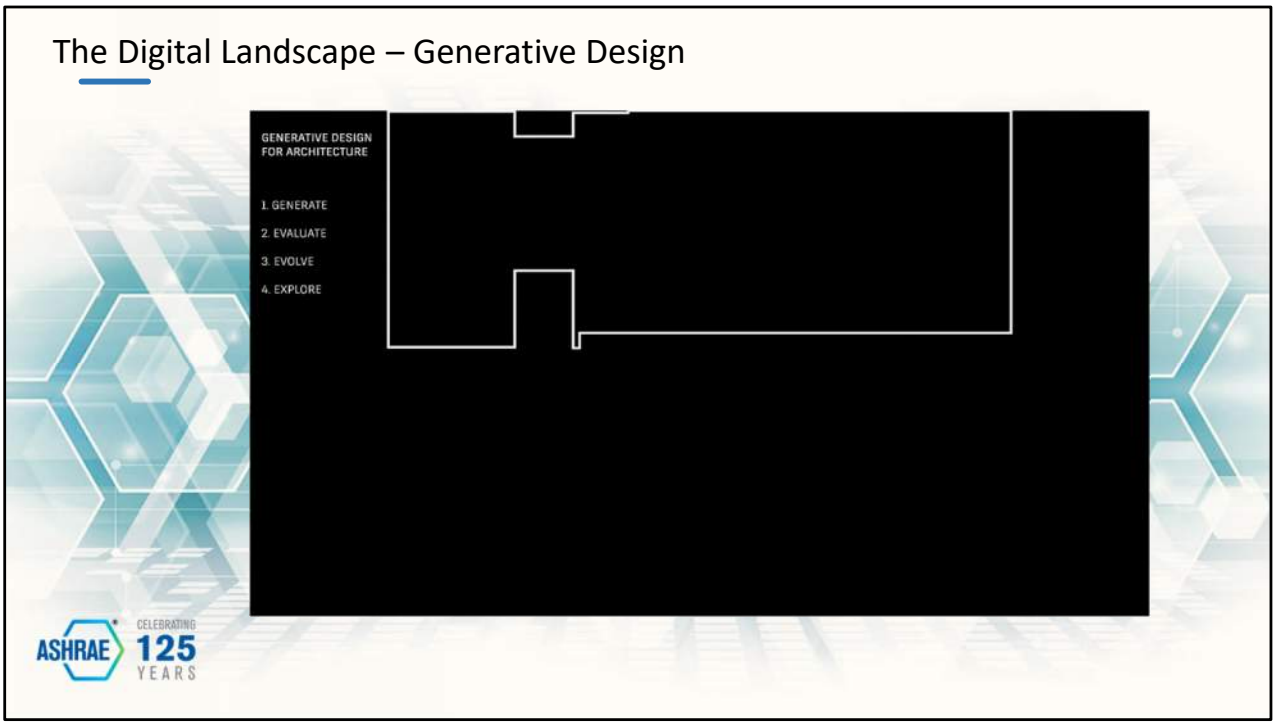
Capture Economy.

Integrate Performance Modeling.

And, **Connect** Operations and Maintenance.

Printed documents, will **no longer**, be the primary representation of the Project. **The Model, becomes the database, of ALL PROJECT KNOWLEDGE!**

The Digital Landscape – Generative Design



Generative Design, is a **fascinating** concept. Picture utilizing, an **augmented** strategy, to **automate** design development.

Algorithms, can test **hundreds** of **variables**, in **thousands** of **iterations**. **Humans**, still define the boundaries and goals; but software, handles **comparison**.

You are watching a simple example of algorithms being used to optimize daylighting solutions.

I still remember, the **countless hours**, that Performance Modeling used to require.

Drawings, had to be **measured** by hand, to capture geometry.

