24TH ANNUAL

24TH LCI CONGRESS
OCTOBER 18-21

Lean construction manufacturing: The new game plan for prefab

Melissa McEwen and Nick Masci, Haley & Aldrich

LEAN GUMBO: THE RIGHT INGREDIENTS FOR PROJECT SUCCESS

OCTOBER 18, 2022

Welcome

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Roadmap for our time together

1. Business Case
2. Assess our own Industrialized Construction Maturity
3. Time Measurement & Waste Identification
4. Product Family Mapping
5. Plant Layout
6. New roles, New Skills, New Opportunities

Business Case

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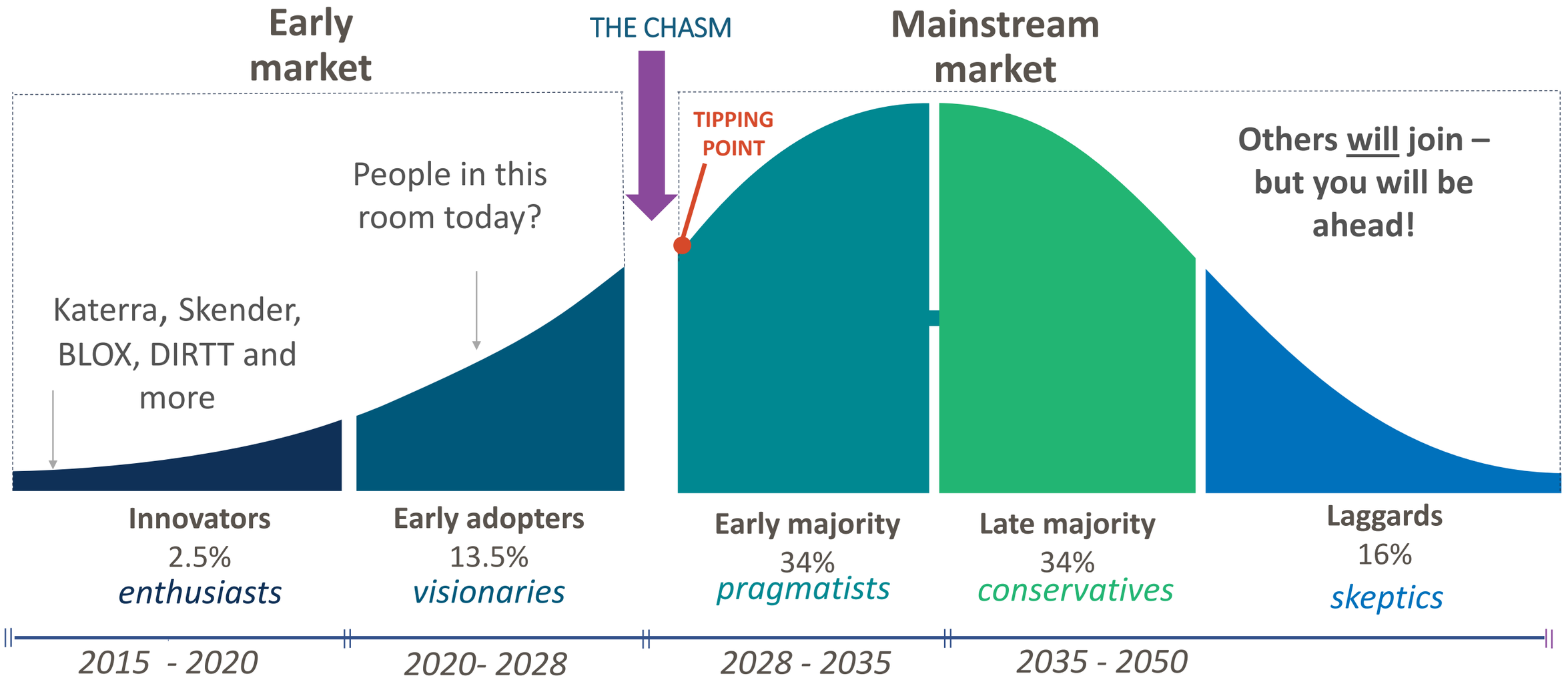
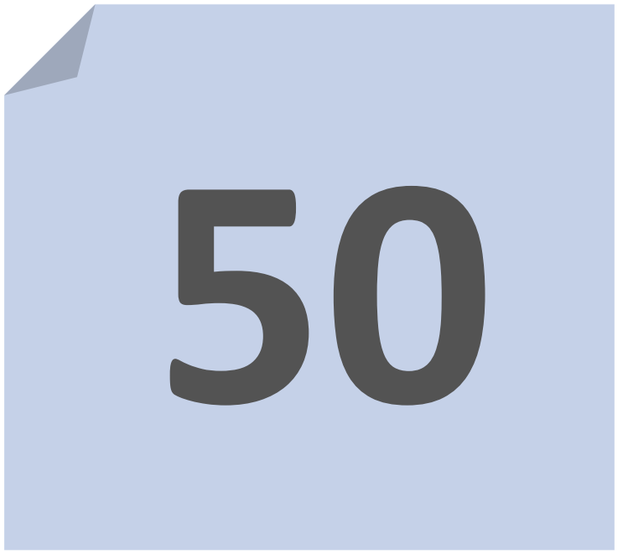
Construction Manufacturing: Adoption of Innovation



Business case for construction manufacturing



50% Faster

70% Fewer People on Site

70% Fewer Deliveries

Industrialized Construction Maturity Assessment

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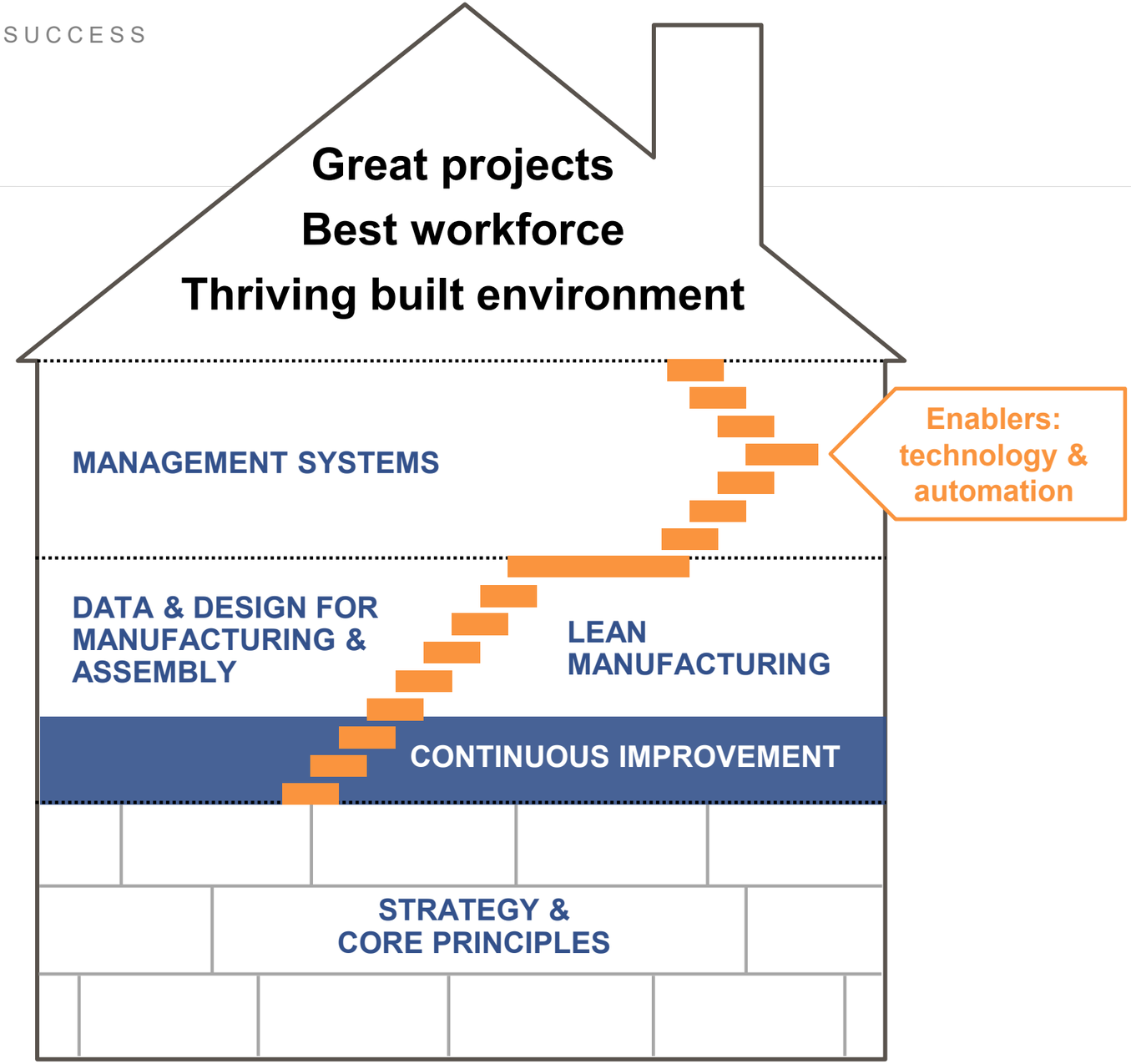
Nemawashi (根回し)

Creating a stable foundation

The (Lean) House of Industrialized Construction



*Adapted for construction from Toyota's House of Lean

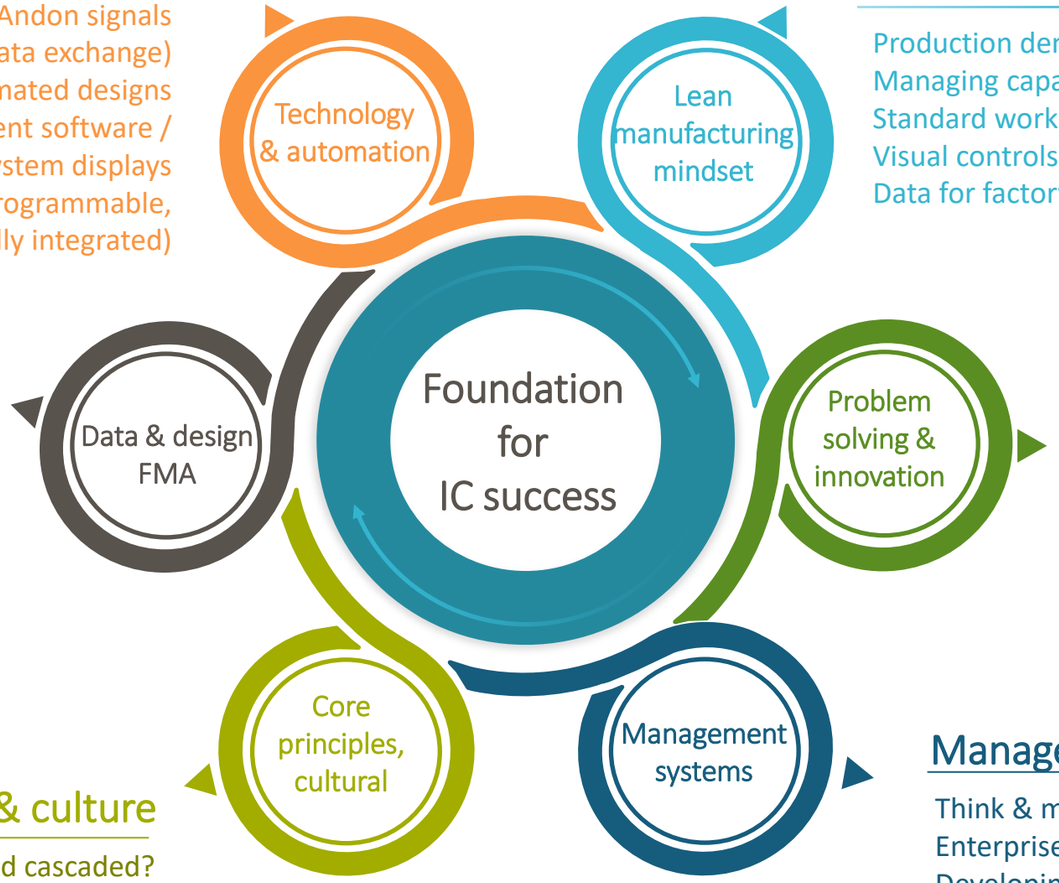
Overview of the Haley & Aldrich Maturity Assessment for IC

Technology & automation

Andon signals
Flow of information & data (common data exchange)
Automated designs
Production / factory management software / Automated system displays
Stages of automation (non-programmable, programmable, fully integrated)

Lean manufacturing mindset

Production demand (Takt) & production control
Managing capacity, load leveling
Standard work & workplace organization (5S)
Visual controls & visual management
Data for factory



Data & design FMA

Early integration with design & suppliers
Path to productization - standard work,
Estimating – design - factory feedback loops
3P & rapid prototyping

