

Reforming Project Management & Construction Education

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Lean Construction Institute**

What has changed Manufacturing, and sharply pushed up productivity, are new concepts. Information and automation are less important than new theories of manufacturing, which are an advance comparable to the arrival of mass production 80 years ago. Indeed, some of these theories, such as Toyota's "lean manufacturing", do away with robots, computers and automation.

Peter Drucker, "The Economist", pg 12, November 3, 2001.

Results in words

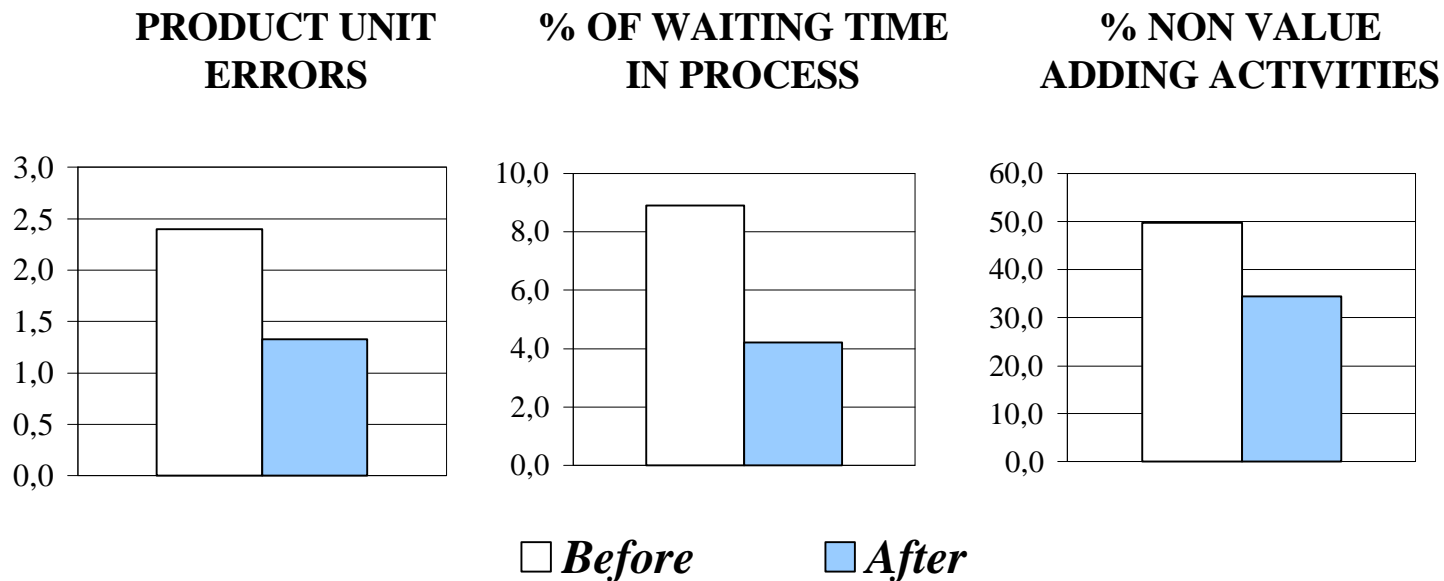
- Workers hourly salaries are going up
- Job satisfaction is improved
 - Participation -> Motivation
 - Higher degree of self justice
- Less claims
- Shorter construction time
- Less errors and omissions
- Lower construction costs
- Improved competitive capacity

Results in numbers

5 test projects (PPB-programme):

- Reduced construction time by up to 20%
- Reduced construction costs by up to 10%
- Up to 35% higher hourly salaries
- 0-errors on several projects