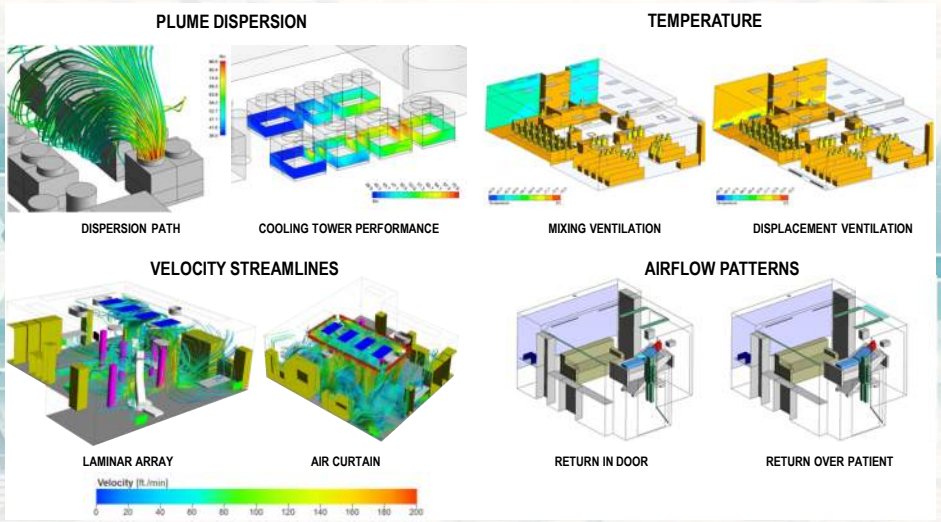
Elements, had to be **found** on details, or in specs.

Systems, had to be **manually** configured, in singular fashion.

One change, required a complete **redo**, of the entire simulation.

Those days, are behind us now! Objective based **Integrated Building Design** is at our fingertips.

The Digital Landscape - Computational Fluid Dynamics



ASHRAE CELEBRATING 125 YEARS

Airflow patterns, are Vital! **Simple** throw patterns, and arrows, on 2D drawings; do not reveal **Truth**. What doors would open to us, if we had **Insight**, into how air should **act**? Tools, such as **Computational Fluid Dynamics (CFD)**, allow us, to:

Visualize, thermal impact.

Understand, the path of air.

Compare, ventilation strategies.

Simulate, Thermal Comfort.

And, **Demonstrate**, Ventilation Effectiveness.

The Digital Landscape – Digital Twin

By connecting sensors, to a digital platform, we can create a **virtual mirror**, of our physical asset. This **Digital Twin**, allows us to embark, on a continuous journey. We,

Collect, **real-time** performance Data.

Provide, an evolving **profile** of **Past**, and **Current**, behavior.

Employ **analytics**, to mine the **Data Lake**; searching for trends and patterns.

Identify, **actionable** intelligence.

Repeat, the cycle.

Now, consider what the power of this **Insight** yields:

For **Commissioning**, we have a **connected tool**, for tuning performance 24/7.

For **Building Performance**, we have a robust engine that monitors and optimizes real-time facility resource impact.

For **Operations**, we **transition** from **Reactive**, to **Predictive** response.

For **R&D**, we have real-world information, that supports **validation** of performative simulations.

I'm **excited** to announce, that the new ASHRAE headquarters, is going to **have** a Digital Twin to support Effective Building Operations! You've been watching, the **genesis** of **Our** Twin, unfold.