Continuous improvement

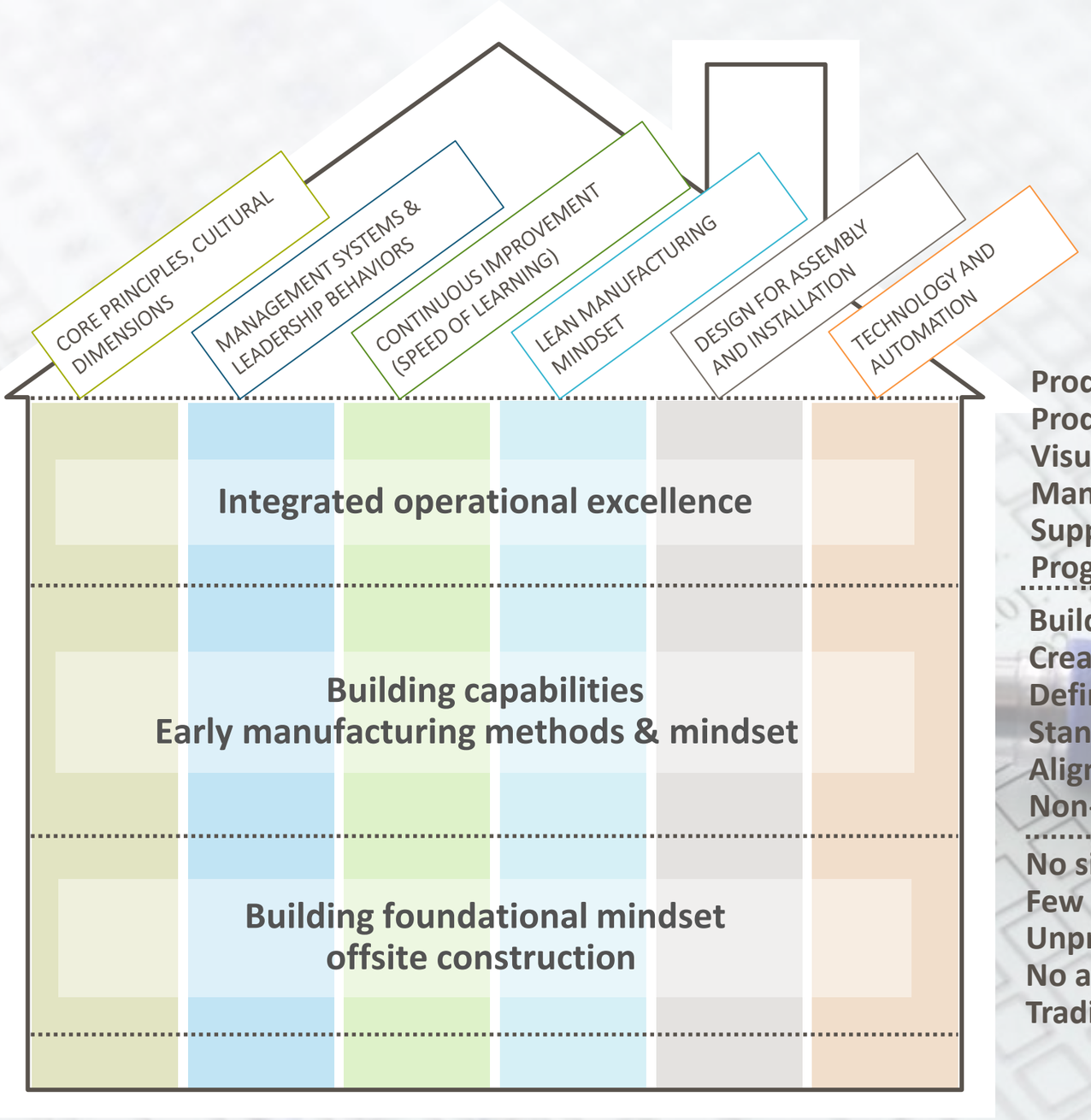
How are the latest tools and best practices applied?
How do we foster innovation?
Making problems visible
Process stability
Knowledge transfer

Strategy, core principles & culture

How is strategy being defined and cascaded?
Focus on customer value / voice of customer
Learning organization

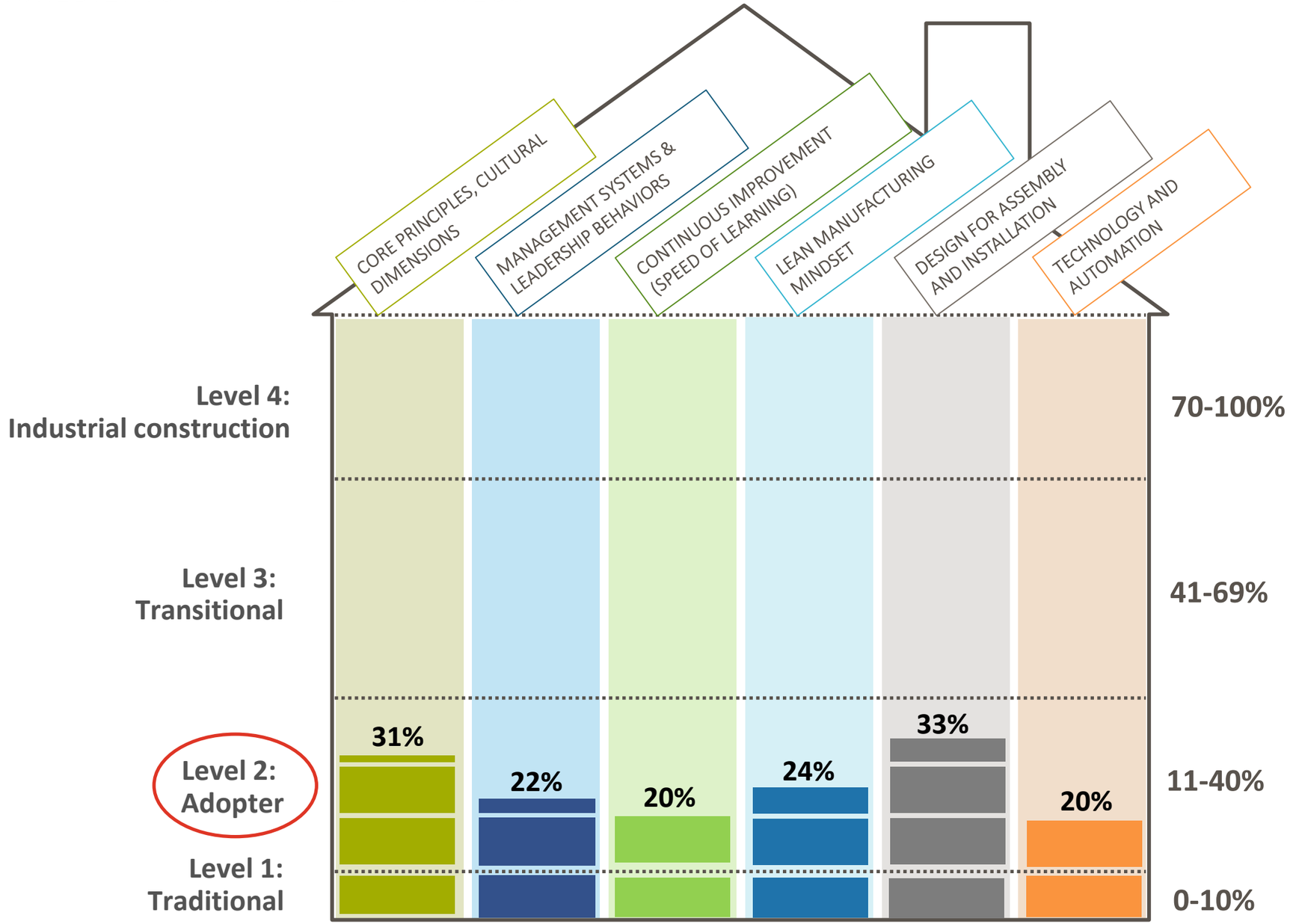
Management systems

Think & manage in value streams (end to end)
Enterprise dashboard aligned with IC metrics
Developing the skills of the future in people
Management at the Gemba



The House of Industrialized Construction Maturity

Sample Company – Haley & Aldrich Maturity Score



Sample Scoring Detail: A robust system with defined attributes to identify where you fall within levels

Range of scores possible:

Your Score: 54 Max Possible Score: 240			**Level 1 Traditional**	**Level 2 Adopter**	**Level 3 Transitional**	**Level 4 IC**
Example Category	**Example Key practices**	**Attributes for each level**	**1**	**2-4**	**5-7**	**8-10**
Finished goods management	Shipping: Field / Onsite Logistics (time of install)	Level 1: We ship whenever our people and products are available Level 2: We have a general schedule and deadlines that we try to meet. Level 3: We manage fabrication to match onsite installs week to week Level 4: Onsite installs are planned and managed to synchronize with production & staff capacity		4		
	Visibility & tracking; Digital Tracking of Products from BOM->---Supplier----->Production---> Field Installation (birth history known)	Level 1: Phone calls and lists (per job) Level 2: Tracking of batches is done as each is completed. Level 3: Per Part, Assembly Level 4: Fully integrated, digital - visibility of anything from Supplier to Field.		3		
	WIP and Finished goods: in control or out of control	Level 1: We build to inventory to keep people busy Level 2: WIP is managed to prevent overproduction Level 3: Min / Max levels for production are visible (e.g., clear Standard Work in Process) Level 4: Inventory is capped to prevent overproduction & Water Spider; "Short-term parking", 8 hours work w/in 10' of worker; see checklists; reduce transportation-waiting-motion-# touches		2		
Jidoka / Autonomation	Ensure everything is right first time at every step of the process (Quality at the Source)	Level 1: We don't have a formal quality assessment process Level 2: Quality is determined by human checks at the end of production Level 3: Start up checklist for work cell, standard work and visual cues to find defects; Work Instructions Level 4: Equipment is intelligent and can spot mistakes & can signal an alert there is an issue. Management is set up to respond to out of standard conditions.		3		

Sample Scoring

Lean Manufacturing Discipline

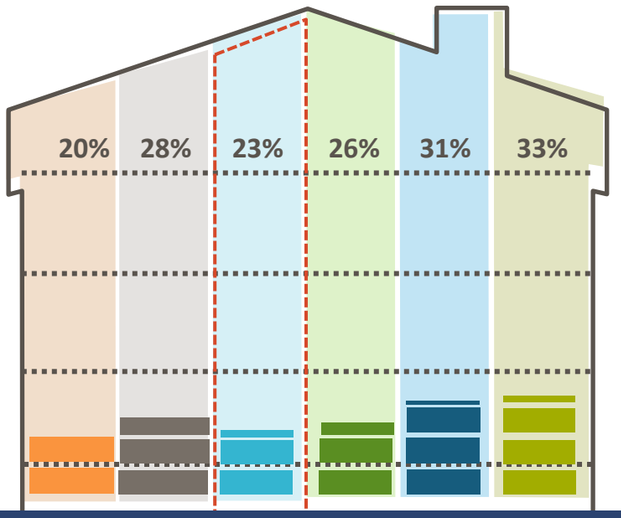
Range of scores possible within each level:

		1	2-4	5-7	8-10
Example Category	**Example Key practices**	**Level 1 Traditional**	**Level 2 Adopter**	**Level 3 Transitional**	**Level 4 IC**
Finished goods management	Shipping: Field / Onsite Logistics (time of install)		4		
	Visibility & tracking; Digital Tracking of Products from BOM->---Supplier----->Production---> Field Installation (birth history known)		3		
	WIP and Finished goods: in control or out of control		2		

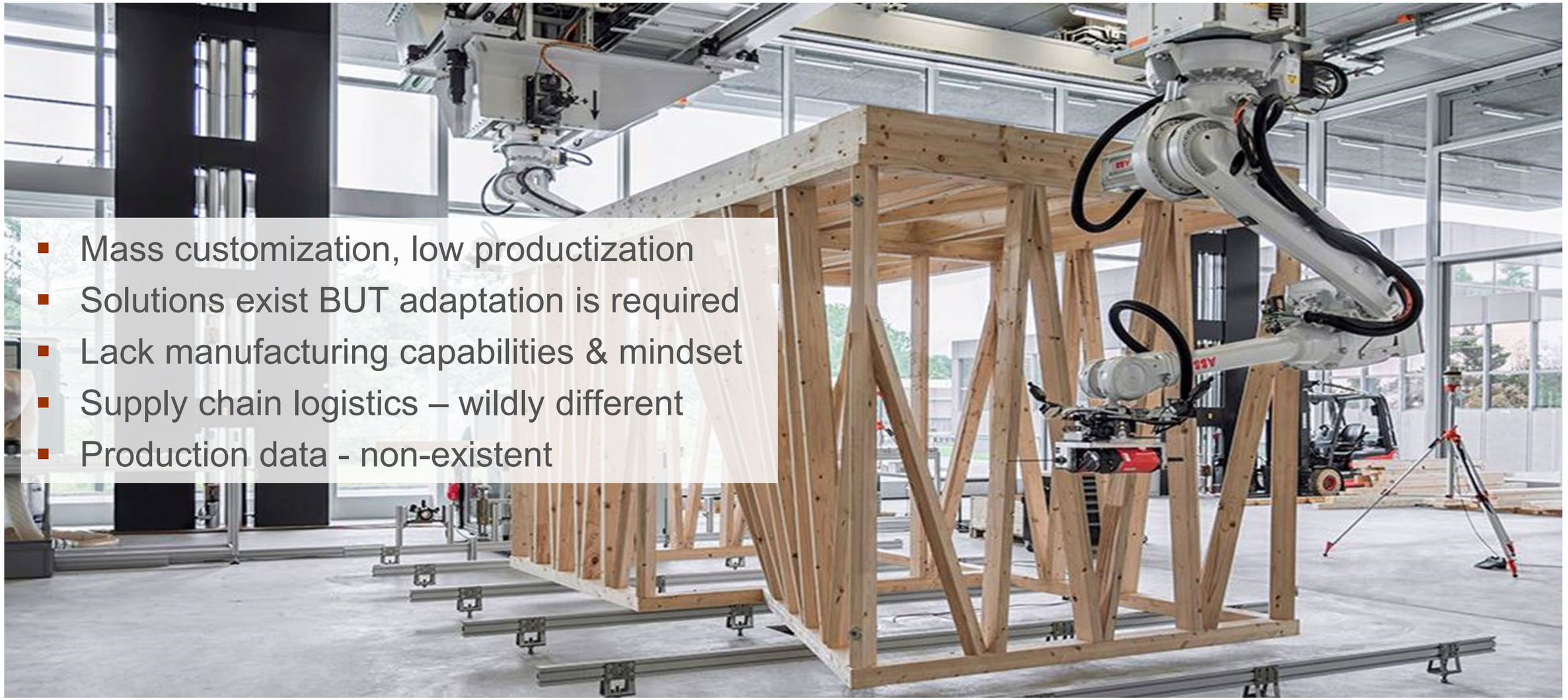
54 ÷ 240 = 23%

Your Score for Section

Maximum Score for Section



Manufacturing knows what construction still can’t see



- Mass customization, low productization
- Solutions exist BUT adaptation is required
- Lack manufacturing capabilities & mindset
- Supply chain logistics – wildly different
- Production data - non-existent