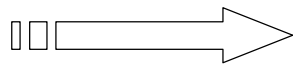
Waste reduction in a design office



44% Decrease

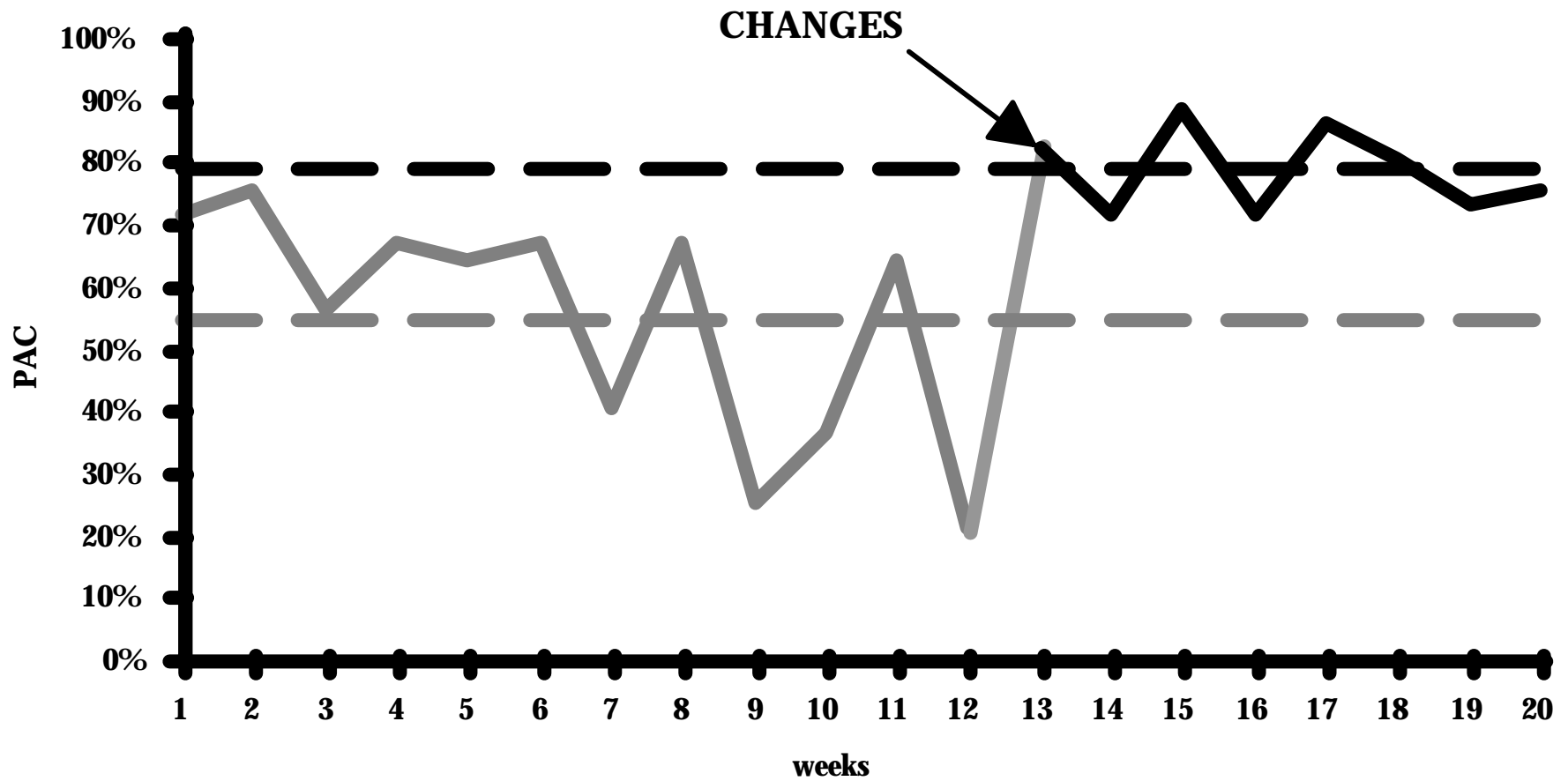
53% Reduction

31% Decrease

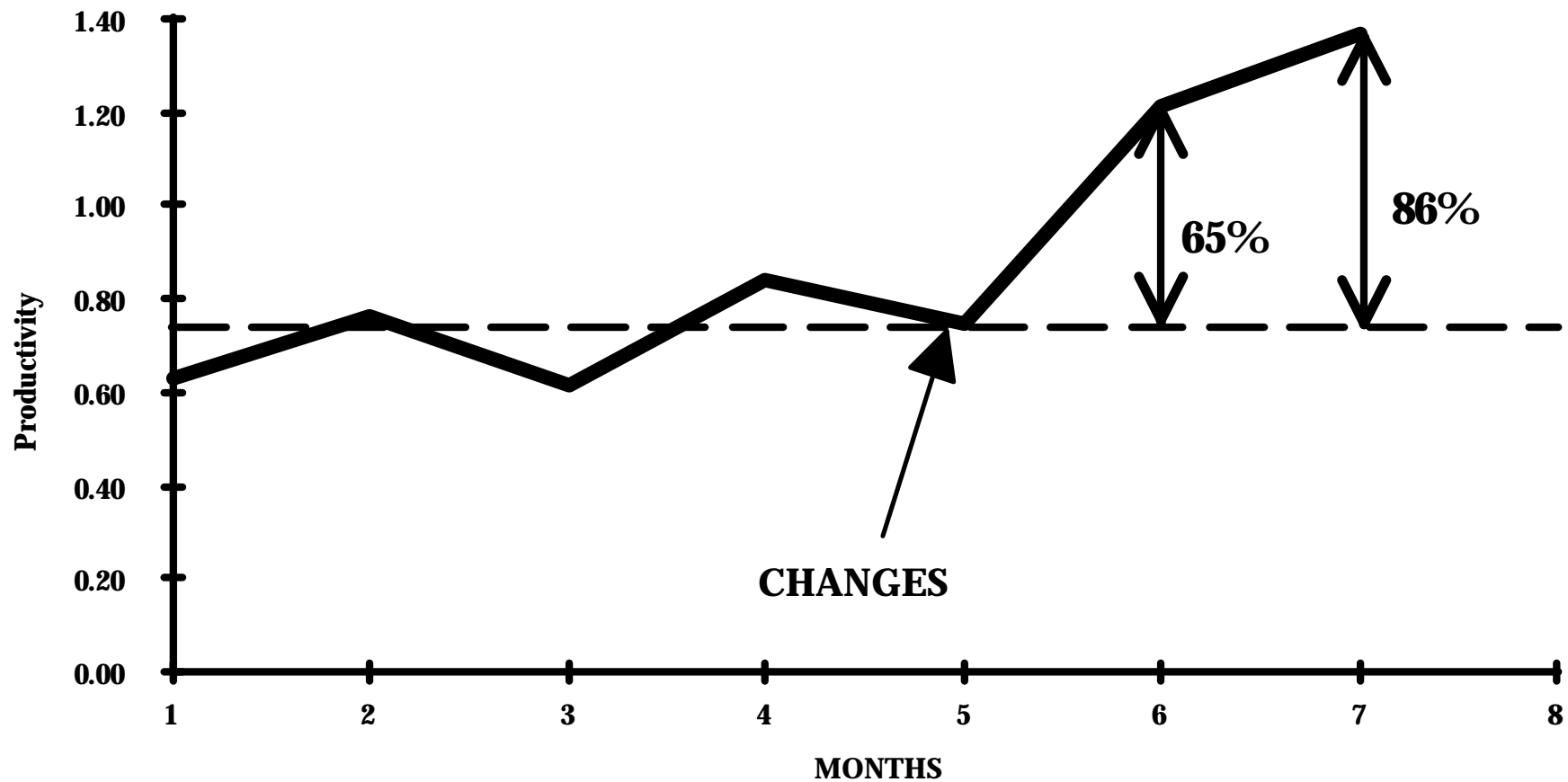


PRODUCTIVITY INCREASE OF 31%

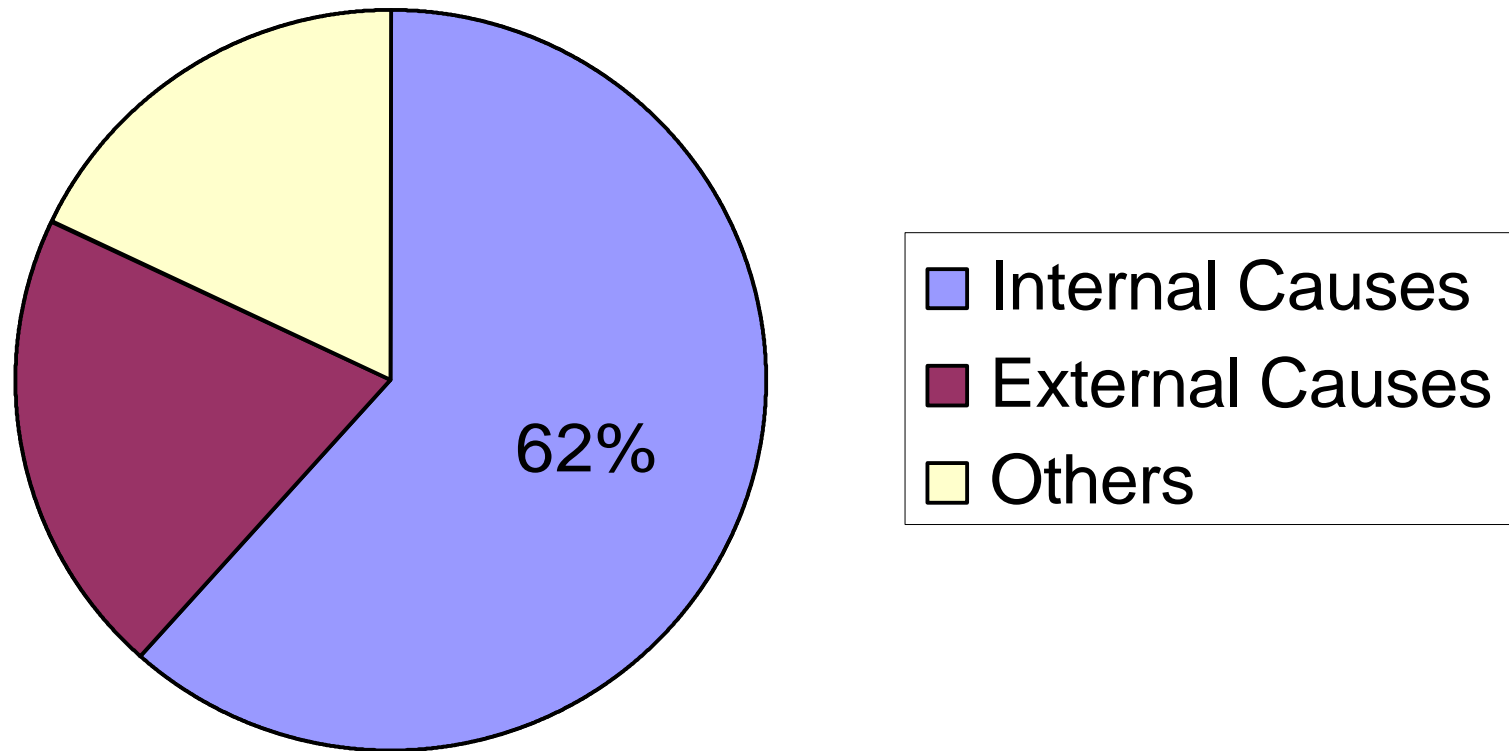
Evolution of PPC



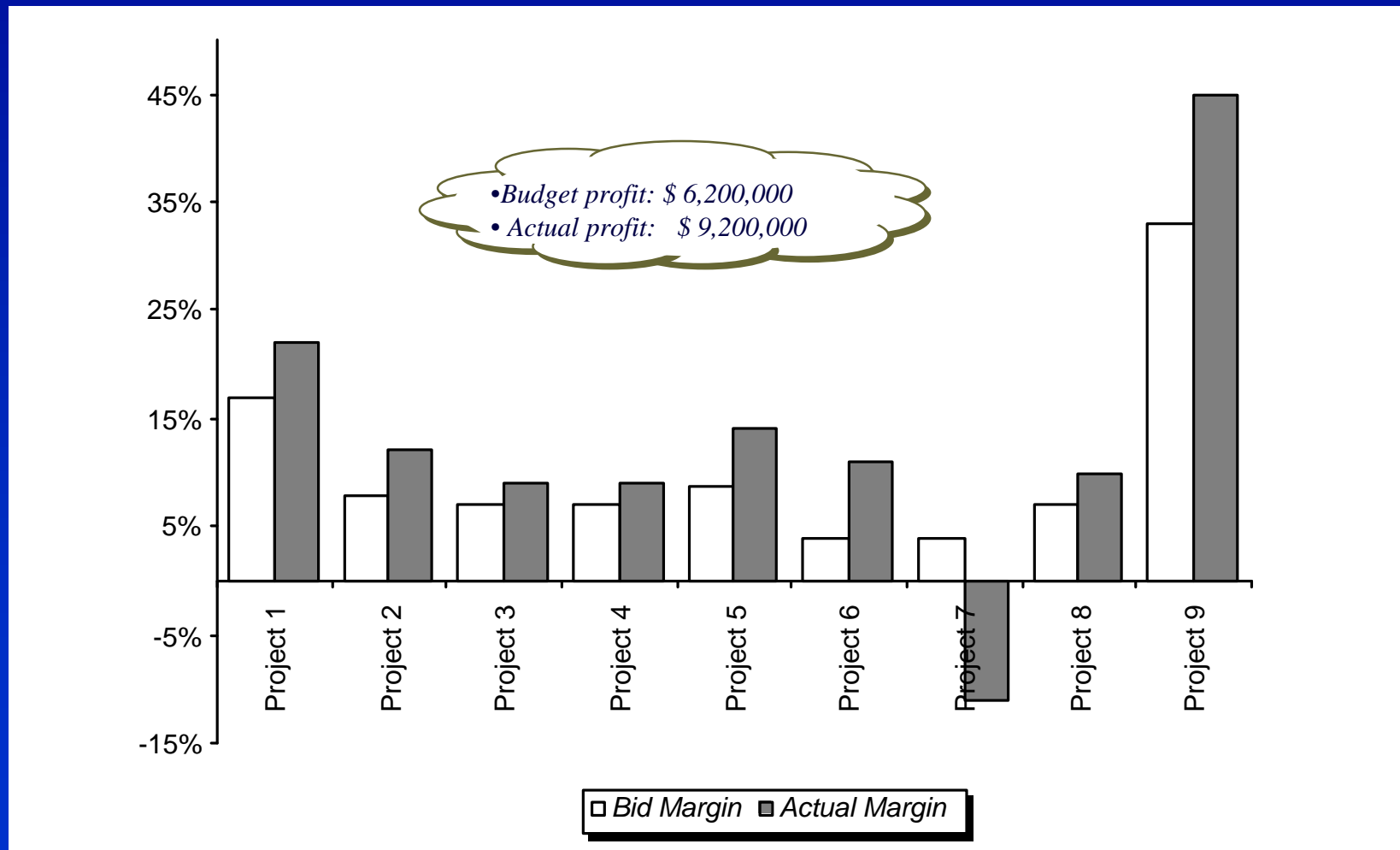
Productivity Evolution



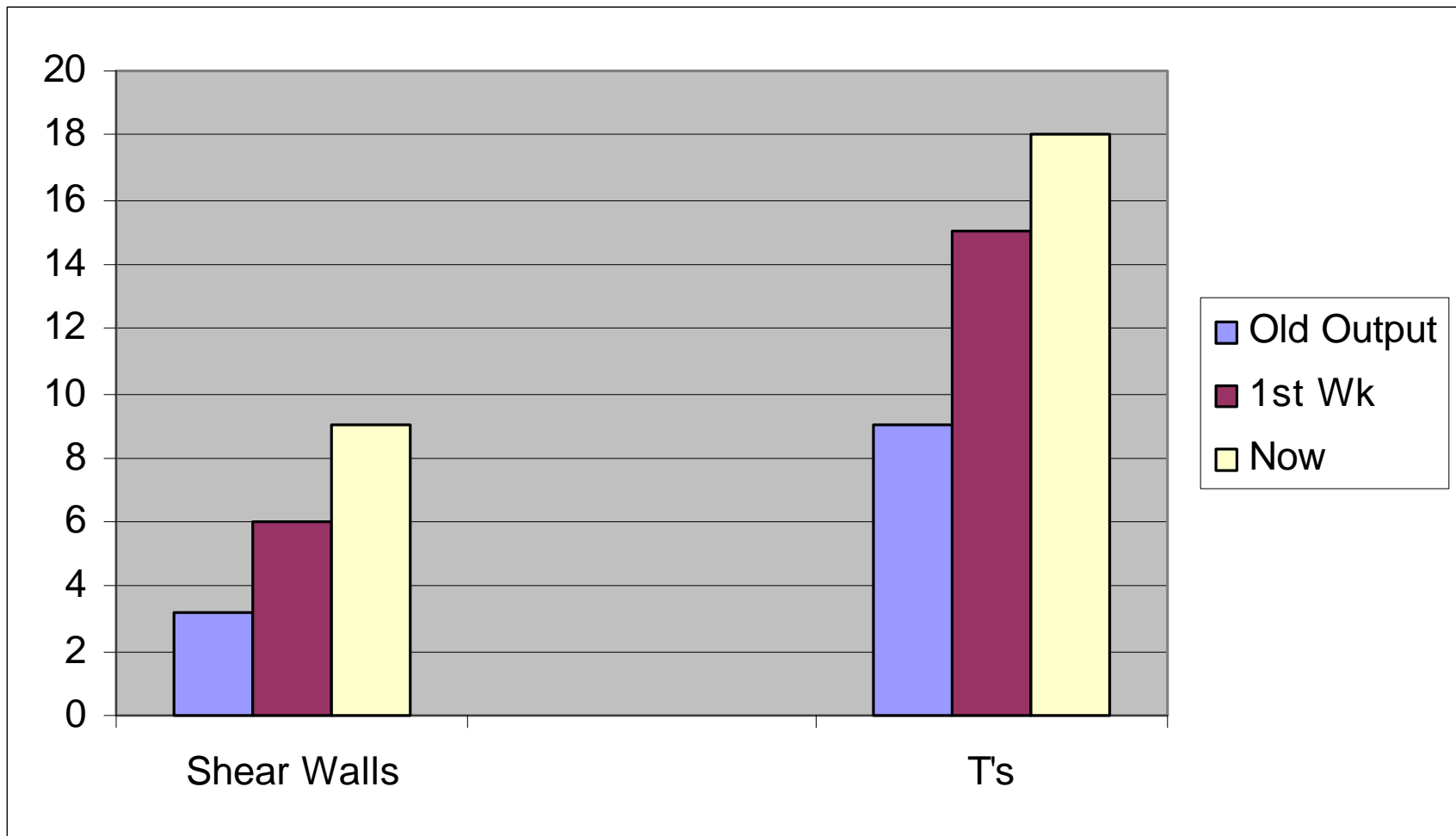
Causes of no Completion



The results show that we are on the right path...



Improvement in Throughput & Productivity



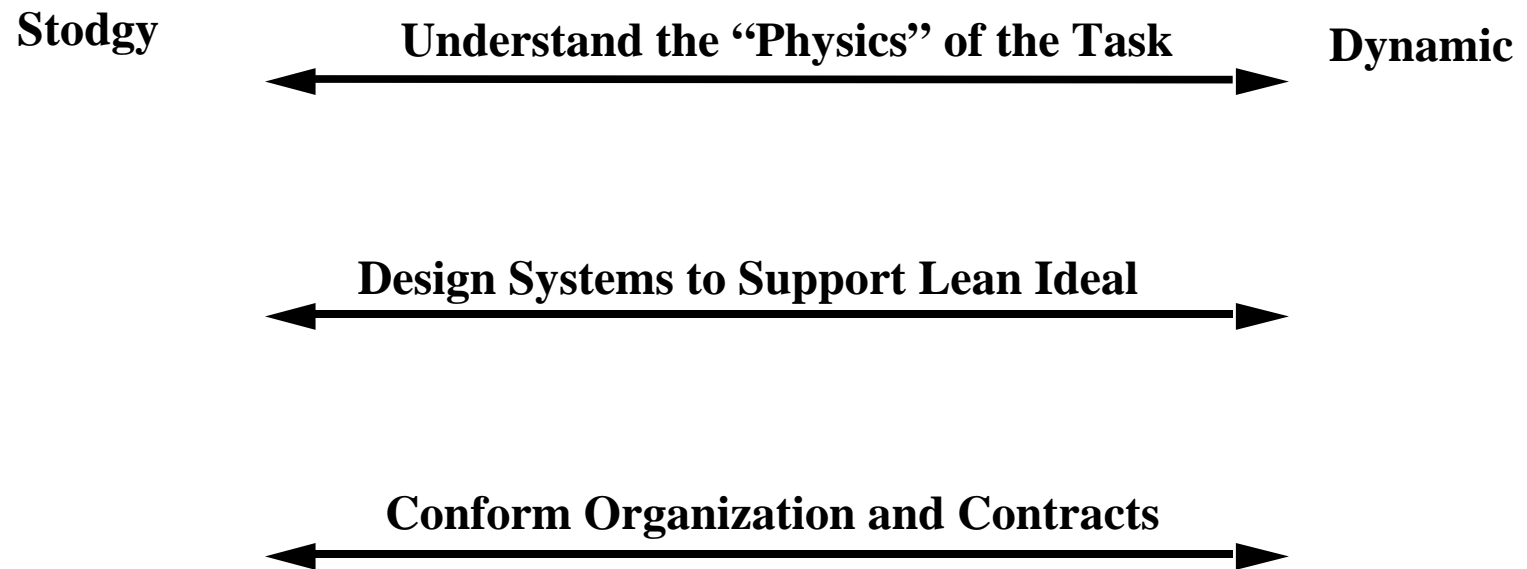
Who else is exploring application?

Owners: Intel, Ford, Solutia, Rice University, BAA

Designers: IDC, Neenan, Burt Hill Kosar Rittelmann,

Constructors: Boldt, Kinetics, Southland Industries, EMCOR, Neenan, Linbeck, DPR, EMCOR, Fluor/Ames/Kramer, Walbridge Aldinger, GyM, Westbrook AC, Simpson Mechanical

Range of Projects & LCI



Objectives of LCI

- **To develop theory and tools for understanding and managing the way work is done throughout the project delivery process, and**
- **To support implementation and dissemination.**

What is this thing called “LEAN”?

- Not mass, not craft. A third form of production system design.
- The Lean Ideal
 - Meet requirements of a unique customer
 - Deliver it instantly
 - Maintain no inventory
- “Give customers what they want, deliver it instantly, with no waste.”