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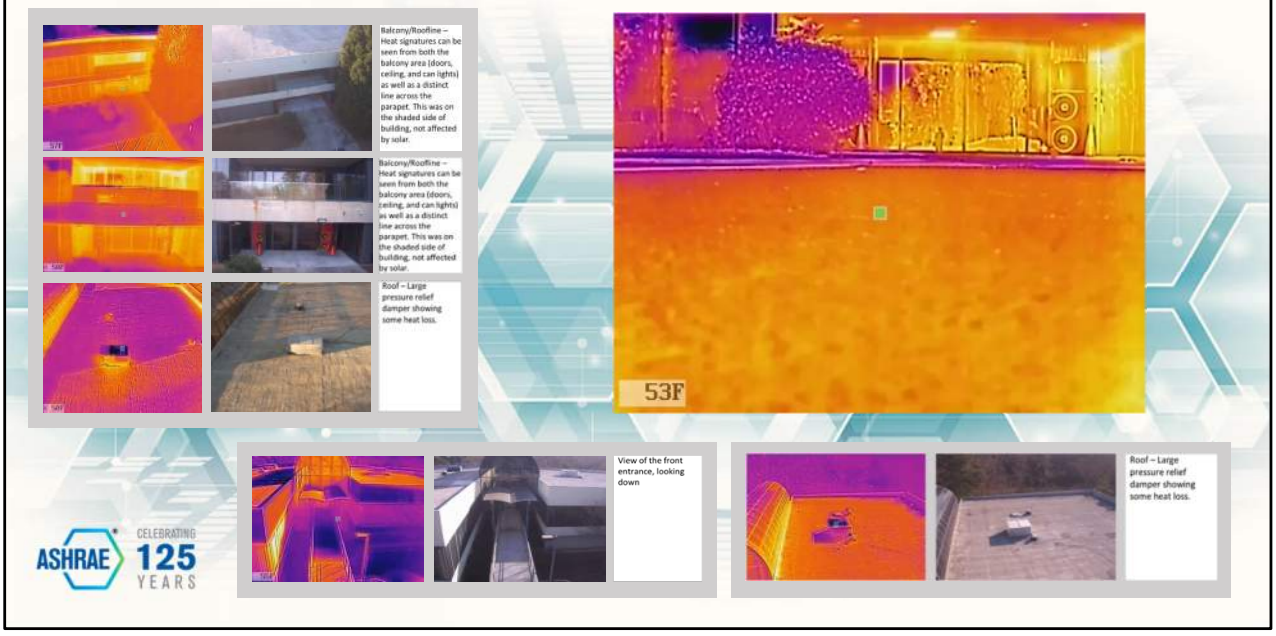
The Digital Landscape – Drones



Drones, provide **invaluable** support logistics:

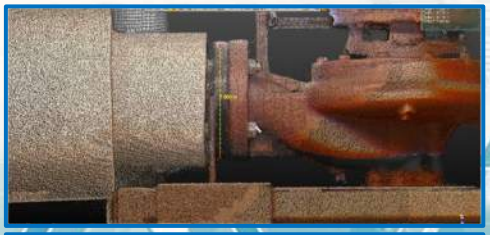
Aerial Mapping, can capture all **site**, and **infrastructure**, content.

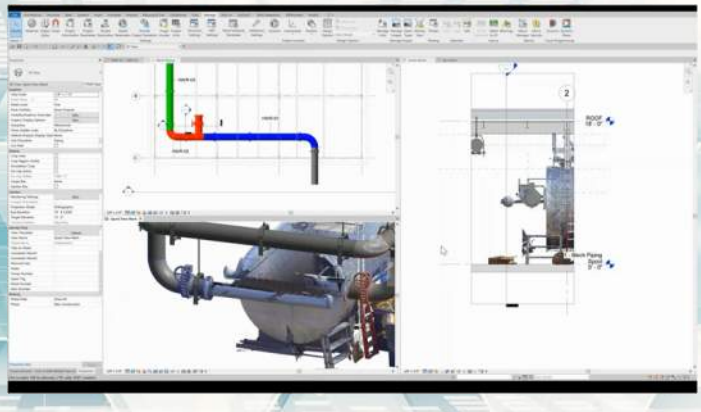
Construction Monitoring, is available at **any** elevation. We are no longer **tethered** to ladders, lifts, and safety harnesses; to **view**.

Thermal Mapping, can be performed, around an **entire** building envelop. This technology, was used to evaluate the As-Built integrity, of the new ASHRAE Headquarters. **Thermography**, provided the **Insight** needed, to modify the existing envelope, for **High-Performance**.