Exercise: Let’s assess where we stand today

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Maturity readiness assessment

Your Assignment:

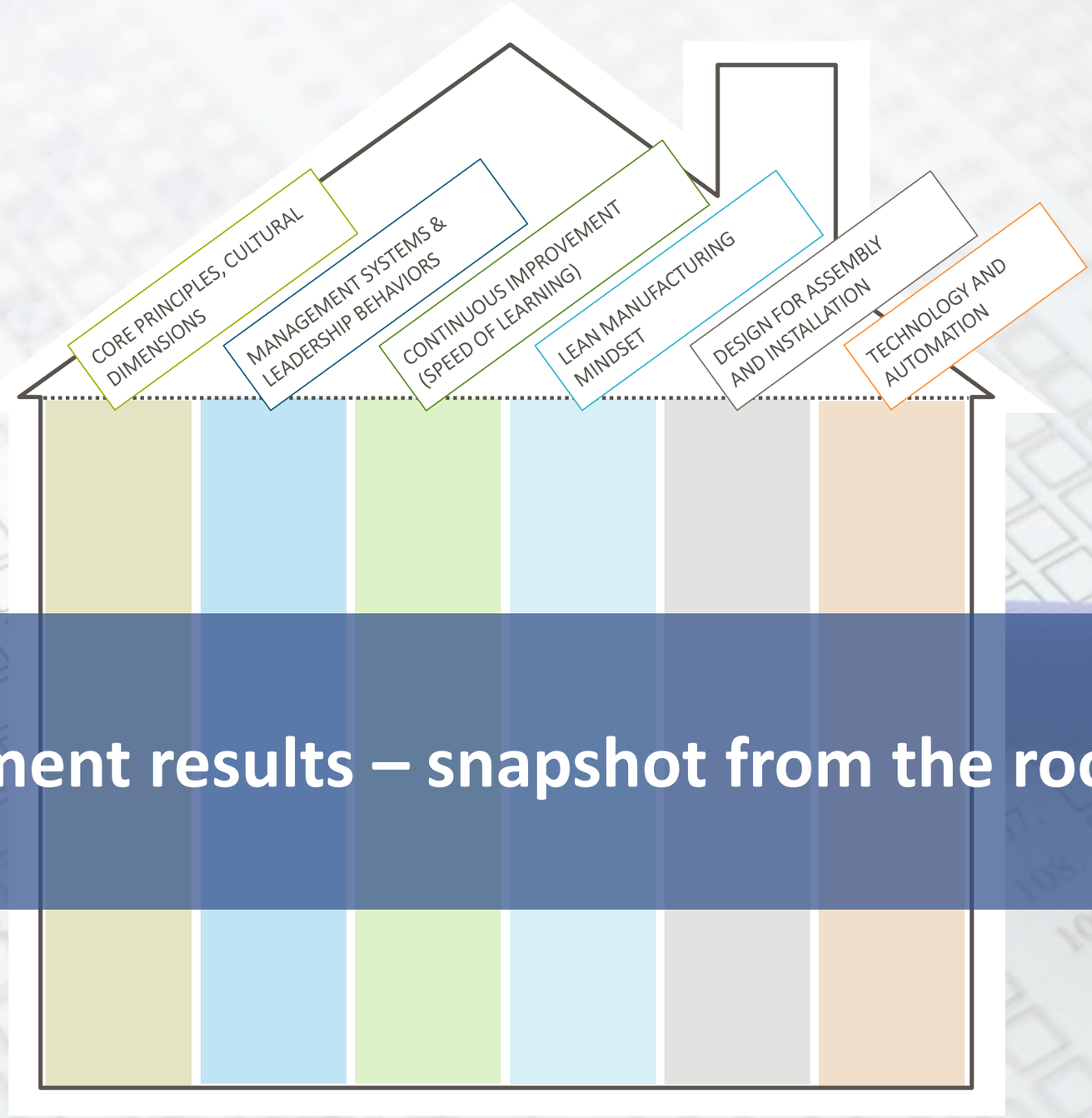
- For your own company assess your maturity in this mini version of H&A's Maturity Assessment.
- For each row – choose your Level (1, 2, 3, or 4)
- Share you results at your table

HALEY ALDRICH

Industrialized Construction Maturity Self-Assessment (ICA)

CORE PRINCIPLES	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Embed Customer Value in Every Part of the Value Chain	We have not defined value streams from the perspective of our customers. X	Each area of the value stream operates independently. ☐	Each step of the value stream treats the next like a valuable customer. ☐	Every person in the value stream understands overall performance, needs and is able to flex when other areas need help. Every area of the company is evaluated based on its ability to generate value. ☐
Promote issue identification to improve performance (safe to make problems visible)	Don't do at all, fear driven culture. ☐	Informal, inconsistent, tribal - requires a person to have comfort and job security to promote issue identification and dig down to root cause. X	Systematic and structured - processes for issue identification; positive reinforcement of problem identification. ☐	"No problem is problem"; our culture is such that we seek problems and, if needed create them (e.g. setting higher targets). Relentless pursuit of perfection. ☐

LEAN MANUFACTURING	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Align Production with Rate of Demand (Takt)	No Takt because we don't know rate of demand or can't trust schedules. Demand is driven by field order (we tack on a few days). X	We understand takt but have significant inventory because we are unable to adjust. The field orders more than they need because they do not trust the fab shop to meet schedule…."better to have it onsite". ☐	Takt Goals established by and work is designed to deliver that takt. We regularly adjust standardized work to achieve lower-cost/faster/more balanced work. ☐	Ability to adjust process to different Takt demands (combine operations, break apart). Yamazumi Charts (stacked bar) are used to understand how to increase productivity by level loading. ☐



Assessment results – snapshot from the room

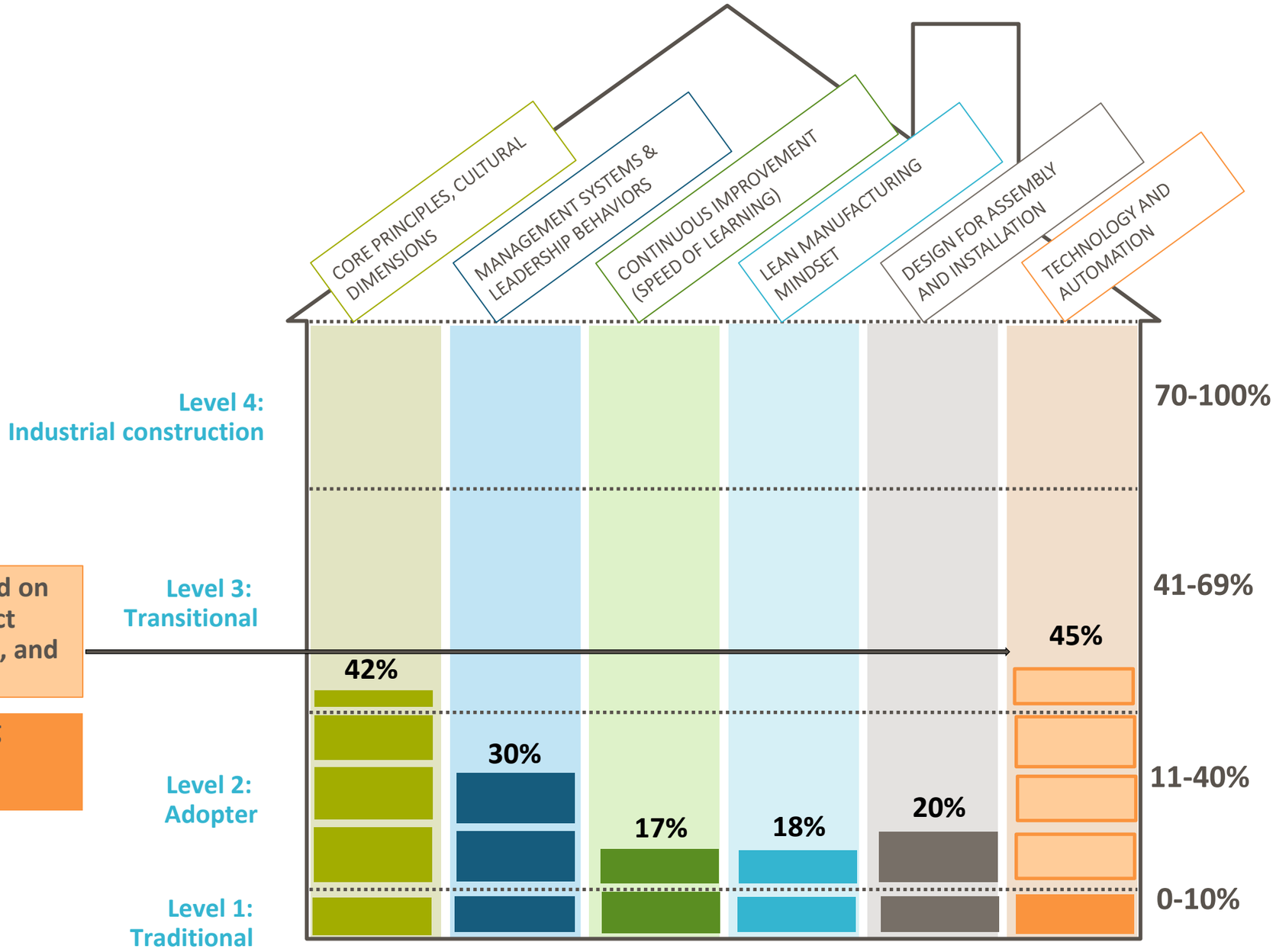
Advancing Prefab 2022: Same Questions

Snapshot of Maturity Assessment	Level 1	Level 2	Level 3	Level 4
How defined are your product families? If defined, are they standardized	20%	70%	<10%	<2%
Design for Manufacturing is changing how we build?	40%	50%	<10%	0%
We have Production Control at the Work Cell Level (vs the project level)	30%	50%	15%	<5%
Production is aligned with rate of demand. Able to optimize for flow and balanced production.	20%	70%	10%	<1%

… And this is probably skewed to the right based on self-assessment

Industrialized Construction Maturity: Here is our view of the US market is currently

Looking across GCs, Specialty Modular, Trades



Foundational Conditions for Success – Manufacturing Mindset

- Intentional Product Strategy
- Collect and use production data
- Supply chain partners – move from transaction to strategic
- New capabilities & roles

Offsite Construction vs. Construction Manufacturing

Poor Ergonomics

How did he get in there?

Non-Industrial Tooling

Better than ladders but ….

Predominant Mindset and behaviors across our industry are “Better Onsite Construction” not “Construction Manufacturing”

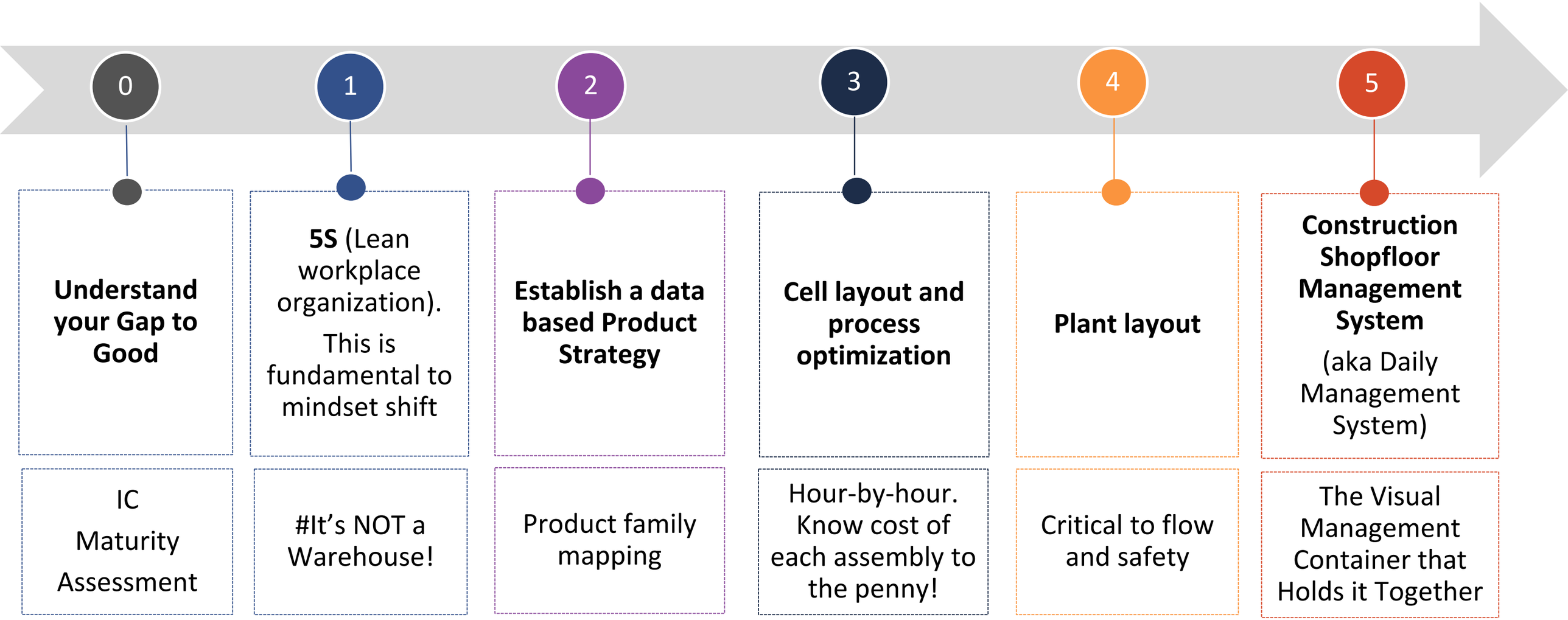
The transformation to manufacturing mindset looks like …