Lean Production Goals

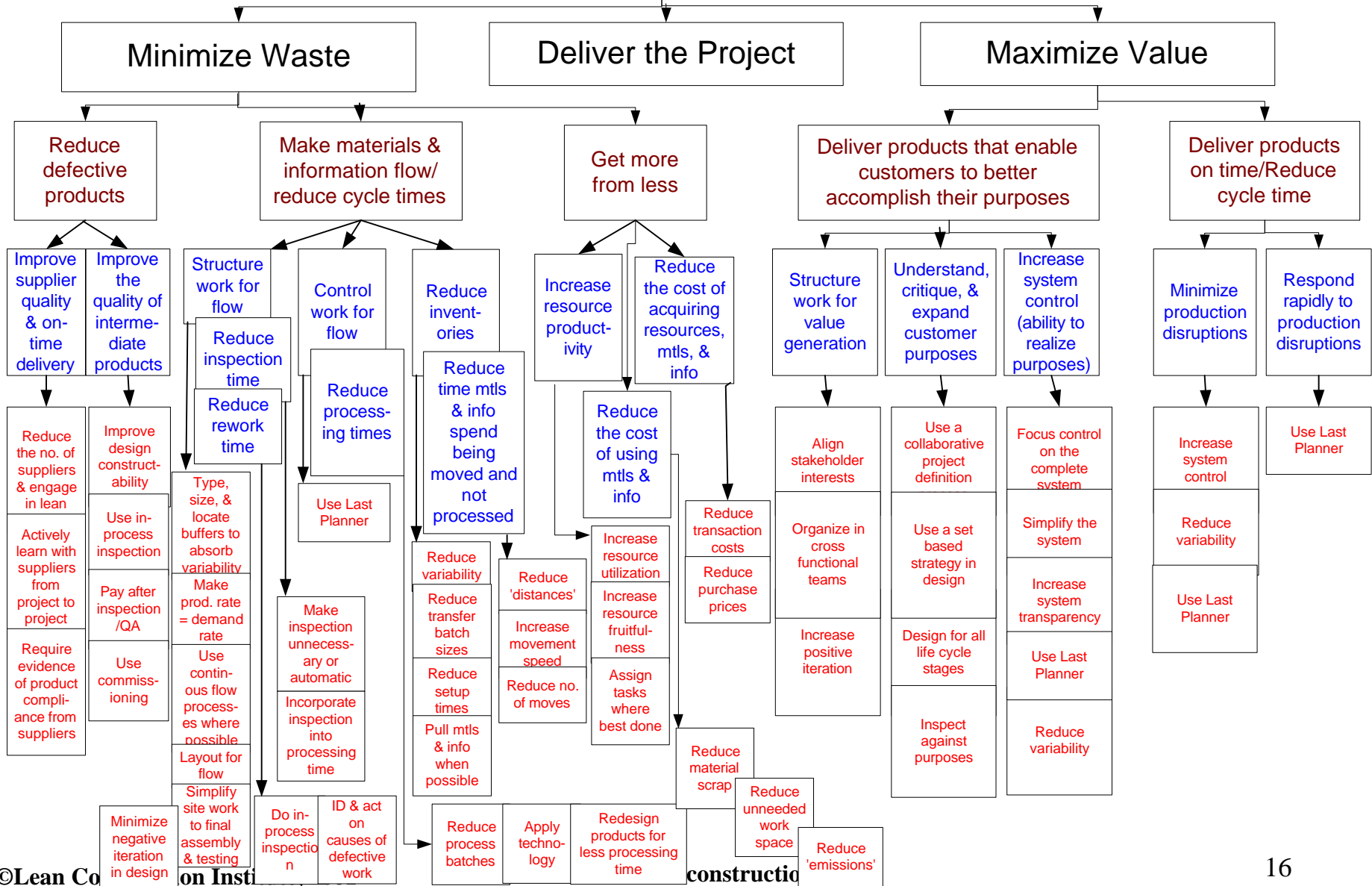
Deliver the product, while...

maximizing value (*give the customer what they need when they need it*) and

minimizing waste (*eliminate anything not needed for delivering value*), and

pursuing perfection (*never stop striving to better achieve the lean ideal*)

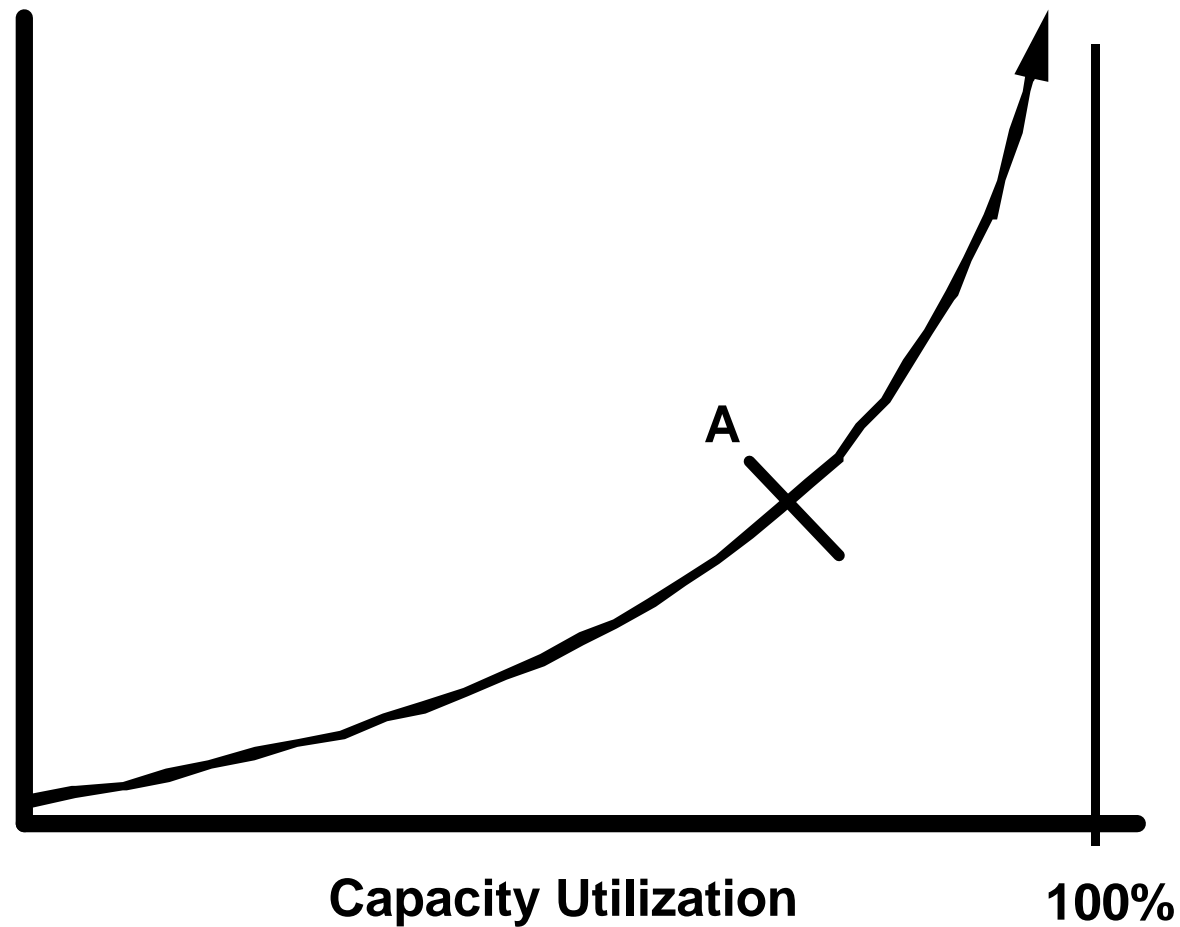
Business Objectives of Project-Based Producers



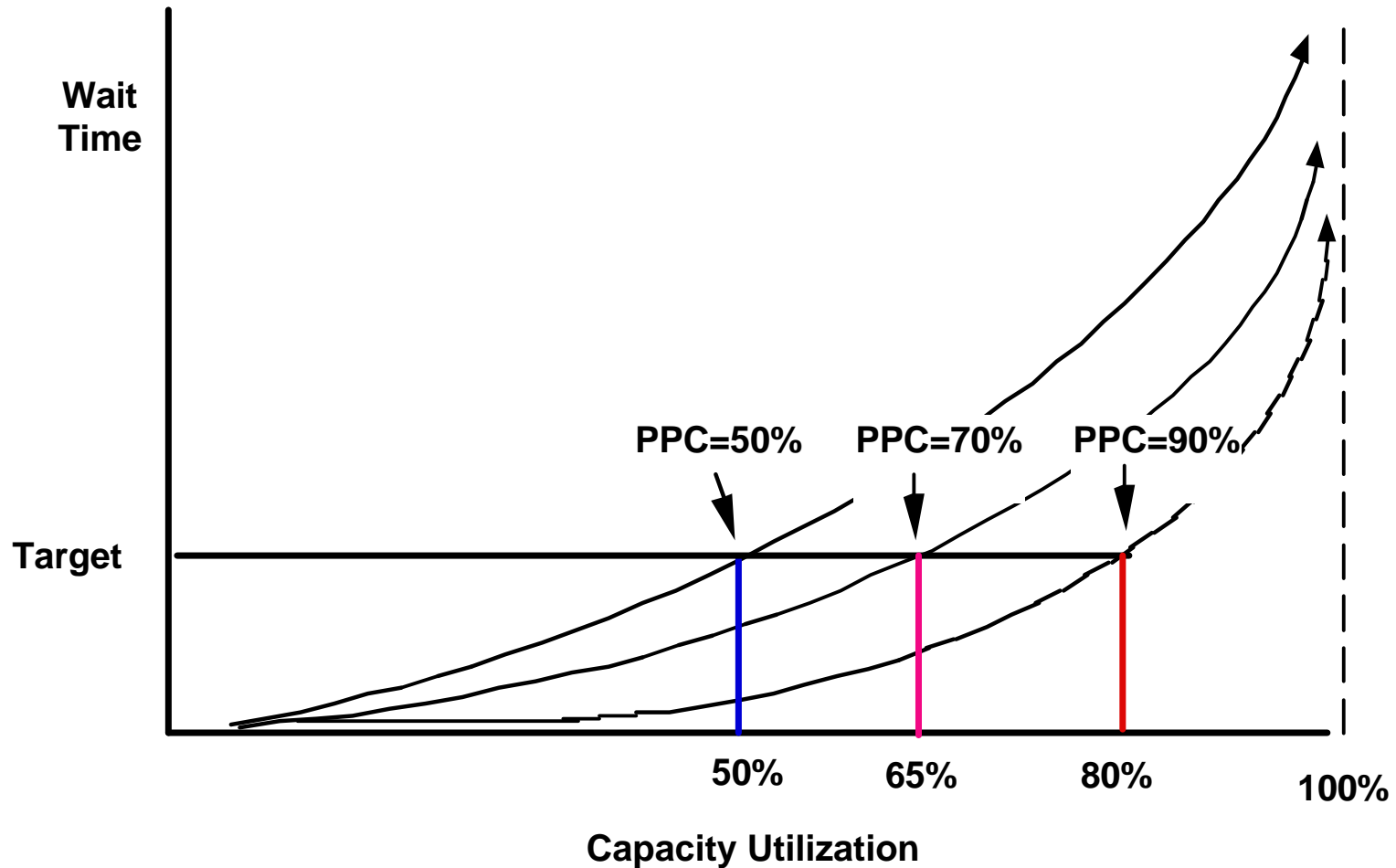
How do we manage projects now?