Think of all the energy that can be saved via revitalization of existing building stock assets at scale. We can **identify** thermal weakness; we can **correct** root cause waste.

The Digital Landscape – Light Detection and Ranging



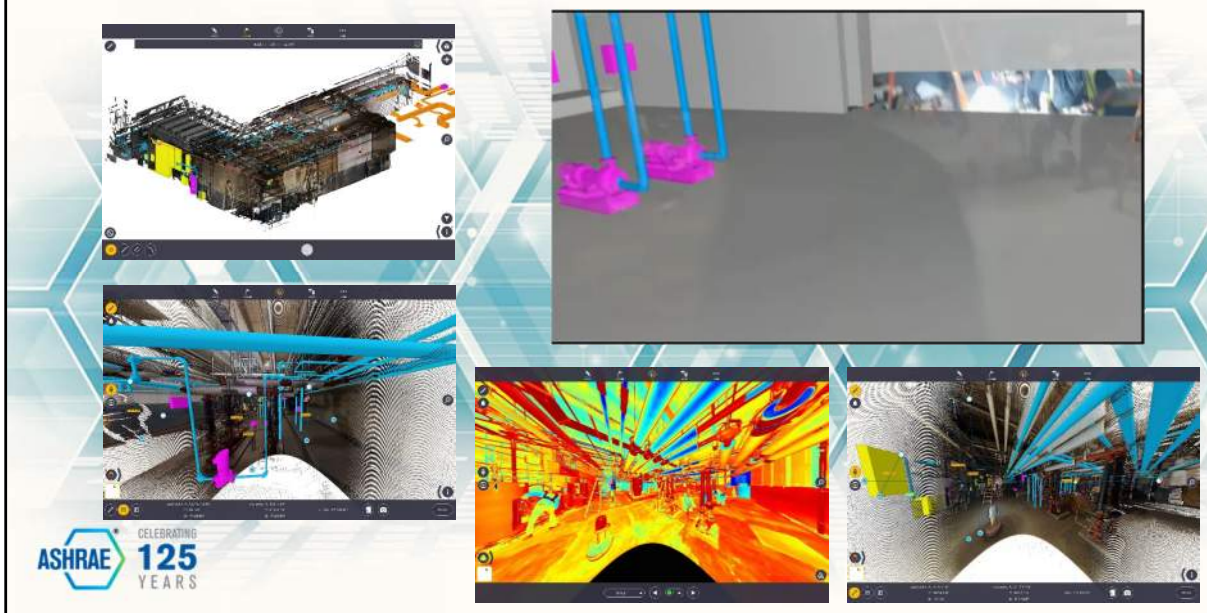


Scanning, via **Light Detection and Ranging (LIDAR)**, delivers **precise** point cloud maps, of surfaces, and complex geometries. We, can scan **densely packed** settings, to capture, **true** As-Built conditions.

We no longer need, to **search** for paper, and attempt to **recreate**, what was built. **Manual** measurement, is eliminated. Waste is removed.

Scanned point clouds, can be **integrated**, to our digital models. **Technology, captures the Truth!**

The Digital Landscape – Augmented Reality



Augmented Reality (AR), can take model data, and **project** a **precision** reference, in the physical world. Peruse the possibilities, as you explore LIDAR scans, and AR projections, inside the new ASHRAE Mechanical Room.

Imagine, using a simple cell phone, and a positioning device, to:

Locate, **exactly** where **penetrations,** and **attachments**, occur.

Project, a **virtual installation**, onto the target zone.

Reveal, where **hidden** infrastructure, is located.

Wearables, allow us to project, **complete** MEP layouts. Virtual **Insight**, allows us to **SEE**, where work results, **should** be performed. **Installed** work, can be **verified**, with the 7D Platform.