From	To
Best-in-class field organization, means & methods	Means, methods, and organization that set the standard for construction manufacturing excellence
Job cost codes	Hour by hour tracking based on cycle times
Everybody & nobody collects data, does analysis. No trust.	Simultaneous data share across entire ecosystem (field, shop, suppliers, etc.).
Ahead our behind is tribal & hidden	Dashboard visible to all. Blocked and starved known immediately (OEE).
Unique project by unique project	Mixed model line (80% of parts similar)

The transformation to manufacturing mindset looks like …

From	To
Production horizon 2-3 weeks ?	Production horizon 3 to 6 mos visible to all employees
Monthly project financial health based on labor hours	Product revenue vs. cost tracked
Material defects expected; low price wins; mile-long list of vendors	Material specifications, equipment, and capabilities are synced; suppliers are intimate in the shop and the field.
Buying subcontracted services	Strategic preferred partner relationship

Where to start



Workplace Organization (5S)

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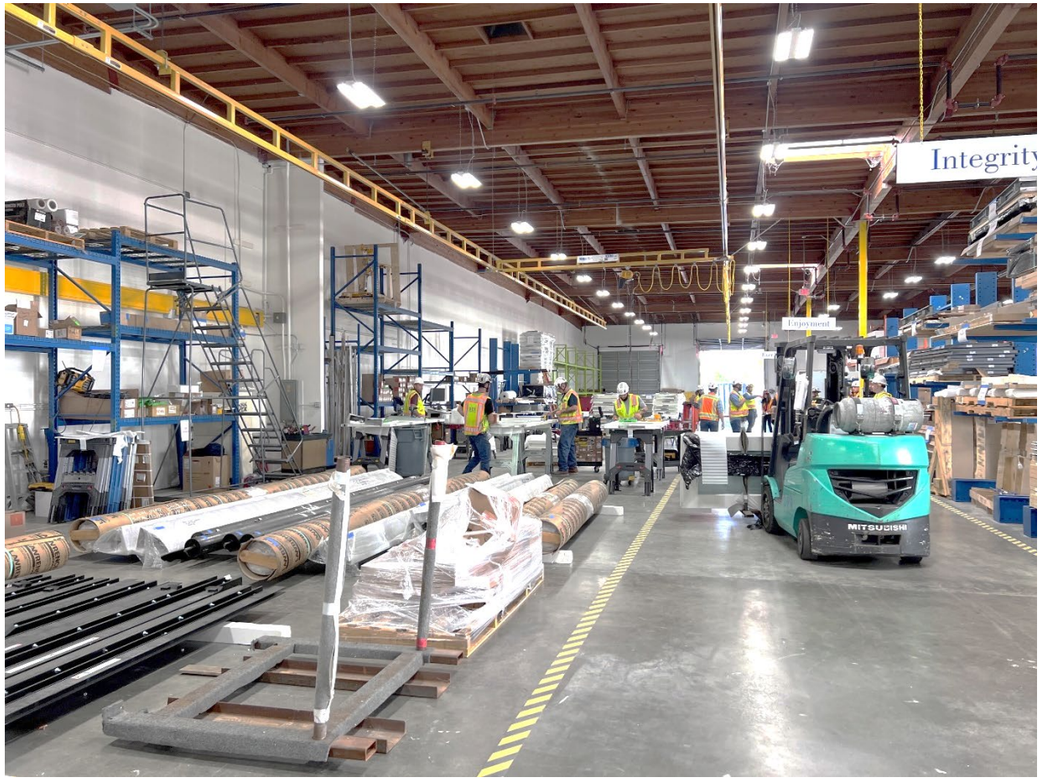
#Itsnotawarehouse

Typical Fab Shop Before 5S

Fabrication Facility with 5S Principles – 60% Racking Removed



#Itsnotawarehouse

Typical Fab Shop Before 5S

Fabrication Facility with 5S Principles – 70 Foot Candles PSF

Learn / Practice: Time Measurement & Waste Identification

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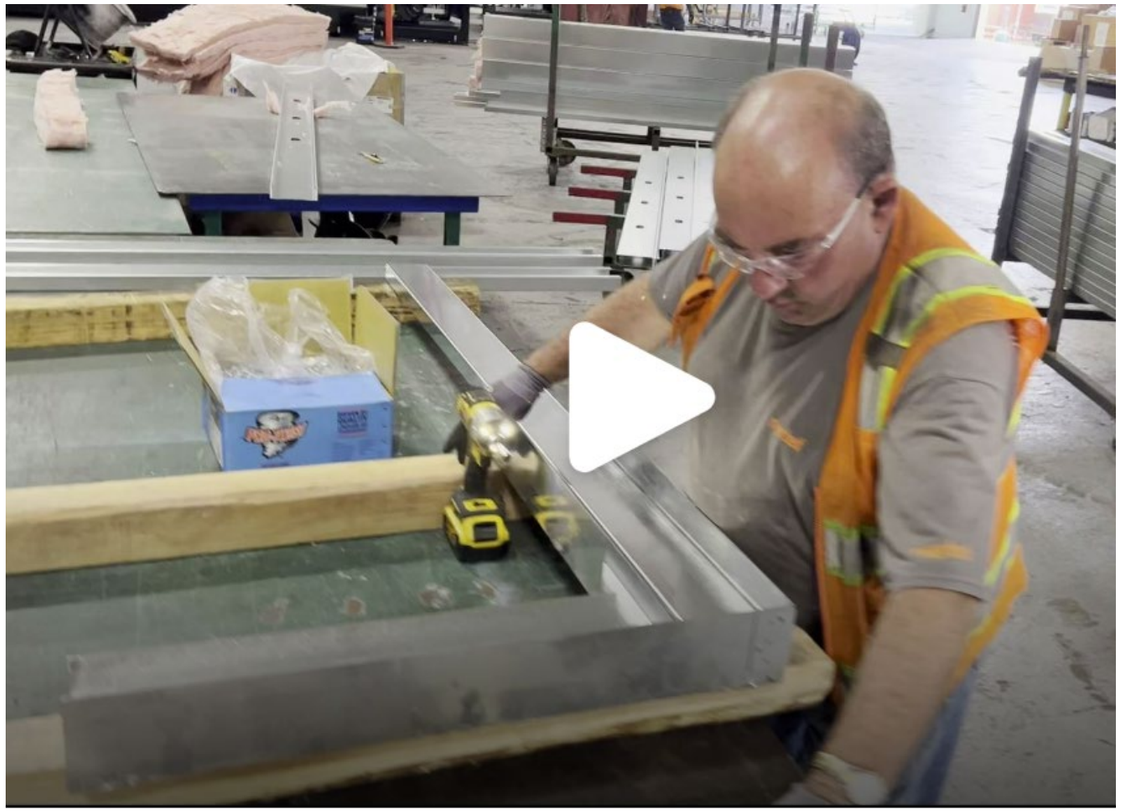
The 4 “One’s” of Flow

1. **One Place** - Put the work together
2. **One Piece** - Make one Move one (aka Single Piece Flow)
3. **One Pace** – Level loading and pacing
4. **One Resource** – Selectively dedicate a resource to the value stream

Video: Making Soffits Fab Shop and Field



This is Mario: he’s making an L-shaped, metal-stud soffit for field install.

Assignment:

Note the instances where the 4 “Ones” of Flow are Broken.

Identify Waste

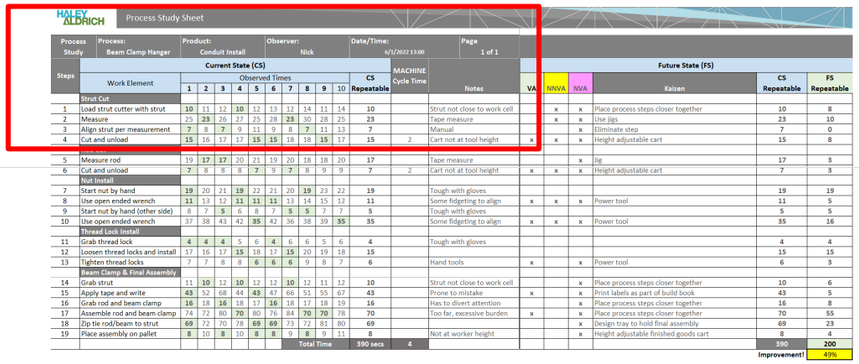
HALEY ALDRICH

Process Study Sheet

Process Study	Process:	Product:	Observer:	Date/Time:	Page
	Beam Clamp Hanger	Conduit Install	Nick	6/1/2022 13:00	1 of 1

Steps	Current State (CS)														Future State (FS)					
	Work Element	Observed Times										CS Repeatable	MACHINE Cycle Time	Notes	VA	NNVA	NVA	Kaizen	CS Repeatable	FS Repeatable
		1	2	3	4	5	6	7	8	9	10									
	Strut Cut																			
1	Load strut cutter with strut	**10**	11	12	**10**	12	13	12	14	11	14	**10**		Strut not close to work cell		x	x	Place process steps closer together	**10**	**8**
2	Measure	25	**23**	26	27	25	28	**23**	30	28	25	**23**		Tape measure		x	x	Use jigs	**23**	**10**
3	Align strut per measurement	**7**	8	**7**	9	11	9	8	**7**	11	13	**7**		Manual			x	Eliminate step	**7**	**0**
4	Cut and unload	**15**	16	17	17	**15**	**15**	18	18	**15**	17	**15**	2	Cart not at tool height	x	x	x	Height adjustable cart	**15**	**8**
	Rod Cut																			
5	Measure rod	19	**17**	**17**	20	21	19	20	18	18	20	**17**		Tape measure			x	Jig	**17**	**3**
6	Cut and unload	**7**	8	8	8	**7**	9	**7**	8	9	9	**7**	2	Cart not at tool height	x	x	x	Height adjustable cart	**7**	**3**
	Nut Install																			
7	Start nut by hand	**19**	20	21	**19**	22	21	20	**19**	23	22	**19**		Tough with gloves					**19**	**19**
8	Use open ended wrench	**11**	13	12	**11**	**11**	**11**	13	14	15	12	**11**		Some fidgeting to align	x	x	x	Power tool	**11**	**5**
9	Start nut by hand (other side)	8	7	**5**	6	8	7	**5**	**5**	7	7	**5**		Tough with gloves					**5**	**5**
10	Use open ended wrench	37	38	43	42	**35**	42	36	38	39	**35**	**35**		Some fidgeting to align	x	x	x	Power tool	**35**	**16**
	Thread Lock Install																			
11	Grab thread lock	**4**	**4**	**4**	5	6	**4**	6	6	5	6	**4**		Tough with gloves					**4**	**4**
12	Loosen thread locks and install	17	16	17	**15**	18	17	**15**	20	19	18	**15**							**15**	**15**
13	Tighten thread locks	7	7	8	8	**6**	**6**	**6**	9	8	7	**6**		Hand tools	x		x	Power tool	**6**	**3**
	Beam Clamp & Final Assembly																			
14	Grab strut	11	**10**	12	**10**	12	12	**10**	12	11	12	**10**		Strut not close to work cell			x	Place process steps closer together	**10**	**6**
15	Apply tape and write	**43**	52	68	44	**43**	47	66	51	55	67	**43**		Prone to mistake	x		x	Print labels as part of build book	**43**	**5**
16	Grab rod and beam clamp	**16**	18	**16**	18	17	**16**	18	17	18	19	**16**		Has to divert attention			x	Place process steps closer together	**16**	**8**
17	Assemble rod and beam clamp	74	72	80	**70**	80	76	84	**70**	**70**	78	**70**		Too far, excessive burden	x		x	Place process steps closer together	**70**	**55**
18	Zip tie rod/beam to strut	**69**	72	70	78	**69**	**69**	73	72	81	80	**69**					x	Design tray to hold final assembly	**69**	**23**
19	Place assembly on pallet	**8**	10	**8**	10	**8**	**8**	9	**8**	9	11	**8**		Not at worker height			x	Height adjustable finished goods cart	**8**	**4**
								Total Time				**390 secs**	**4**						**390**	**200**
																			Improvement!	49%

Step 1. Define the Current State



HALEY ALDRICH — Process Study Sheet

Process Study	Process: Beam Clamp Hanger	Product: Conduit Install	Observer: Nick	Date/Time: 6/1/2022 13:00	Page 1 of 1

Current State (CS) / Future State (FS)