- **Determine client requirements and design to meet them. Align design to quality, schedule and budget limits.**
- **Manage the project by breaking it into pieces, estimating duration and resource requirements for each piece, then put the pieces in a logical order with CPM.**
- **Assign or contract for each piece, give start notice and monitor each piece to assure it meets safety, quality, schedule and cost standards. Take action on negative variance from standards.**
- **Coordinate using the master schedule and weekly meetings.**
- **Cost may reduced by productivity improvement. Duration by speeding each piece or changing logic. Quality and safety get better with inspection and enforcement.**

More Physics: Variability, Lead Time, & Capacity Utilization



PPC and Capacity Utilization



Essential Features of Current Practice

- Activity centered - Batch and Queue that trades efficiency for apparent security.
- Inflexible to changes in business case and owner requirements after concept design.
- Control begins with Tracking cost and schedule.
- Improving local productivity/speed leads to Unreliable Work Flow further reducing project performance.
- Protecting activities leads to adversarial relations.
- Planning system cannot Coordinate the work between crews.

The Opportunity in Projects

Change the way projects are managed!

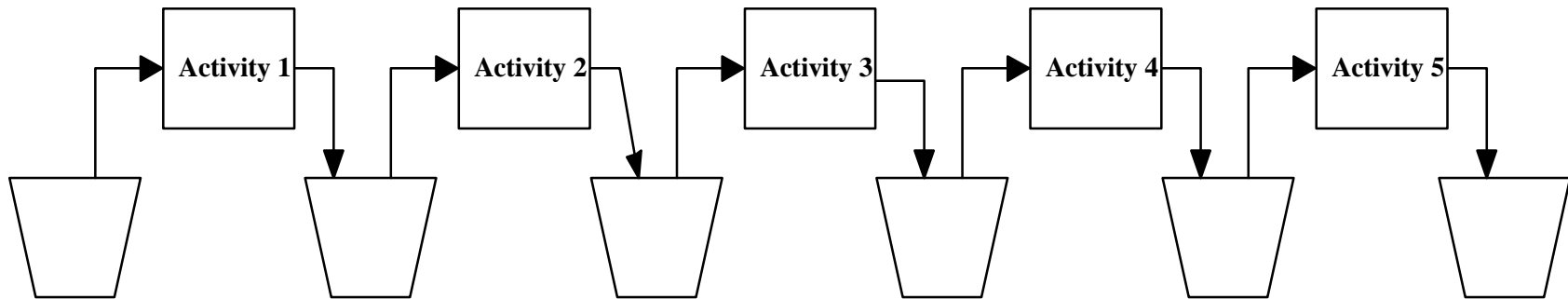
– Current practice

- Takes too long, costs too much, kills too many
- Rests on a deficient theory; an incomplete understanding of work, its control and improvement
- Confuses scheduling with production management.
- Commercial contracting trades system efficiency for a fantasy of security. Bob Lane, BAA
- Increases risk and uncertainty
- Causes sub-optimal performance

Designing Project Based Production Systems

- **Understand the physics of production (making - dependence and variation, and design - wicked problems).**
- **Assure design, planning and logistic systems all support reliable and speedy workflow.**
- **Provide organizations to support these systems.**
- **Draft contracts that create these organizations.**

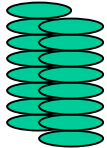
Dice Game



- Move a 100 units/tasks/requirements into the last bucket.
- Roll in sequence to the end of the line.
- Average roll of 5.
- How many times will the die have to be passed down the line?
- When will the red chip, #50 be at station 4?

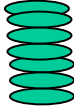
Sample Game

7



20			
15			
10			
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0			

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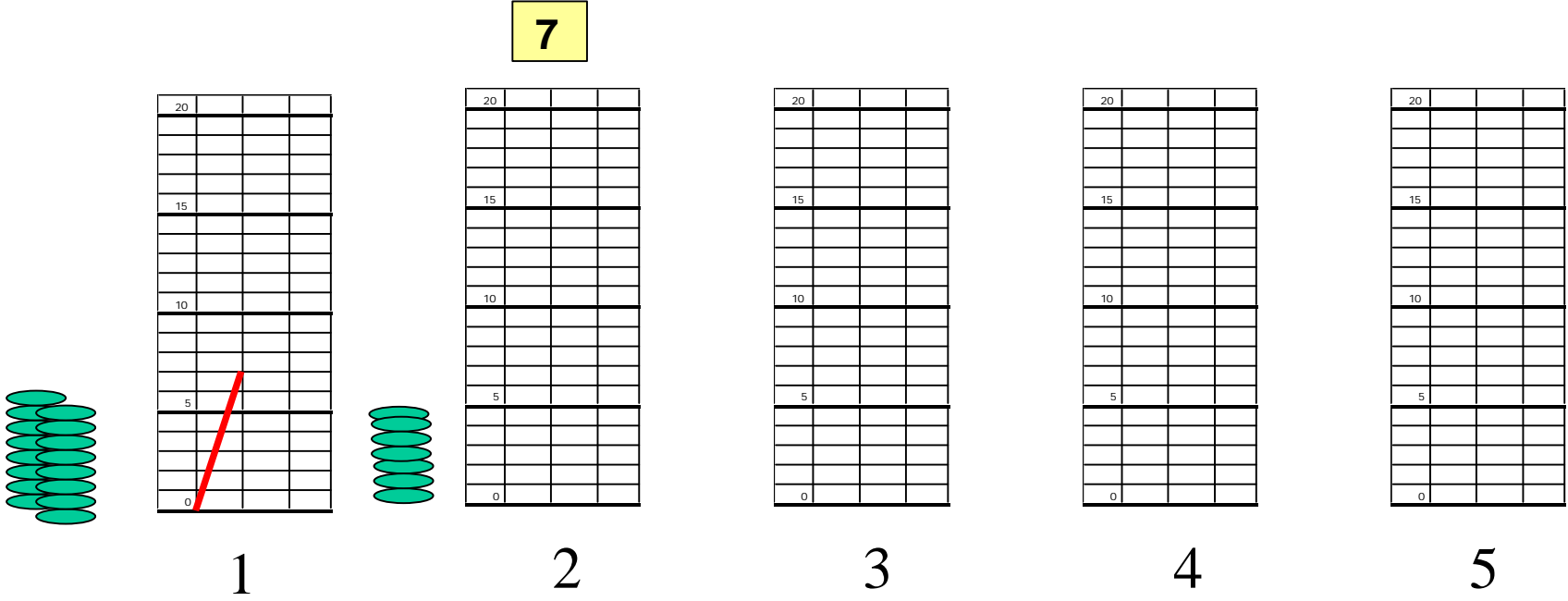
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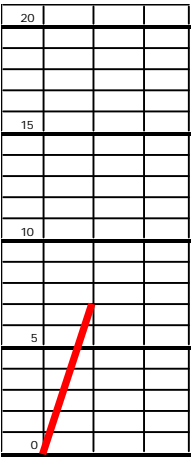
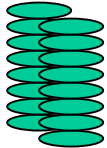
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Sample Game