Design for Manufacture and Assembly
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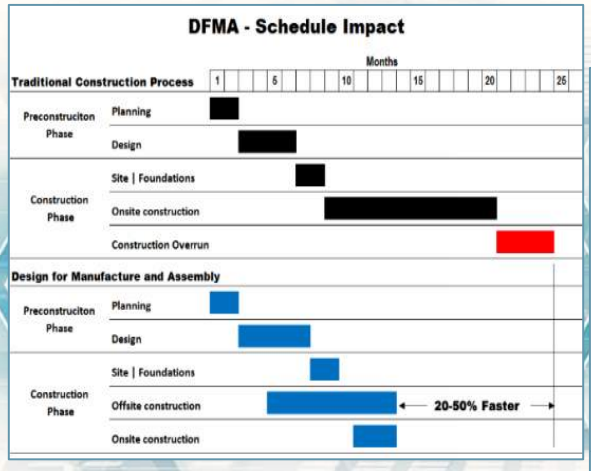
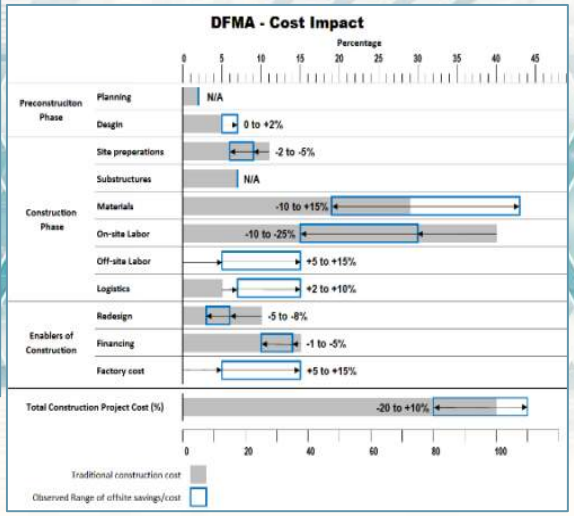
Design for Manufacture and Assembly – Value Proposition





Our 3rd, and Final Step, moves our journey, Off-Site. Design for Manufacture and Assembly (DfMA) strategies, challenge where work, **is physically performed**.

What, are the **benefits**, of decoupling Work? Well,

Parallel work, leads to **shorter** schedules, and **reduced** overhead.

Vertically integrated supply chains, **drive costs down**.

Automation, **reduces** human, and material, waste.

Precision, **enhances** quality control, and **reduces** rework.

Applied correctly; this equates to; **enhanced** Economy, Time, and Quality.

Design for Manufacture and Assembly - Transportation

Modular, requires us to think differently, about **system** design. **Transport Logistics,** will influence layout and configuration.

Design for Manufacture and Assembly - Standardization

Repeatability and **Standardization,** enable production efficiency.

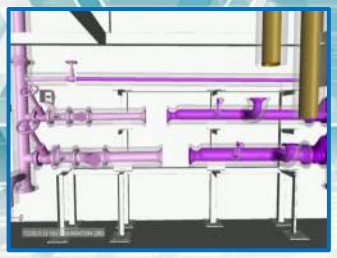
Design for Manufacture and Assembly – On-Site Logistics




On-Site Logistics, determine **interface**.

We are only limited, by what can be shipped, or moved!

Design for Manufacture and Assembly – Assemblies



Modular, is a **scalable** expression, that can be executed, at **many** levels.

In its **simplest** form, we can prefabricate basic assemblies to support On-Site, or Off-Site, **Just-in-Time Flow**.

Design for Manufacture and Assembly – Racks




Facility Services can be designed and built on racks to reduce on-site overhead clutter and laydown burden.

Design for Manufacture and Assembly – Equipment

Let's **increase** scale, to the equipment level. Unitized skids; can be built, tested, commissioned, and validated; offering **complete MEP setup**.

Wiring integrity, can be **verified**. Sequences of operation, can be **simulated**. Functional attributes, can be **checked off**.

Design for Manufacture and Assembly – Rooms

Super-Skids, Rooms, and Floors can all be, **Imagineered**.