Steps	Work Element	Observed Times 1	2	3	4	5	6	7	8	9	10	CS Repeatable	MACHINE Cycle Time	Notes	VA	NNVA	NVA	Kaizen	CS Repeatable	FS Repeatable
	Strut Cut																			
1	Load strut cutter with strut	10	11	12	10	12	13	12	14	11	14	10		Strut not close to work cell		x	x	Place process steps closer together	10	8
2	Measure	25	23	26	27	25	28	23	30	28	25	23		Tape measure		x	x	Use jigs	23	10
3	Align strut per measurement	7	8	7	9	11	9	8	7	11	13	7		Manual			x	Eliminate step	7	0
4	Cut and unload	15	16	17	17	15	15	18	18	15	17	15	2	Cart not at tool height	x	x	x	Height adjustable cart	15	8
	Strut Install																			
5	Measure rod	19	17	17	20	21	19	20	18	18	20	17		Tape measure			x	Jig	17	3
6	Cut and unload	7	8	8	8	7	9	7	8	9	9	7	2	Cart not at tool height	x	x	x	Height adjustable cart	7	3
	Nut Install																			
7	Start nut by hand	19	20	21	19	22	21	20	19	23	22	19		Tough with gloves					19	19
8	Use open ended wrench	11	13	12	11	11	13	14	15	12	11	11		Some fidgeting to align	x	x	x	Power tool	11	5
9	Start nut by hand (other side)	8	7	5	6	8	7	5	5	7	7	5		Tough with gloves					5	5
10	Use open ended wrench	37	38	43	42	35	42	36	38	39	35	35		Some fidgeting to align	x	x	x	Power tool	35	16
	Thread Lock Install																			
11	Grab thread lock	4	4	4	5	6	4	6	6	5	6	4		Tough with gloves					4	4
12	Loosen thread locks and install	17	16	17	15	18	17	15	20	19	18	15							15	15
13	Tighten thread locks	7	7	8	8	6	6	6	9	8	7	6		Hand tools	x		x	Power tool	6	3
	Beam Clamp & Final Assembly																			
14	Grab strut	11	10	12	10	12	12	10	12	11	12	10		Strut not close to work cell			x	Place process steps closer together	10	6
15	Apply tape and write	43	52	68	44	43	47	66	51	55	67	43		Prone to mistake	x		x	Print labels as part of build book	43	5
16	Grab rod and beam clamp	16	18	16	18	17	16	18	17	18	19	16		Has to divert attention			x	Place process steps closer together	16	8
17	Assemble rod and beam clamp	74	72	80	70	80	76	84	70	70	78	70		Too far, excessive burden	x		x	Place process steps closer together	70	55
18	Zip tie rod/beam to strut	69	72	70	76	69	69	73	72	81	80	69					x	Design tray to hold final assembly	69	23
19	Place assembly on pallet	8	10	8	10	8	8	9	8	9	11	8		Not at worker height			x	Height adjustable finished goods cart	8	4
								Total Time				390 secs	4						390	200
																		Improvement!		49%

Process Study	Process: Beam Clamp Hanger	Product: Conduit Install	Observer: Nick	Date/Time: 6/1/2022 13:00	Page 1 of 1

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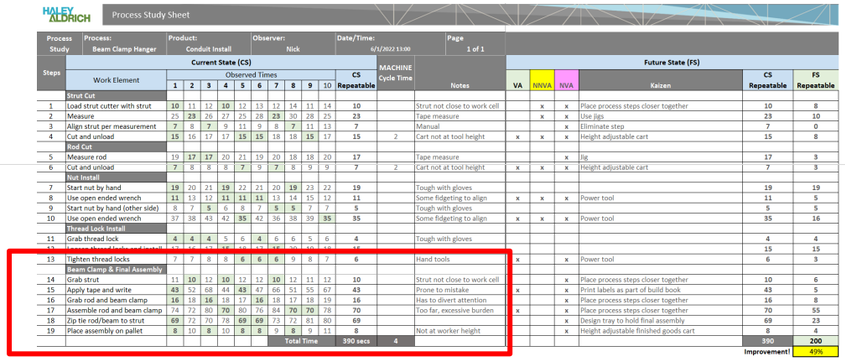
	Strut Cut													
1	Load strut cutter with strut	**10**	11	12	**10**	12	13	12	14	11	14	**10**		Strut not close to work cell
2	Measure	25	**23**	26	27	25	28	**23**	30	28	25	**23**		Tape measure
3	Align strut per measurement	**7**	8	**7**	9	11	9	8	**7**	11	13	**7**		Manual
4	Cut and unload	**15**	16	17	17	**15**	**15**	18	18	**15**	17	**15**	2	Cart not at tool height

Step 2. Calculate the CS Cycle Time



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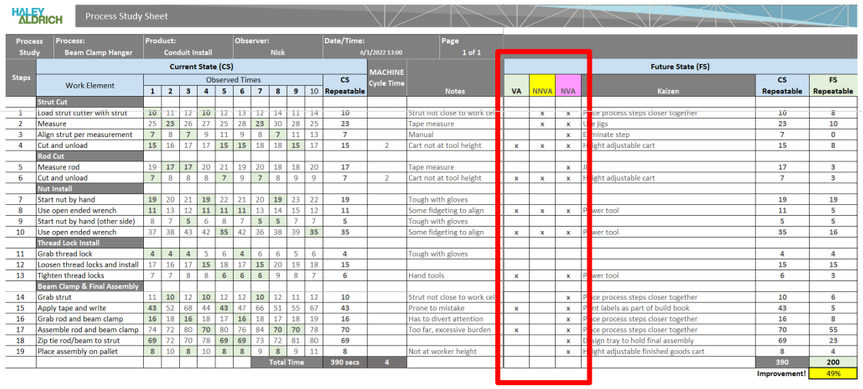
Steps	Work Element	Current State (CS) Observed Times 1	2	3	4	5	6	7	8	9	10	CS Repeatable	MACHINE Cycle Time	Notes	Future State (FS) VA	NNVA	NVA	Kaizen	CS Repeatable	FS Repeatable
	Strut Cut																			
1	Load strut cutter with strut	10	11	12	10	12	13	12	14	11	14	10		Strut not close to work cell		x	x	Place process steps closer together	10	8
2	Measure	25	23	26	27	25	28	23	30	28	25	23		Tape measure		x	x	Use jigs	23	10
3	Align strut per measurement	7	8	7	9	11	9	8	7	11	13	7		Manual			x	Eliminate step	7	0
4	Cut and unload	15	16	17	17	15	15	18	18	15	17	15	2	Cart not at tool height	x	x	x	Height adjustable cart	15	8
	Rod Cut																			
5	Measure rod	19	17	17	20	21	19	20	18	18	20	17		Tape measure			x	Jig	17	3
6	Cut and unload	7	8	8	8	7	9	7	8	9	9	7	2	Cart not at tool height	x	x	x	Height adjustable cart	7	3
	Nut Install																			
7	Start nut by hand	19	20	21	19	22	21	20	19	23	22	19		Tough with gloves					19	19
8	Use open ended wrench	11	13	12	11	11	11	13	14	15	12	11		Some fidgeting to align	x	x	x	Power tool	11	5
9	Start nut by hand (other side)	8	7	5	6	8	7	5	5	7	7	5		Tough with gloves					5	5
10	Use open ended wrench	37	38	43	42	35	42	36	38	39	35	35		Some fidgeting to align	x	x	x	Power tool	35	16
	Thread Lock Install																			
11	Grab thread lock	4	4	4	5	6	4	6	6	5	6	4		Tough with gloves					4	4
12	[illegible]	[illegible]										[illegible]							15	15
13	Tighten thread locks	7	7	8	8	6	6	6	9	8	7	6		Hand tools	x		x	Power tool	6	3
	Beam Clamp & Final Assembly																			
14	Grab strut	11	10	12	10	12	12	10	12	11	12	10		Strut not close to work cell			x	Place process steps closer together	10	6
15	Apply tape and write	43	52	68	44	43	47	66	51	55	67	43		Prone to mistake	x		x	Print labels as part of build book	43	5
16	Grab rod and beam clamp	16	18	16	18	17	16	18	17	18	19	16		Has to divert attention			x	Place process steps closer together	16	8
17	Assemble rod and beam clamp	74	72	80	70	80	76	84	70	70	78	70		Too far, excessive burden	x		x	Place process steps closer together	70	55
18	Zip tie rod/beam to strut	69	72	70	78	69	69	73	72	81	80	69					x	Design tray to hold final assembly	69	23
19	Place assembly on pallet	8	10	8	10	8	8	9	8	9	11	8		Not at worker height			x	Height adjustable finished goods cart	8	4
									Total Time			390 secs	4						390	200
																			Improvement!	49%

Beam Clamp & Final Assembly												
Grab strut	11	**10**	12	**10**	12	12	**10**	12	11	12	**10**	
Apply tape and write	**43**	52	68	44	**43**	47	66	51	55	67	**43**	
Grab rod and beam clamp	**16**	18	**16**	18	17	**16**	18	17	18	19	**16**	
Assemble rod and beam clamp	74	72	80	**70**	80	76	84	**70**	**70**	78	**70**	
Zip tie rod/beam to strut	**69**	72	70	78	**69**	**69**	73	72	81	80	**69**	
Place assembly on pallet	**8**	10	**8**	10	**8**	**8**	9	**8**	9	11	**8**	
							Total Time				**390 secs**	**4**

Cycle Time: The time it takes an operator to complete all the work elements in one **Unit of Production**

Step 3. Call out Waste

Future State (FS)					
VA	NNVA	NVA	Kaizen	CS Repeatable	FS Repeatable
	x	x	Place process steps closer together	10	8
	x	x	Use jigs	23	10
		x	Eliminate step	7	0
x	x	x	Height adjustable cart	15	8
		x	Jig	17	3
x	x	x	Height adjustable cart	7	3
				19	19
x	x	x	Power tool	11	5
				5	5
x	x	x	Power tool	35	16
				4	4
				15	15
x		x	Power tool	6	3
		x	Place process steps closer together	10	6
x		x	Print labels as part of build book	43	5
		x	Place process steps closer together	16	8
x		x	Place process steps closer together	70	55
		x	Design tray to hold final assembly	69	23
		x	Height adjustable finished goods cart	8	4
				390	200
				Improvement!	49%



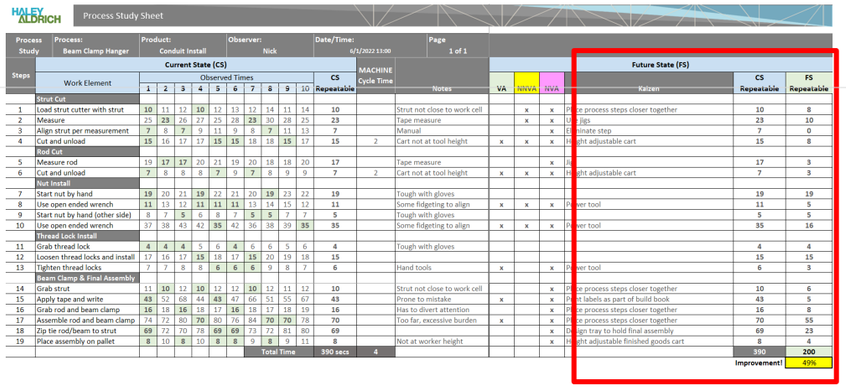
Value Add: What the customer is willing to pay for. Changes the form, fit or function.

Necessary but Non-Value Add: Things that must happen, but customer not willing to pay for; e.g., excess transportation, motion

Non-Value Add: Waste that is target for removal.

Step 4: Process Kaizen

Future State (FS)					
VA	NNVA	NVA	Kaizen	CS Repeatable	FS Repeatable
	x	x	Place process steps closer together	10	8
	x	x	Use jigs	23	10
		x	Eliminate step	7	0
x	x	x	Height adjustable cart	15	8
		x	Jig	17	3
x	x	x	Height adjustable cart	7	3
				19	19
x	x	x	Power tool	11	5
				5	5
x	x	x	Power tool	35	16
				4	4
				15	15
x		x	Power tool	6	3
		x	Place process steps closer together	10	6
x		x	Print labels as part of build book	43	5
		x	Place process steps closer together	16	8
x		x	Place process steps closer together	70	55
		x	Design tray to hold final assembly	69	23
		x	Height adjustable finished goods cart	8	4
				390	200
				Improvement!	49%



Kaizen: Continuous improvement of an entire value stream or an individual process to create more value with less waste.

Step 5. Bring it Home with Financial Analysis

	Hanger in Field	Prefab Hanger (CS)	Prefab Hanger (FS)
Minutes per Unit	7.4 minutes	6.5 minutes	3.7 minutes
# Units per Year	40,000	40,000	40,000
Labor Rate	$75	$50	$30
Total per Year	**$370,000**	**$216,667**	**$74,000**

$296,000 Savings per Year

Exercise: Time Measurement

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Let's practice time measurement

Your Assignment:

1. Fill out the header of your Time Measurement & Kaizen Worksheet
2. Get a stopwatch ready on your phone
3. Listen to overview of pipe bending process
4. Hit start on stopwatch as video begins
5. Capture data in the first 3 columns:

- Operation element – 'the work step'
- Starting point – the first motion that indicates start of operation (e.g. pick up drill)
- 1 (secs) – record end time of operation

Video: Pipe Bending Time Motion Study

Let’s practice time measurement

Video: Pipe Bending Time Motion Study

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Your Assignment:

1. Fill out the header of your Time Measurement & Kaizen Worksheet
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4. Hit start on stopwatch as video begins
5. Capture data in the first 3 columns:
   - Operation element – 'the work step'
   - Starting point – the first motion that indicates start of operation (e.g. pick up drill)
   - 1 (secs) – record endtime of operation
6. **Go back and do the math to determine duration of each step**
7. **'Fluctuation' - note any steps that have significant fluctuation in duration**
8. **'VA/NNVA/NVA' - note whether steps are value-added, necessary non-value added, non-value added**

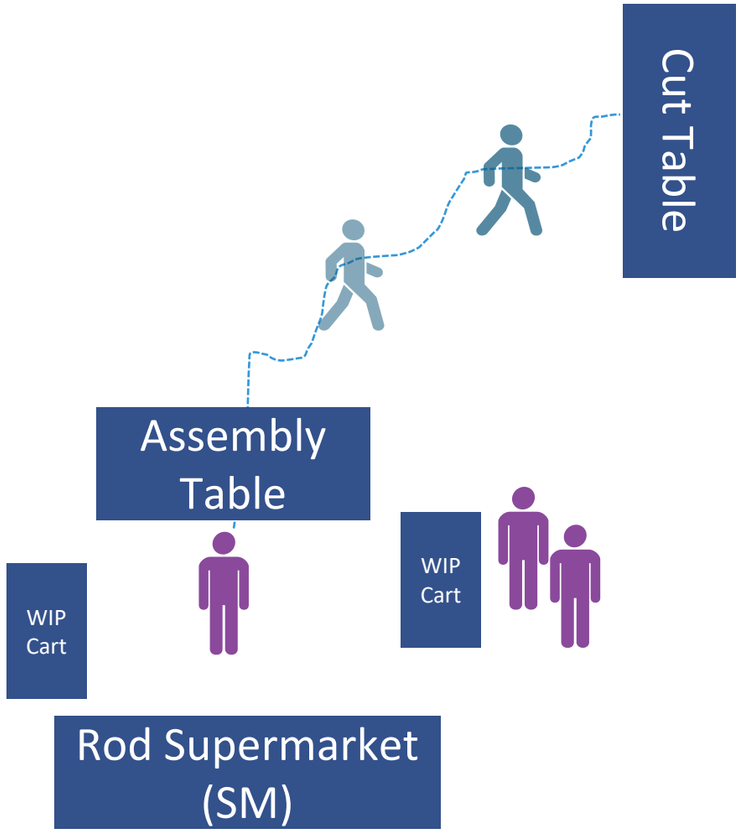
Why do we care?