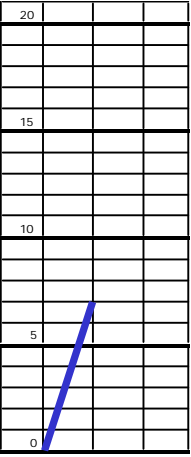


Sample Game

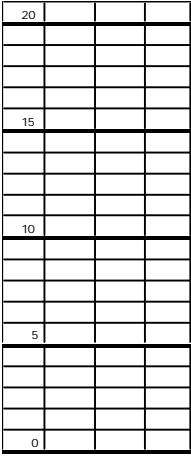
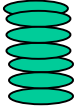
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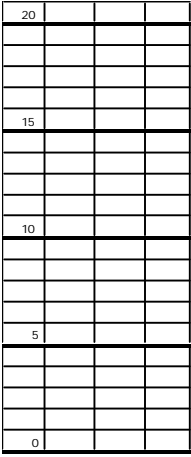
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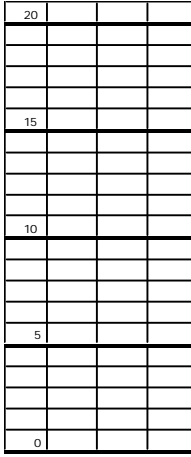
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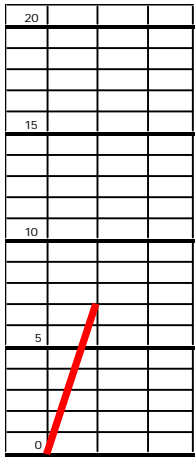
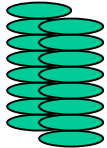
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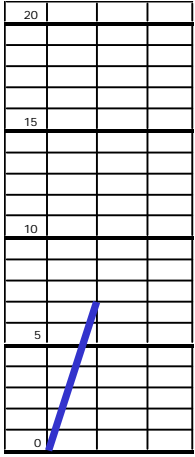
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Sample Game

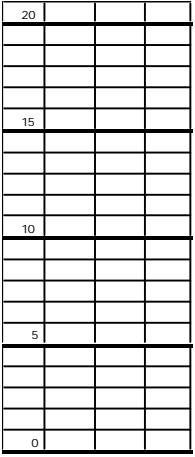
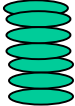
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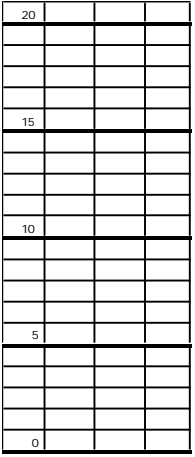
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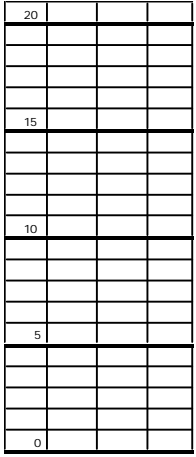
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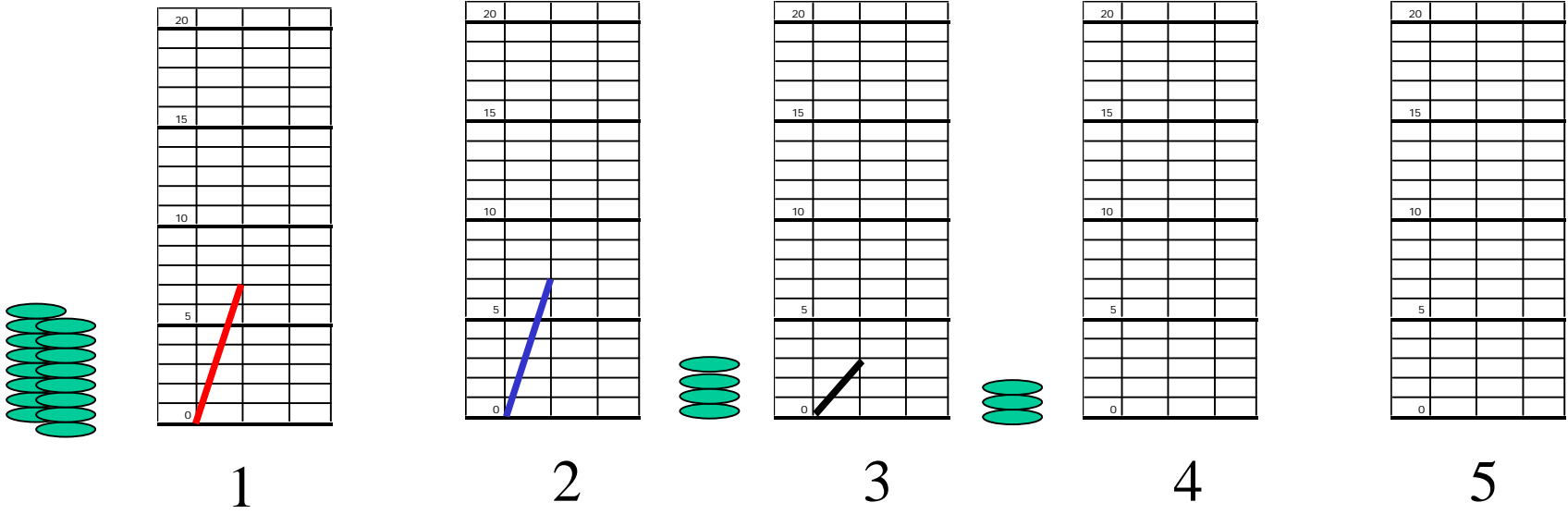
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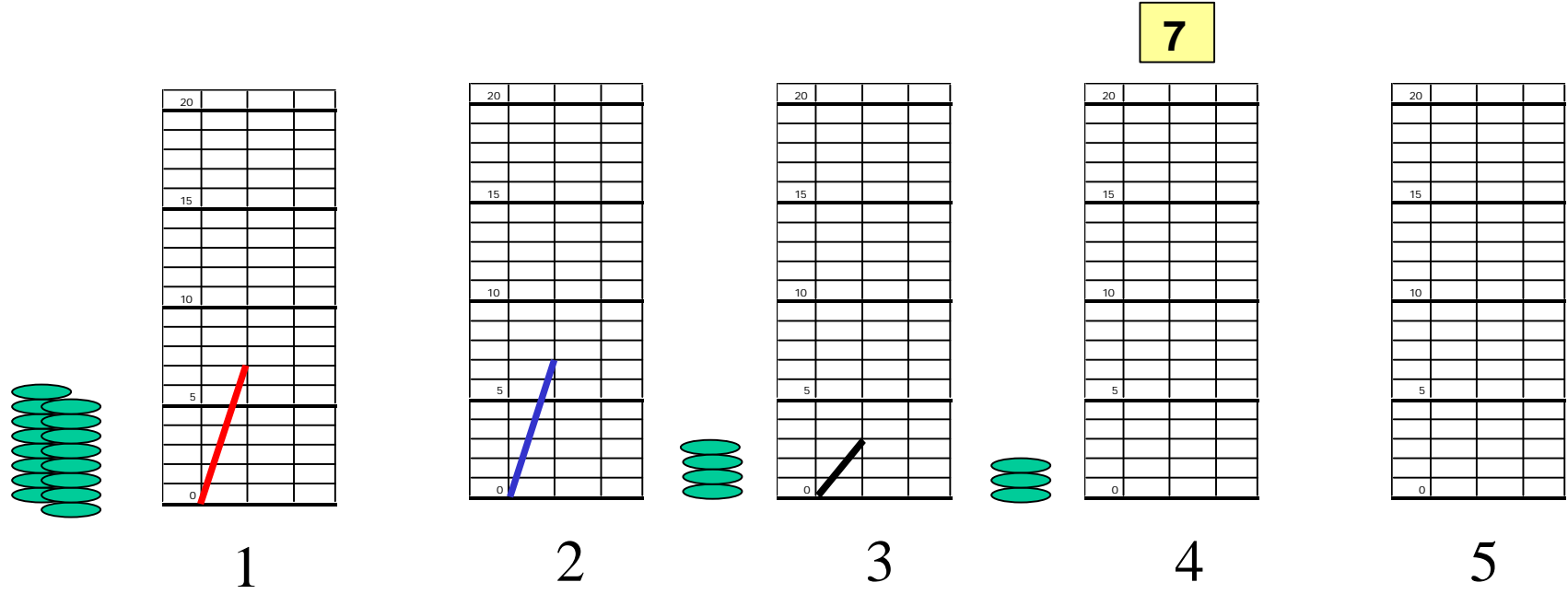
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Sample Game