Picture a world, where **Central Plants**, are **delivered** to the jobsite.

Maintaining: Design for Manufacture and Assembly - Buildings

The true definition, of "**at-scale**", can be understood when we realize, complete **BUILDINGS** can be modular.

Pause, and **reflect** on this a minute. We can **now**:

Design, a virtually precise Building.

Build it, off-site.

Prepare the site, to receive the modular solution.

Ship the modules, to the project site, staged for "Just-In-Time" **Flow**.

Then **Assemble** the modules, in sequence, to form a complete structure.

Let your takeaway on the DfMA narrative, flow something like this. Work results **no longer** need, to adhere to Start-to-Finish thought. We have evolved. **We have decoupled, the sequential Supply Chain**!


The New Age
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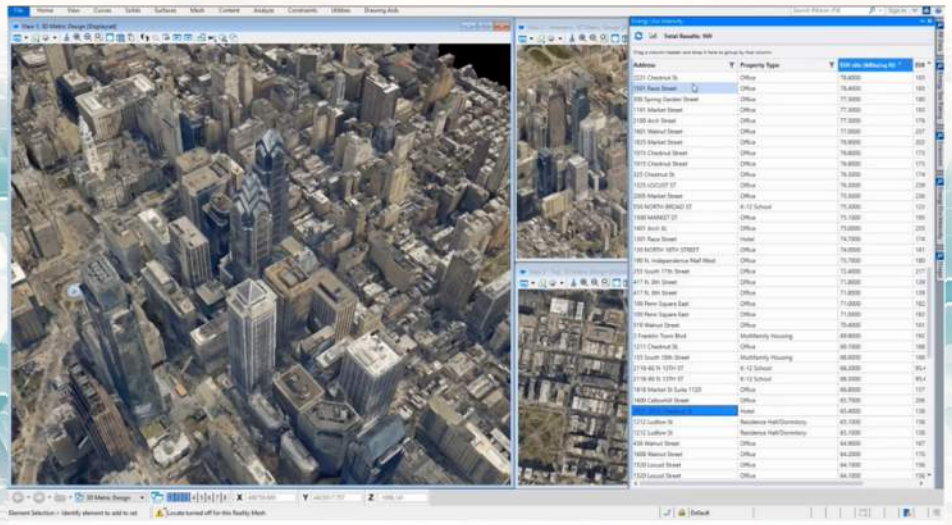
The New Age



Welcome to the Future!

A **New Age** awaits. **Collaboration**, **Value**, **Digital**, and **Off-Site** are changing Our ecosystem.

Collaboration, breaks **Us** from fragmentation.

We, have an opportunity to **challenge** what **Work** is, how it should be **approached**, and where it can be **performed**.

We, can **engage** our workforce, in activities that **seek**, and **create**, Value.

Data, becomes a critical resource. Everything, that **unfolds** in the future, **revolves** around **Data**.

I know some of you, have **already** started to travel this path. Many of you, have **not**. **Innovators** and **Novices**, here's a **critical** point to remember. **Our** Harvest, is realized, when **We** implement technology, to improve **Our** productivity. **Humans, are the key!** It is up to **Us**, to determine how **We** benefit, from a **connected** Digital World.

The New Age

The years 2020-2021, will be remembered, **in infamy**, as the period of the **Global Pandemic**. We are **witnesses**, to **indescribable** tragedy. As for **Our** industry,

Supply chains have been **broken**.

Projects have **ground** to a halt.

Worker productivity has been compromised.

Co-location events have **ceased**.

If we **can** look past the tragic aspects of this point in time, **opportunity** can be found. The very tools and procedures, needed to improve our Harvest, are being **thrust** upon us. We are engaging, in **digital** collaboration, to survive.