Time Motion Analysis is the precursor to Kaizen!

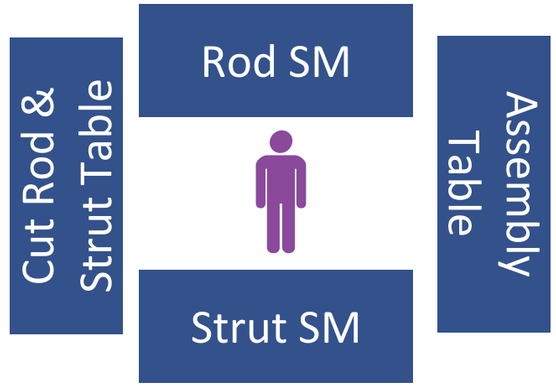
Time Motion Analysis is the precursor to Work Cell Optimization

Work Cell Optimization Reduce Waste

Electrical Hangers: Current State



Electrical Hangers: Future State



Downtime Waste	
Defects	Jigs, Reduction in # of Tools, Faster to Finished Goods
Over production	Single piece flow vs Batch
Waiting	From 3 Operators to 1 Operator
Transportation	Work cell is nested for proximity
Motion	Work cell nested, tables at operator height
Extra Processing	Number of process steps reduced

Work Cell Optimization – the Principles Work (even in construction) !

	Hanger in Field	Prefab Hanger (CS)	Prefab Hanger (FS)
Minutes per Unit	7.4 minutes	6.5 minutes	3.7 minutes
		12% Improvement	**43% Improvement**
# Units per Year	40,000	40,000	40,000
Labor Rate	$75	$50	$30
Total per Year	**$370,000**	**$216,667**	**$74,000**

$296,000 Savings per Year

Work Cell Principles

- **Layout:** U-Shape, L-Shape, Linear (last resort)
- **Counter-clockwise:** for work and material flow desirable
- **Line Side Replenishment:** Parts come to the workers ready to use
- **Say No to large containers:** small containers and racks

Work Cell Principles: Go for Single Piece Flow

- Optimize time by **Reducing motion**
- **Reduced work in process** → faster throughput
- **Space savings** → Less WIP → Smaller workstations.
- Improved quality control through **rapid feedback** (Batch hides defects!)
- Unlocks opportunities for **improved ergonomic cells**

Is it ever okay to Batch? Yes!

The time and motion benefits of Single Piece Flow are not universal. There are tradeoffs relative to *economies of scale* opportunities.

Impossible to know without data!

BREAK

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Exercise: Product family mapping

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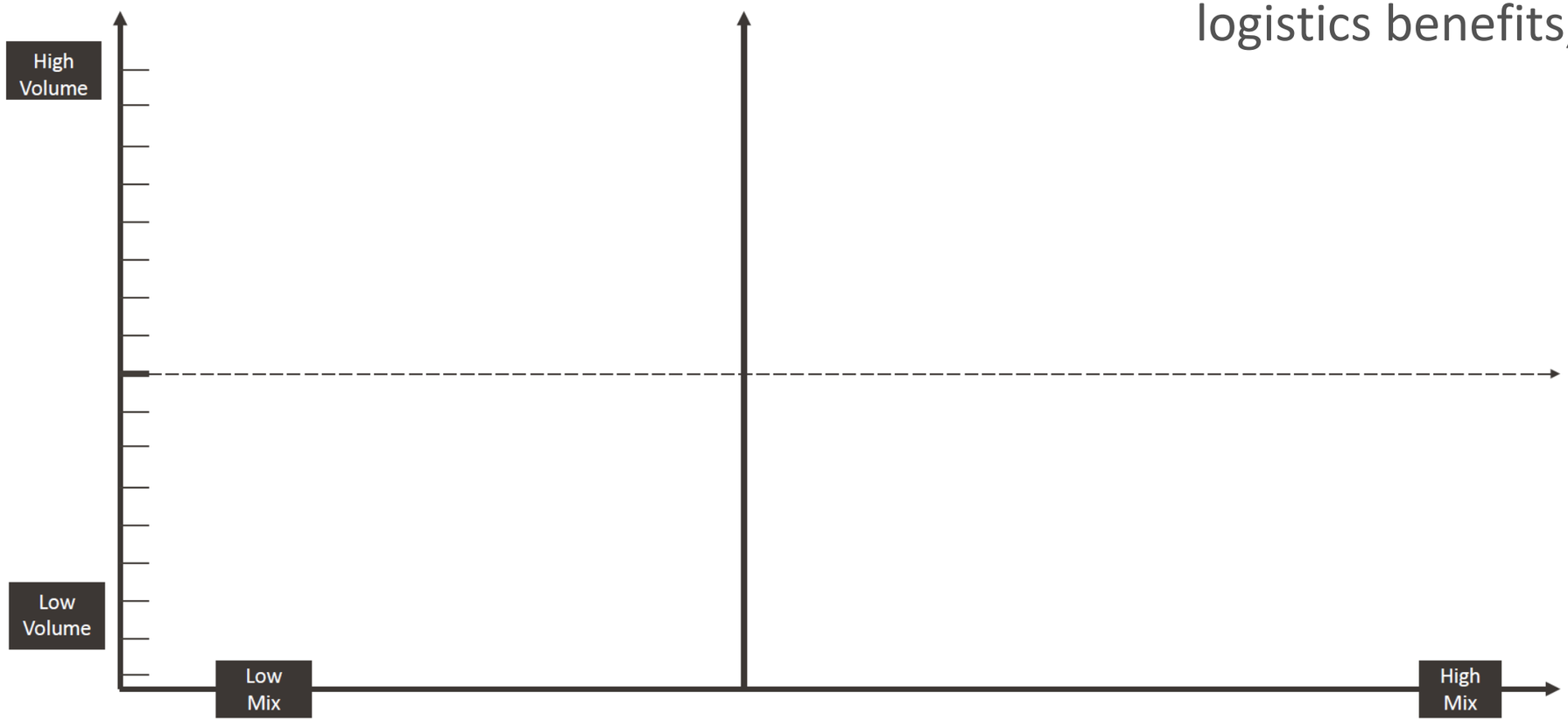
Exercise: Using product family mapping to get started

1. Map your Product Families based on **Mix and Volume** (not by project, but whole business)

2. Add dots / circle to note which ones would also have added benefits (reduce field complexity, logistics benefits, etc)



Exercise: Moving towards Data Driven Product Strategy

3 The whole exercise is DATA Driven based on real data from real time motion studies. Try to fill in the table for at least the information you already know/

Assembly Type	# of Assemblies Required in the Next 12 Months	Hours Saved Per Unit by Using Prefab	Total Hours Saved	Avg. Labor Rate Differential Field vs. Fab	Prefab Transportation Cost	Potential One Year Prefab Savings
Example Load Centers	1,000	25	25,000	$55	- $300 X 20 trips	$1,369,000

#poundsand

Exercise: Plant Layout

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Practice thinking like an Industrial Engineer

The story:

We have defined our prefab product lines and are convinced that our company's future rests with prefab. We have a P&S agreement on a piece of land. Now we must define the building boundaries for permitting.

It's time to layout the plant to ensure we have flow, we can meet customer demand, and we define shipping and receiving and associated building openings.

We will use the time between now and occupancy (~14 months) to bring a manufacturing mindset to our workforce and move solidly into Level III of the IC Maturity Assessment.

(**Disclaimer:** Today does NOT make you an industrial engineer. Hire a consultant or bring an IE in house (or likely both eventually).

Practice thinking like an Industrial Engineer - Exercise Parameters:

Concept: 40,000 square foot prefab assembly facility

3 primary product lines:

Product line 1 – two work cells, each work cell is 1,500 square feet and requires outside exhaust.

Product line 2 – two work cells, each work cell is 2,500 square feet and requires overhead crane.

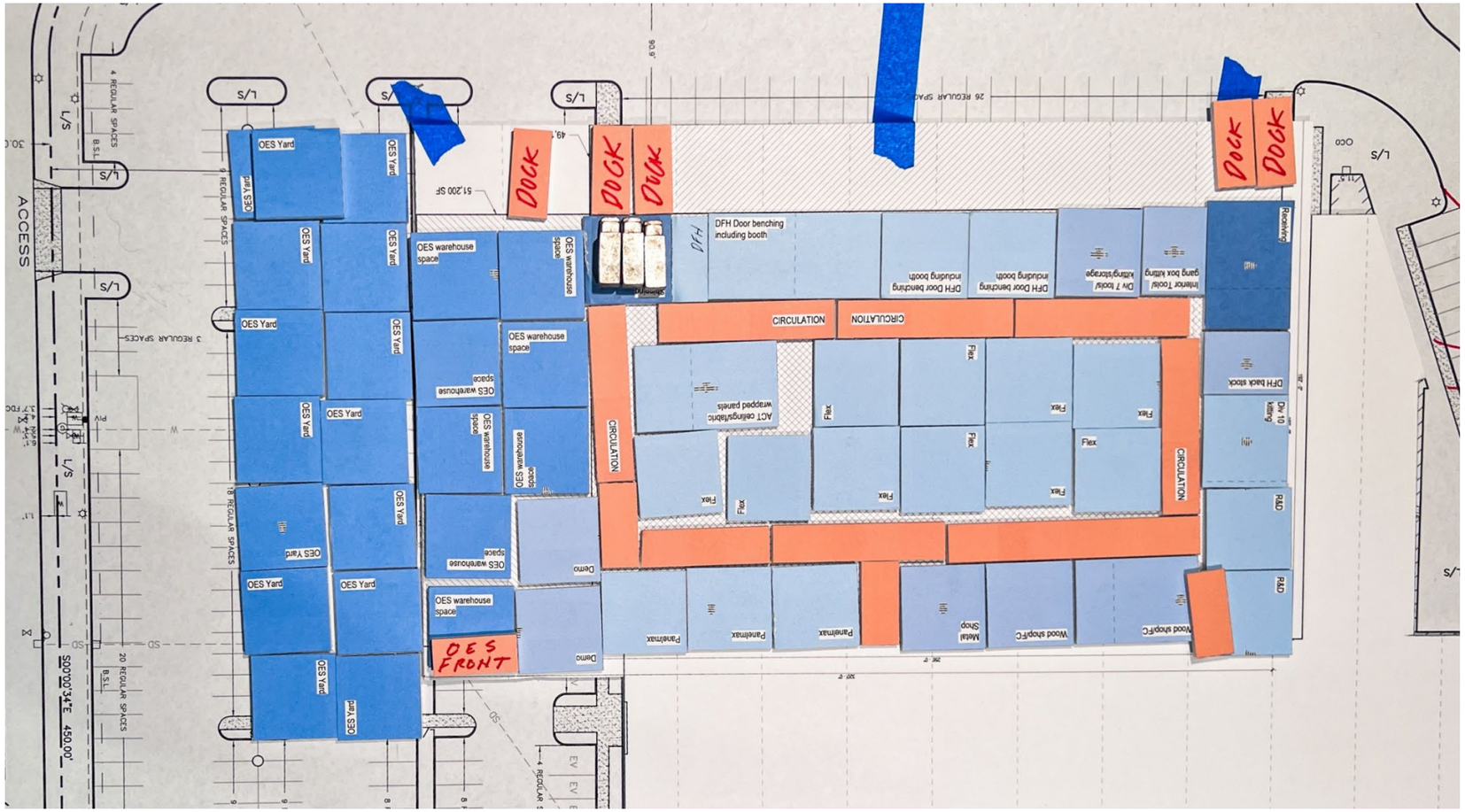
Product line 3 – one work cell at 1,000 square feet.

Assumptions: the maximum width of finished goods is 20 feet; will use CombiLift (articulating forklift); aisle widths will be 16 feet

Determine -- Is this the right amount? What is the right shape? How will you accommodate for shipping and receiving? What monuments, if any, are you placing? We plan to automate in 5 years – how does this design accommodate for that plan?

(**Disclaimer:** Today does NOT make you an industrial engineer. Hire a consultant or bring an IE in house (or likely both eventually).

Work Product Example



Reminder: The 4 “One’s” of Flow

1. **One Place** - Put the work together
2. **One Piece** - Make one Move one (aka Single Piece Flow)
3. **One Pace** – Level loading and pacing
4. **One Resource** – Selectively dedicate a resource to the value stream

Plant Layout Core Principles

Use the flow principles

- Receive material close to the point of use.
- As work advances it should progress toward shipping bay if possible.
- Put work operations together.
- Avoid backtracking of material and people
- Enable supervisor to see the operations they are responsible for.

Warehouse & Inventory Principles

- Work with Suppliers to set frequent smaller deliveries.
- Work to understand production volumes and supplier capabilities to inform required racking.
- Orient warehouse racking to prevent fork truck reorientation.