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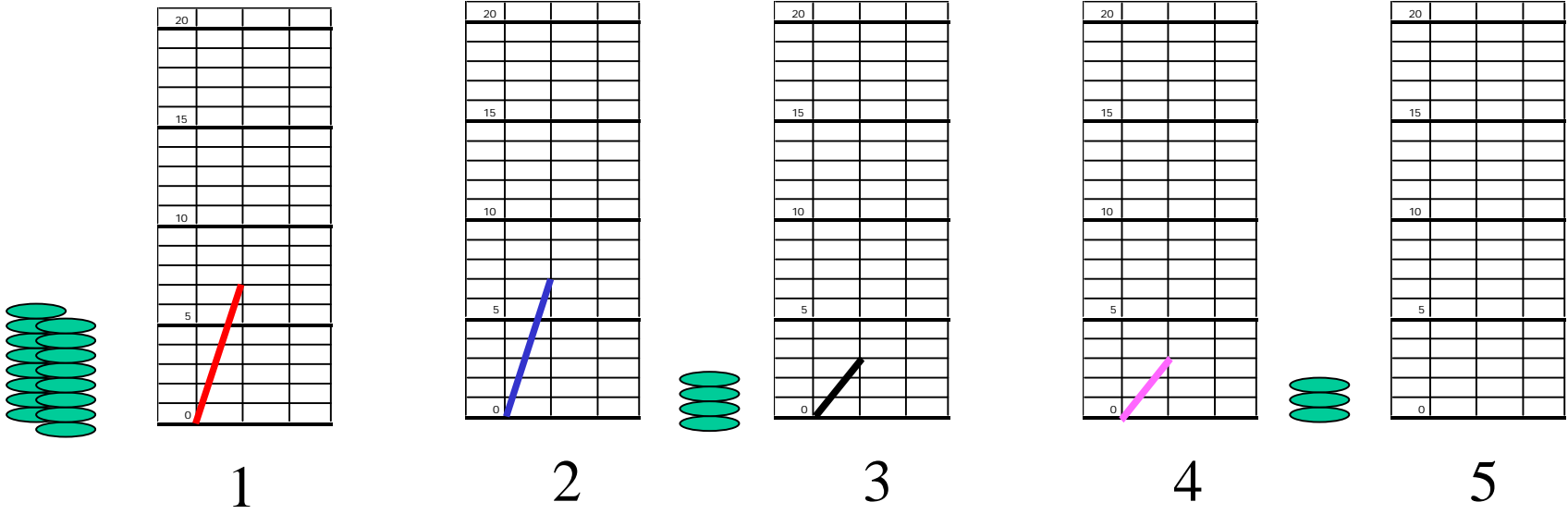


Sample Game

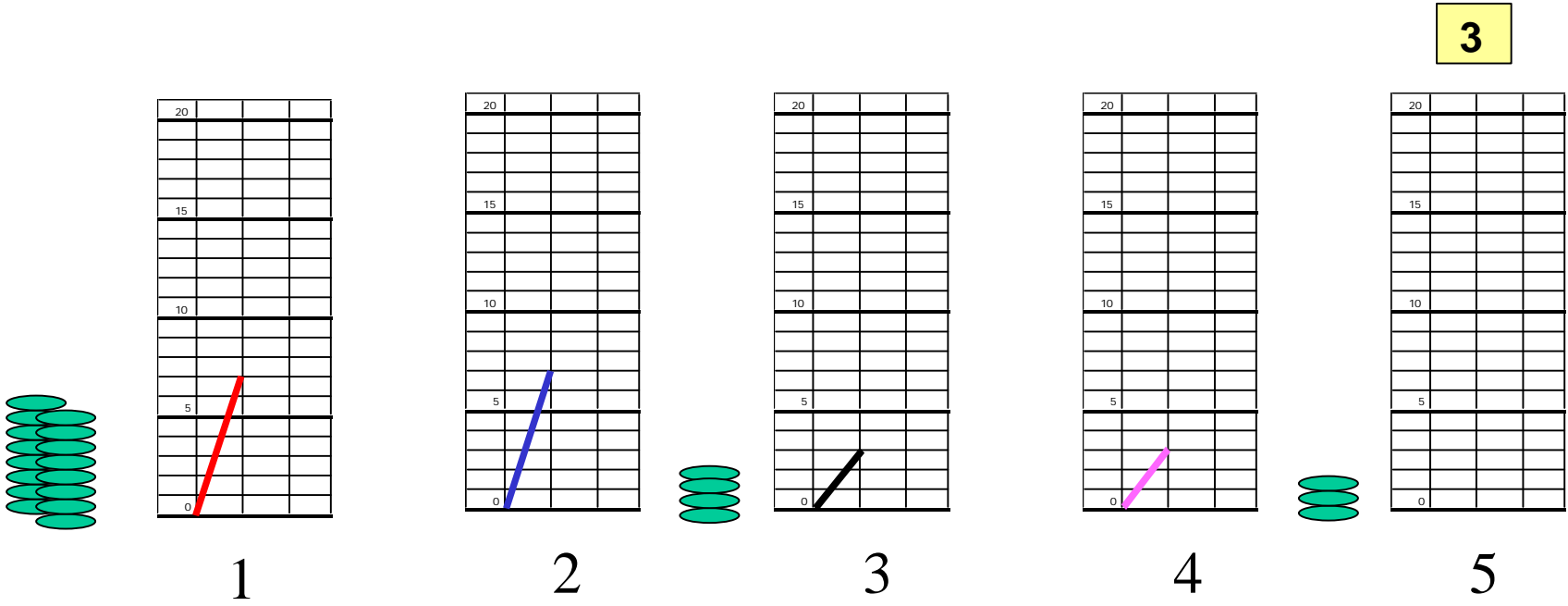


Sample Game

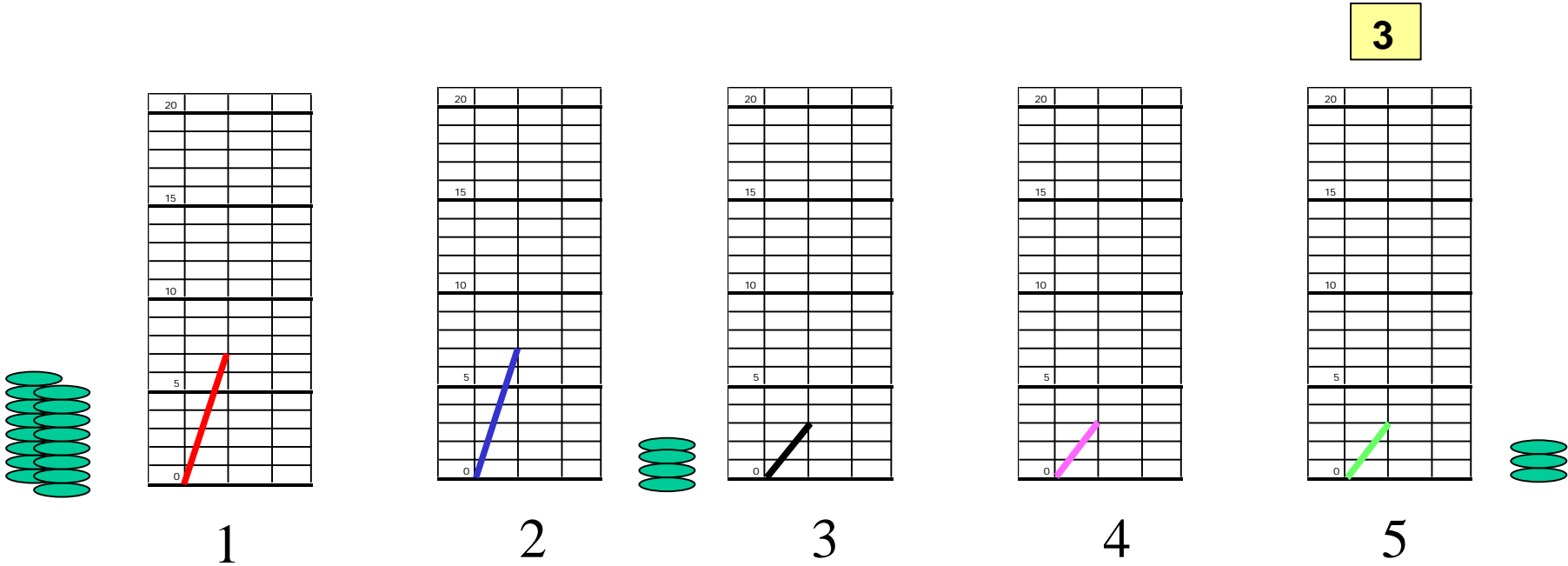
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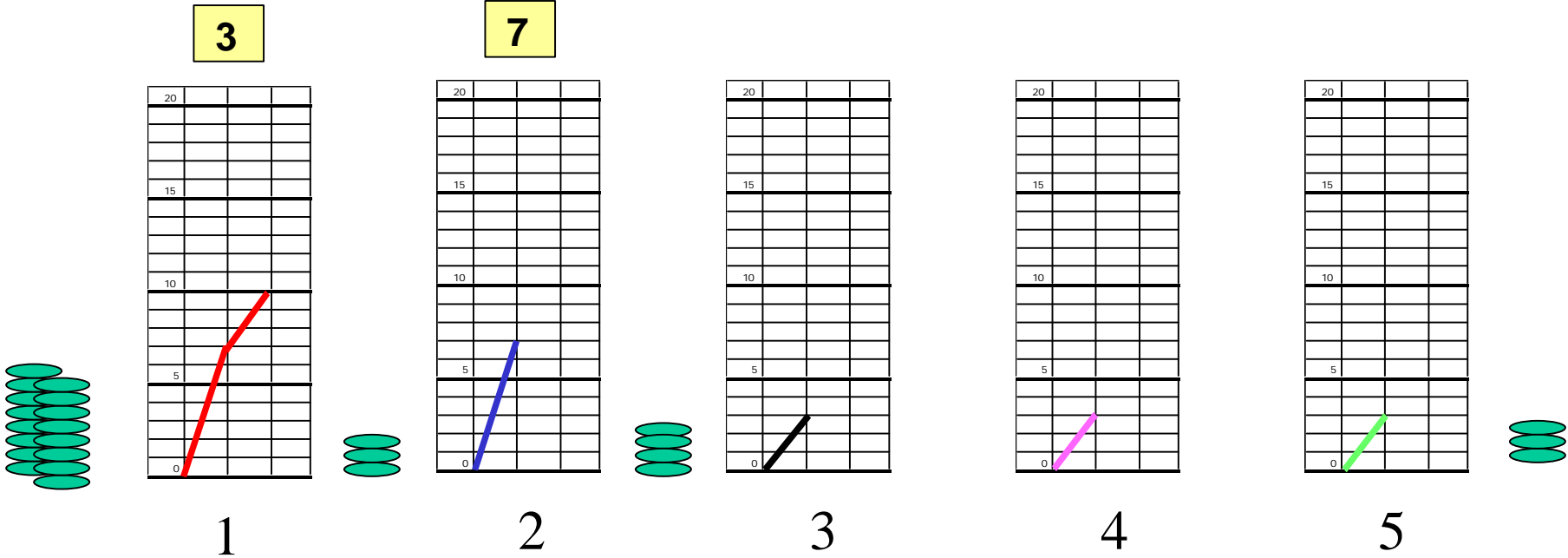
Sample Game