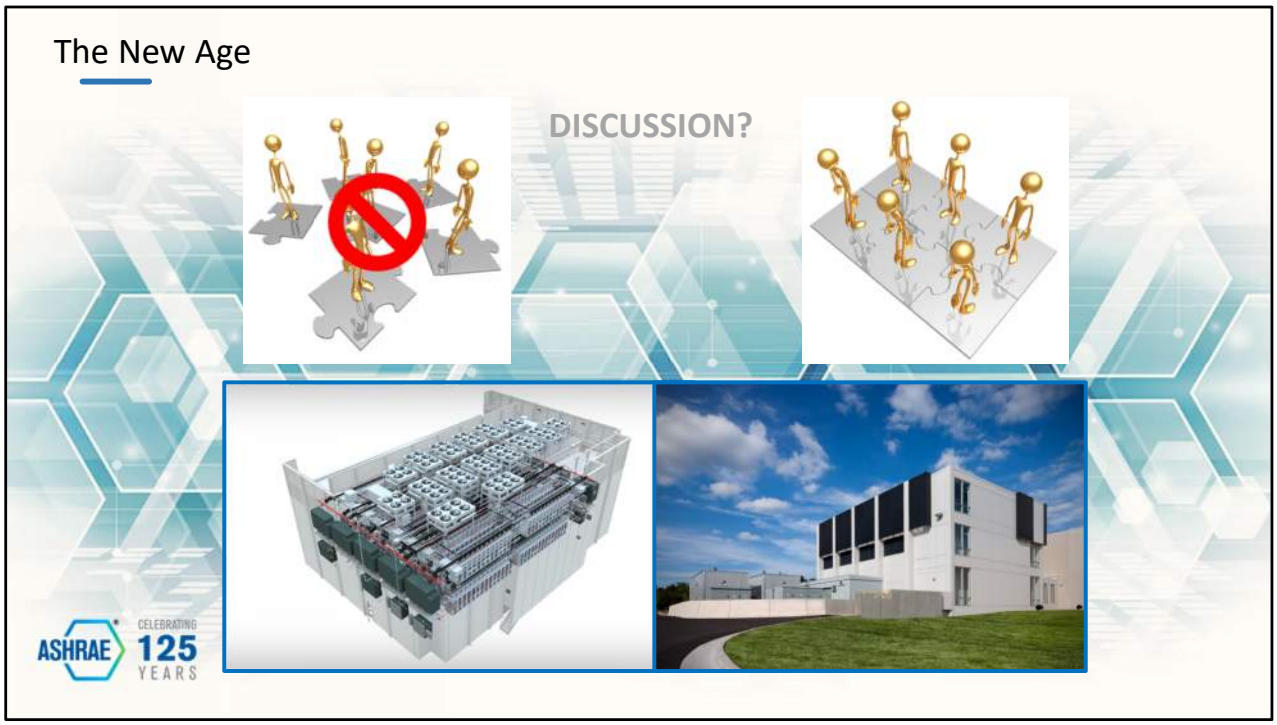
Reactive measures, however, do not resolve the question: What can "**I**" do to **deliver** a bountiful Harvest? Here, is what **You** can do; or better yet, **should do!**

Implement a corporate **Digital Core**. **Work**, **Workforce**, and **Workplace** must be **connected!**

Commit to a **Digital Culture**; that **Expands** appetite for risk, **Encourages** experimentation, **Invests** in digital talent, and **Expands** collaboration skills.

Adopt **Lean Collaboration**, as a core philosophy.

And finally, **Connect** all Stakeholders and the Supply Chain, to expand your understanding, of what **IS** possible.



Industry 4.0, and the Digital Age of Connection, are here! Our World, and Industry, are changing dramatically; by **Force** and **Maturation**.

Buildings of the future, whether new or old, **will** become data-driven. The entire **Design–Build–Operate** journey will evolve from silos and static points in time, to dynamic real-time asset management. Are we ready?

JOIN me, in <u>Preparing</u>, <u>Planting</u>, <u>Maintaining</u>, and <u>Delivering</u> Society's bountiful <u>Harvest</u>!

Thank You!

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