New Roles, New Skills, New Opportunities

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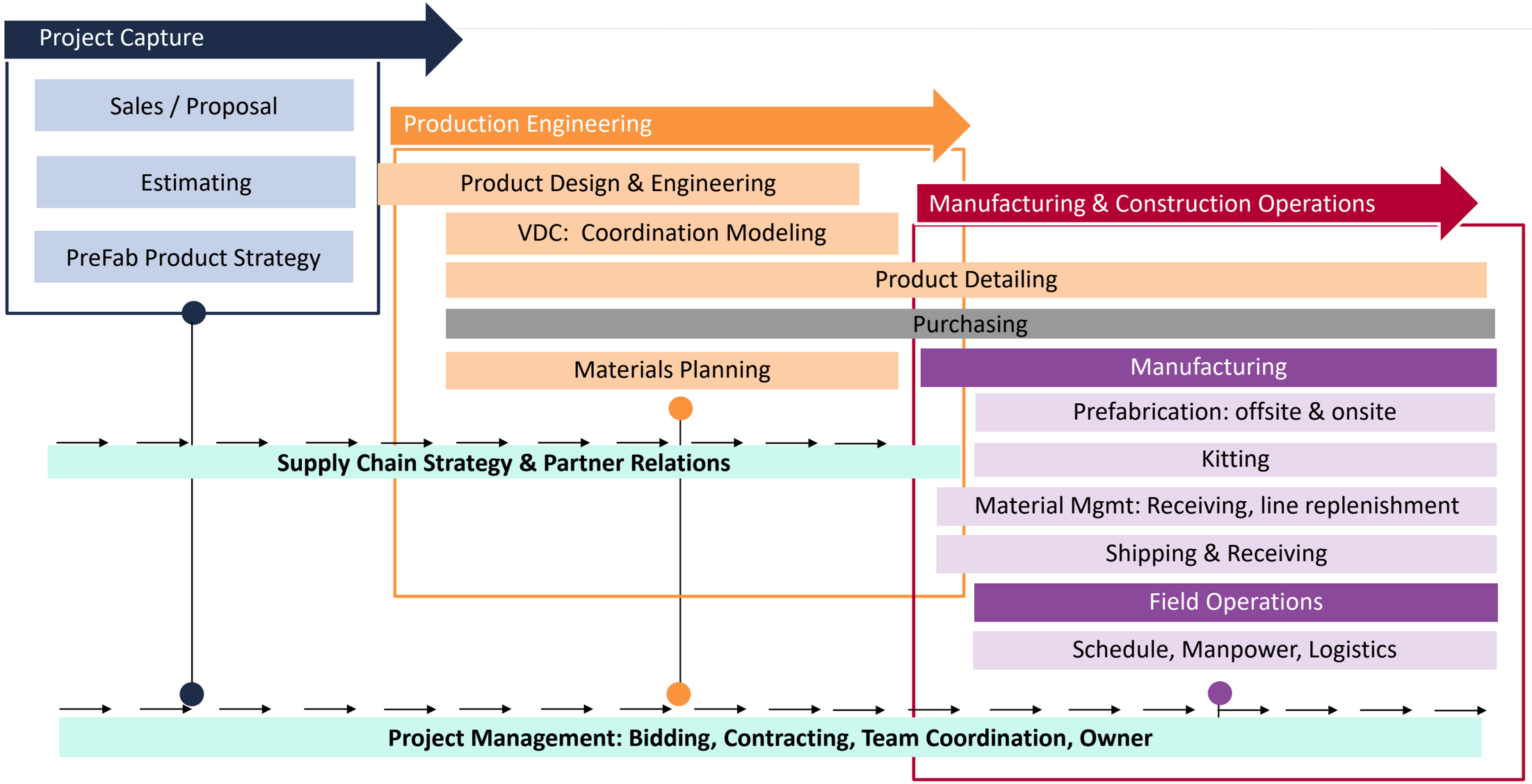
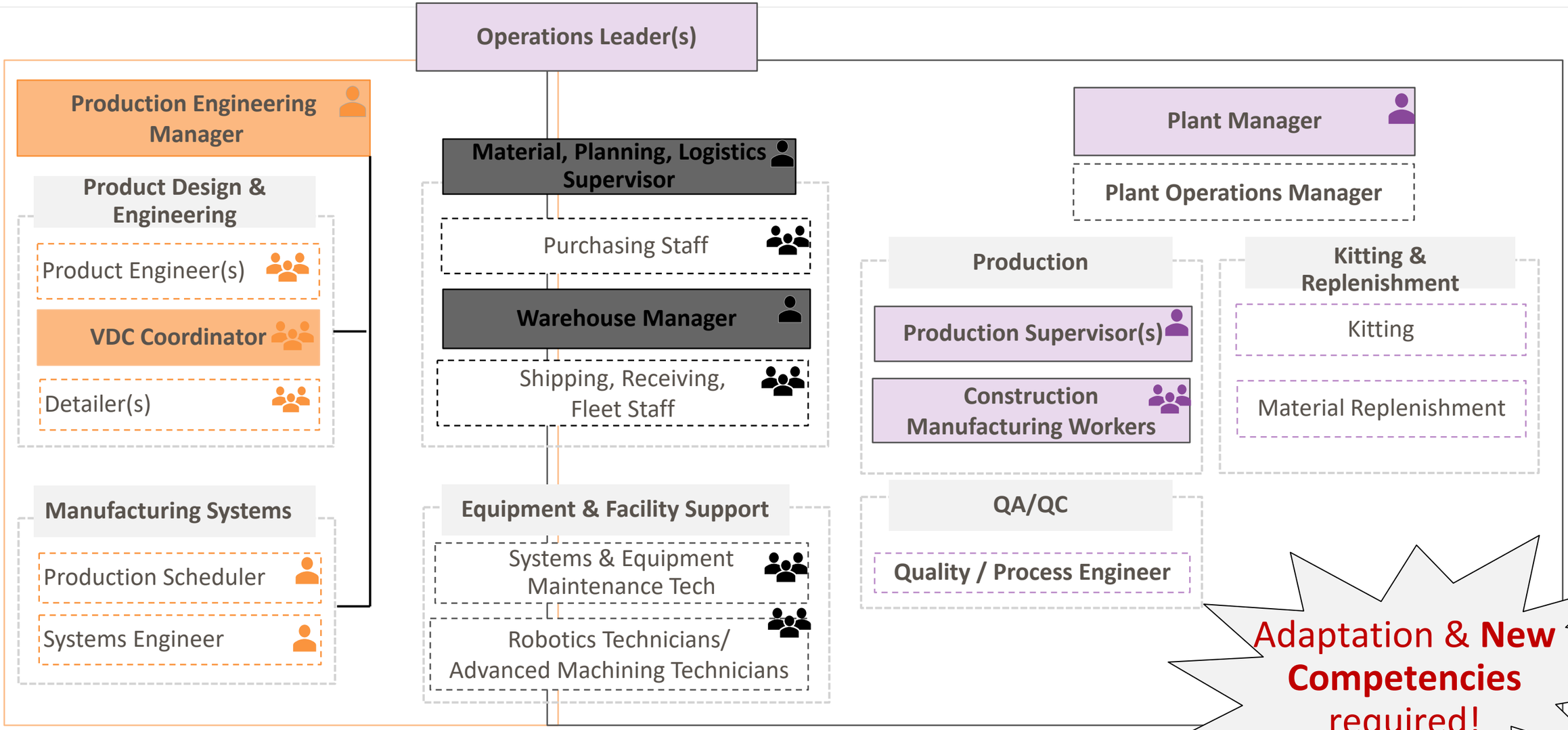
Rethinking traditional construction functions to Construction Manufacturing based functions



New Production Engineering and Manufacturing Roles



Examples of Shift from Level 2 to Level 3: Skill Development

From

General Craft Apprenticeship Journey

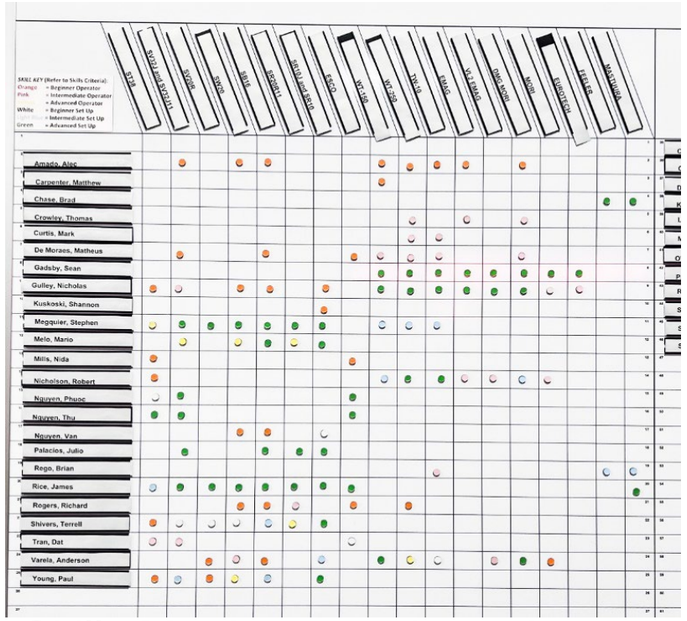
Manager is unsure of competency, requiring frequent intervention

To

Cross-Trained Construction Manufacturing Skills by Plant assemblies, processes, and equipment

- Beginner Operator
- Intermediate Operator
- Advanced Operator
- Beginner Set-Up
- Intermediate Set-Up
- Advanced Set-Up

Recognize Every Person



Skills Matrix expands workers skills – **includes craft and new construction mfg skills.**

Wrap up

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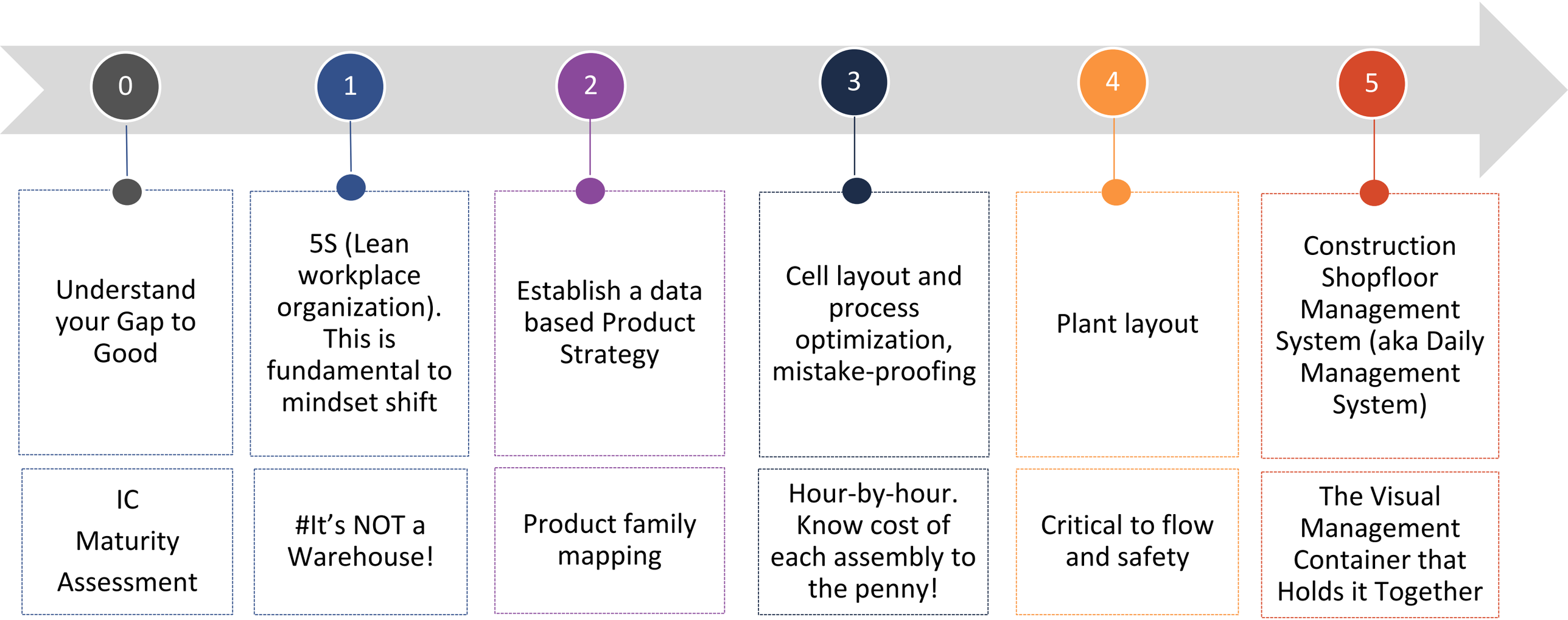
Where are you ready to you apply this tomorrow?



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Take Mini IC Assessment Survey at our Booth – win a prize!

Industrialized Construction Maturity Self-Assessment (ICA)

CORE PRINCIPLES	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Embed Customer Value in Every Part of the Value Chain	We have not defined value streams from the perspective of our customers. ☐	Each area of the value stream operates independently. ☐	Each step of the value stream treats the next like a valuable customer. ☐	Every person in the value stream understands overall performance, needs and is able to flex when other areas need help. Every area of the company is evaluated based on its ability to generate value. ☐
Promote issue identification to improve performance (safe to make problems visible)	Don't do at all, fear driven culture. ☐	Informal, inconsistent, tribal - requires a person to have comfort and job security to promote issue identification and dig down to root cause. ☐	Systematic and structured - processes for issue identification; positive reinforcement of problem identification. ☐	"No problem is problem"; our culture is such that we seek problems and, if needed create them (e.g. setting higher targets). Relentless pursuit of perfection. ☐

LEAN MANUFACTURING	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Align Production with Rate of Demand (Takt)	No Takt because we don't know rate of demand or can't trust schedules. Demand is driven by field order (we tack on a few days). ☐	We understand takt but have significant inventory because we are unable to adjust. The field orders more than they need because they do not trust the fab shop to meet schedule…."better to have it onsite". ☐	Takt Goals established by and work is designed to deliver that takt. We regularly adjust standardized work to achieve lower-cost/faster/more balanced work. ☐	Ability to adjust process to different Takt demands (combine operations, break apart). Yamazumi Charts (stacked bar) are used to understand how to increase productivity by level loading. ☐
Production Control at the Work Cell	Managing to try to achieve project schedule (weekly at best); No visual management at all; gut driven. ☐	We have daily targets and tracking of some sort, perhaps even time sheets or cost codes. ☐	Hr. by hr. tracking at work cell with visual mgmt. (We know if we are ahead or behind); Targets established and visible. We understand ahead/behind at all levels - at a glance. ☐	We have a factory data system that allows us to see blocked/starved; continually improving our work cell performance and can demonstrate improvements to cost, quality and delivery. ☐
Single-Piece-Flow vs. Batch	Fab / Field : We batch almost exclusively and send stuff from fab shop to field in huge batches (whole floor, whole job). ☐	Concept of Batch vs SPF is at least discussed (even if words not used) in cell process and shipping from Fab to Field (in right volume for install closer to SPF). ☐	Feedback Process exists (SPF); informs work space design (appropriate size); Kanban is in place and effective. Line side replenishment keeps WIP point-of-use inventory to a minimum. ☐	One piece flow is a continual goals through value streams, SMED (Single Minute Exchange of Die) systems are in place, Inventory management system linked to work cell flow. ☐
Data Capture & Analytics as a Core Practice	Collecting no data / data only at macro level (# of assemblies produced daily, weekly, annual, # of defects, daily/weekly timesheets). ☐	Overarching work cell data (worker time and production) is tracked. ☐	Collecting work cell data at appropriate production increment; tracking defects and causes. We know the cost of each assembly to the cent. ☐	System to analyze and act on data. If more than one fab facility, comparing data sets and leveling production demand. ☐
Quality at the Source	We don't have a formal quality assessment process. ☐	Quality is determined by human checks at the end of production. Defects routinely make it to the field even though we "think" our rate of defect is low. No formal feedback loop from field. ☐	Start up checklist for work cell, standard work and visual cues to find defects. 100% feedback loop from field. ☐	Equipment is intelligent and can spot mistakes & can signal an alert there is an issue. Management is set up to respond to out of standard conditions. ☐
Standardized Work vs. Tribal Knowledge	Relies on human experience and storytelling to convey skill set required. ☐	People build to match standards based on model parts and/or readily available reference information. Skills matrix in place and monitored. ☐	Operator Method sheets, work instructions, visible at work cell (digital or electronic) - created by workers, with support from management; New workers proficient with minimal training. ☐	Regular time study, standard work combination sheet, line balance, standard work chart, Work method sheet to improve on standard work. ☐
Workplace Organization Drives Flow and Ideas	No 5S (Lean Workplace Organization). We are constantly looking for things and end up running to Home Depot. ☐	Random acts of 5S (a bin here or there, a shadow board hear or there, etc.). Orderliness comes and goes because we have no method to sustain. ☐	Work Cell and Plan 5S is daily activity. Low excessive WIP and Inventory. 5S zone leaders actively contribute several ideas per week. We have high-intensity lighting and white walls. ☐	5S system in place with audits, zone leaders, inspections, etc. 5S zones . ☐

Industrialized Construction Maturity Self-Assessment (ICA)

(DfMA) Design for Manufacturing Assembly	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Product Families Defined & standardized; Design Rules and Specifications: Fixed yet Flexible	We have not identified standard designs, product families or a strong set of standard components. We look and act like a job shop. ☐	Products use some standard designs, though designs are largely recreated for each production run. ☐	Product families support production efficiencies and allow for customization within standardization boundaries. ☐	Design, layout, fabrication and installation use integrated software systems to ensure first time quality and efficient production/install. Product details used by +80% of design teams. ☐
Design for Assembly and Installation	Designs may be hand-written or are created using standard CAD software such as Fusion. ☐	A design database allows re-use of successful components and standardization of fabrication technology. ☐	Human designs are assessed by an AI system for technical effectiveness and mistake-proofing. We only design what can be manufactured. Less than 20% rework. ☐	An AI system creates a ranked slated of design options for human review which meet technical and other specifications. The kit-of-parts flows from trade partner to designers. ☐

CONTINUOUS IMPROVEMENT	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Identify and Eliminate waste (Make problems visible). Systematic method to Promote issue identification to improve performance (vs Core principle - which is its okay to do it).	Seeing waste is not part of the culture. DOWNTIME (or other acronym) is not pervasive, so waste is bucket vs. identify motion, transport, etc. ☐	Employees have "eyes for waste", work to remove it, and see how this impacts the value stream vs. my work. ☐	Everybody connects the waste they see to the company strategy and systematically removes waste that impairs progress (toward strategic goals). Countermeasures and Idea Systems flourish. ☐	Every person in the value stream understands overall performance, needs and is able to flex when other areas need help. Every area of the company is evaluated based on its ability to generate value. We get dozens of ideas/employee/year. ☐
Those closest to the work are the people that define the work; Solve problem at lowest possible level	It's easier to sweep problems under the rug. ☐	Problems are management's job; employees work on production. ☐	People doing the work often make suggestions when they see issues. ☐	Advanced Tiered Escalation problem solving. Any barrier to production is identified in morning huddle and resolved by noon. Information flows up - authority flows down. ☐
Systematically analyze and solve issue root causes	When something goes wrong, we fix it though we still don't embrace "problems are gold". ☐	When something goes wrong, we can usually see the cause and fix it though defects are still being passed down the line. ☐	We are able to see defects at or close to the source. Problem identification is robust though the same problem or defect is prone to happen again. ☐	See and solve problems as close to the source as possible and fix without turning away such that the defect can never happen again. ☐

MANAGEMENT SYSTEMS	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Leader Standard Work	Management spend most time in their offices or meetings to make sure the company "runs right". ☐	People on the shop floor (or field) know there is a big disconnect between management perception and the reality of putting work in place. ☐	Managers support team needs by systematically spending 40-60% of time at the Gemba in accordance with go see-ask why-show respect vs. gotcha. Managers understand that 95% of all failures and defects are caused by management systems and are humbled in front of frontline workers. Bring reports to the shop floor vs. summon to office. ☐	Senior executives systematically spend 10-30% of their time where value is added and help identify key improvement targets to further strategy. Managers and executives divide time between Gemba walks, huddles/status board reflection, problem response and mentoring. ☐
Vendor & Supply Chain Engagement	Our suppliers vary because we're always looking for a better prices, relationships are transactional. Suppliers deliver what we order. Vendors win with donuts and lunches. ☐	Suppliers understand what we value and work to be sure their value is continually improved. Vendors can be seen on our job sites to understand if ultimate value is being delivered. ☐	Deeply integrated relationship with frequent cross-visits to challenge each other and utilize each other's resources (carts, trucks). Purchase specifications based on equipment maintenance and software support (automation, robotics). ☐	Suppliers regularly walk our value streams and contribute to new product design to see how their materials are used and work with us (Kaizen) to make improvements. ☐

Time Measurement & Kaizen Worksheet

Operation: From: To: Date & Time:

Operator: Shift: Recorded by:

Seq.	Operation Element	Starting Point	1 (secs)	10 (secs)	Fluctuation	VA	NNVA	NVA	**FROM**: Current State	**TO**: Future State	Key Kaizen
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
		Cycle Time									For the purpose of our workshop together, we will only observe one cycle. See instructions on back side for conducting back in your shop or on the job site.
		Improvement									

INSTRUCTIONS:

Operation Elements

- Time Human task and Machine task separately
- Define start points for each element to ensure a repeatable cycle. Examples:
  - Hand touches part
  - Part touches rack
  - Welder fires
- The sheet is set up to collect 10 cycles. 10 Cycles is very effective for fast and high-volume production. For longer cycle times try to study at least 5.

Charted Time

- Round each measurement to the nearest second
- Charted time is the most frequent rounded value

Fluctuation

- Fluctuation refers to timing variability of the observations
- Fluctuation is the difference of Max time and the Min time from observations.
- We want to minimize fluctuation. It causes waste in our work cycle, and it is a symptom of lack of control.
  - Example 1: if during an assembly operators struggled to fit parts together this could cause fluctuation. This is a random event and is a signal that there is opportunity for improvement.
  - Example 2: Periodic Work causes fluctuations. This is work that needs to be done on occasion. This is a nonrandom event. For example, is if a box has to be built every 10 parts. If we have good single piece flow, it is preferable to have a water spider perform such tasks because it is disruptive to strong standard work.

Determining Cycle Time

- The cycle time would be the sum of the charted times.
- If a periodic task cannot be placed on a water spider, then account for the work by turning into a time / piece rate. Box takes 60 sec to build per 10 parts. This periodic box building adds 6 sec per parts.

HALEY ALDRICH

Daily Management System

Operation:
Operator(s): Date: Team Leader:

1. Establish Hour-By -Hour Production Targets

Inputs	
CT=Total Labor Time	
Run Rate	
Available Time	

Hour	Available Min	Available Sec	Parts/Hr 100%	Parts/Hr ___%
TOTAL				

2. Create Hour-by-Hour Tracking

Hour	Available Min	Plan	Actual	Variance	Reason	Team Leader Sign-off
TOTAL						

EXAMPLE:

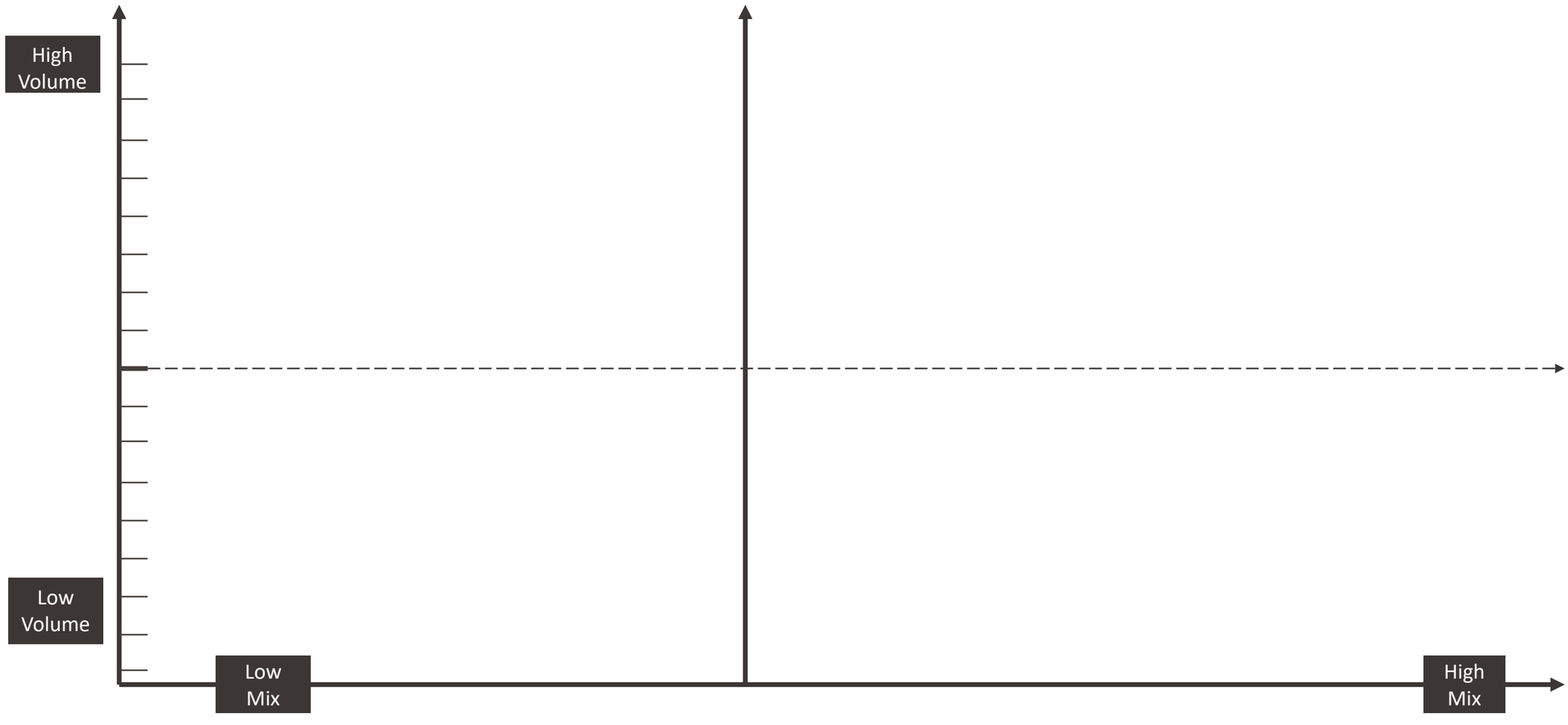
1. Establish Hour-By -Hour Production Targets

Inputs	
CT=Total Labor Time	267
Run Rate	80%
Available Time	26100

Hour	Available Min	Available Sec	Parts/Hr 100%	Parts/Hr 80$%
1	50	3000	11	9
2	60	3600	13	11
3	50	3000	11	9
4	60	3600	13	11
5	45	2700	10	8
6	60	3600	13	11
7	60	3600	13	11
8	50	3000	11	9
TOTAL	435			79

Product Family Mapping

Assembly Type	# of Assemblies Required in the Next 12 Months	Hours Saved Per Unit by Using Prefab	Total Hours Saved	Avg. Labor Rate Differential Field vs. Fab	Prefab Transportation Cost	Potential One Year Prefab Savings
Example Load Centers	1,000	25	25,000	$55	- $300 X 20 trips	$1,369,000



24TH LCI CONGRESS
OCTOBER 18-21

Thank you for attending this presentation. Enjoy the rest of the 24th Annual LCI Congress!