Sample Game

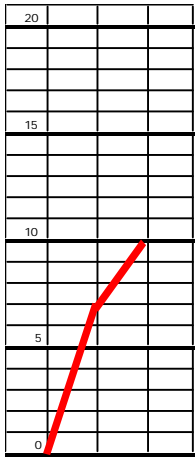
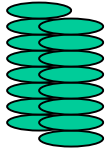


Sample Game

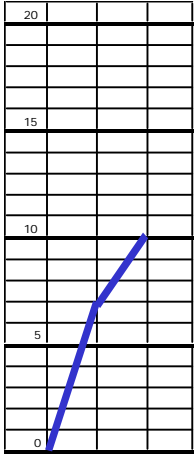


Sample Game

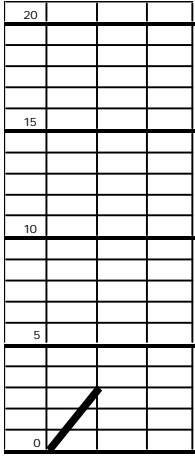
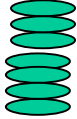
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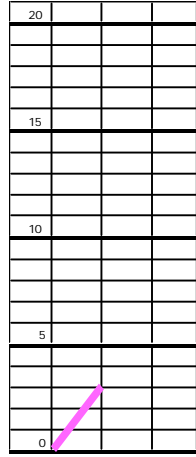
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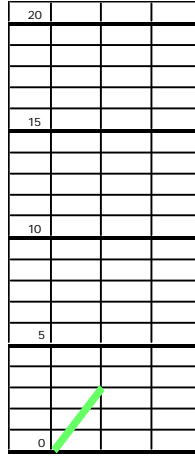
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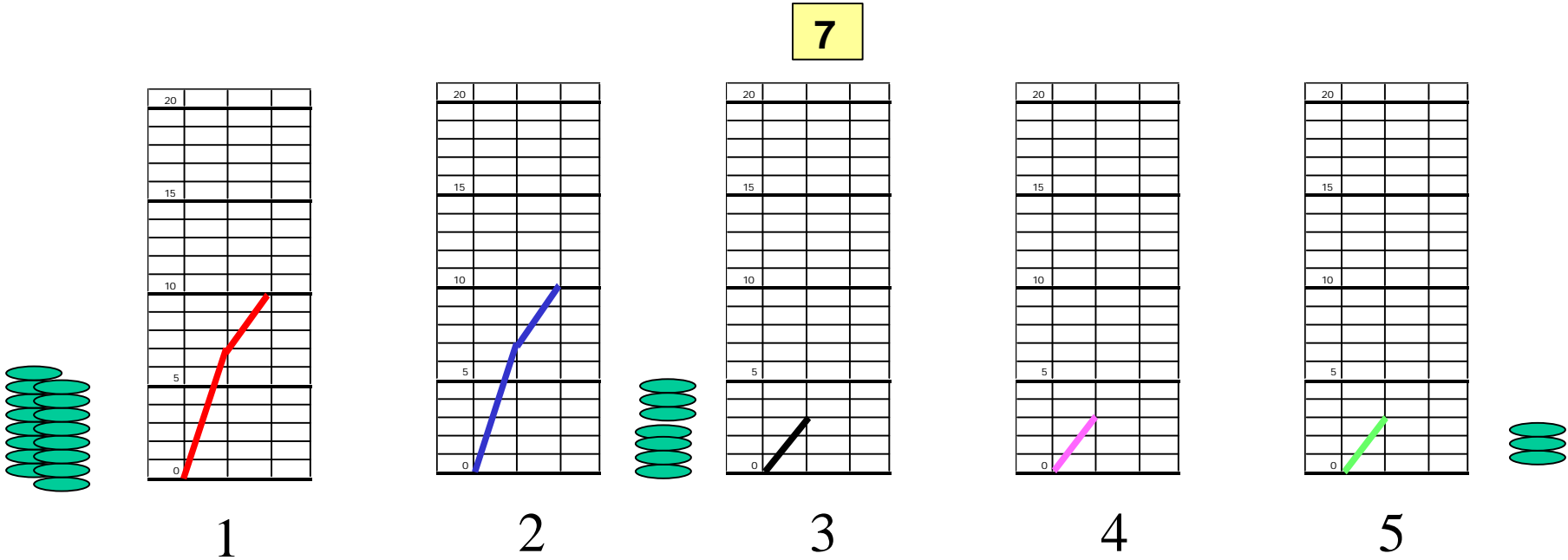
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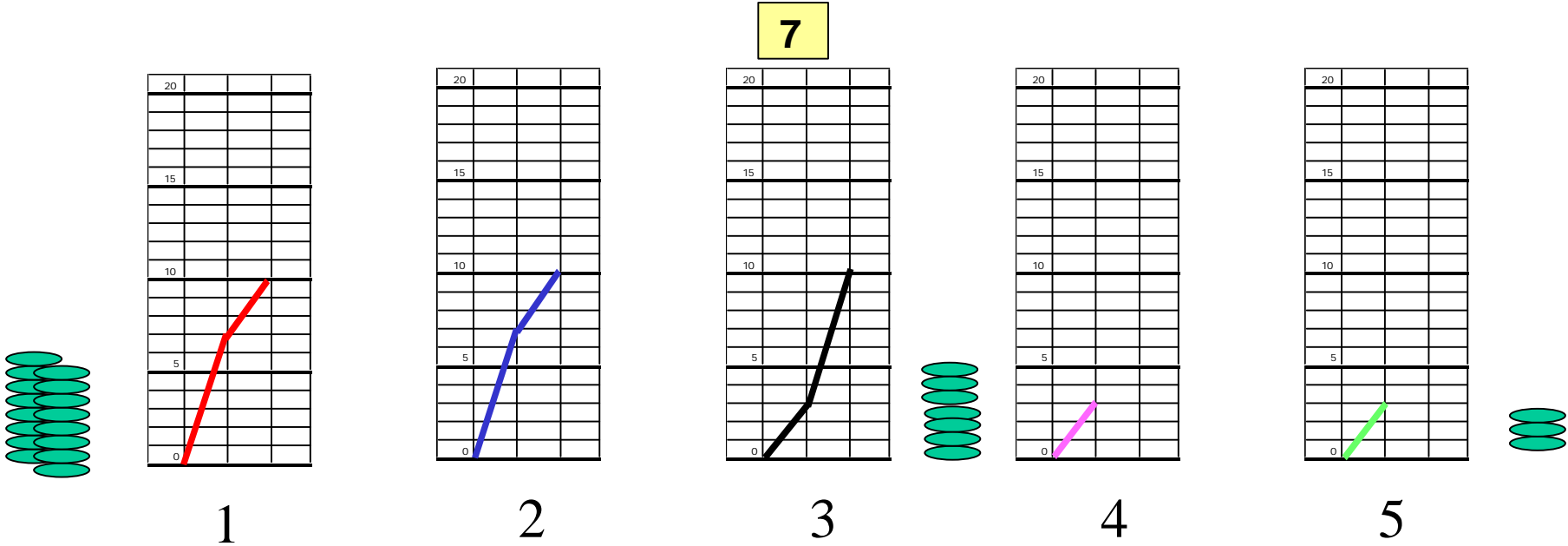
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Sample Game

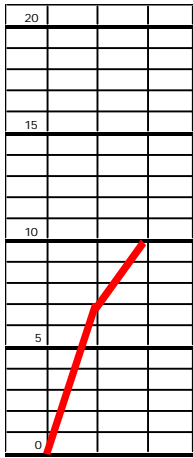
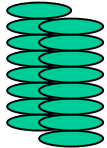


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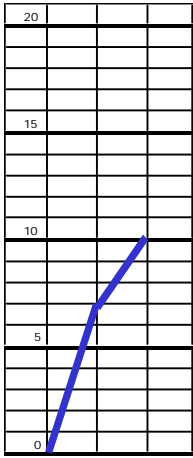


Sample Game

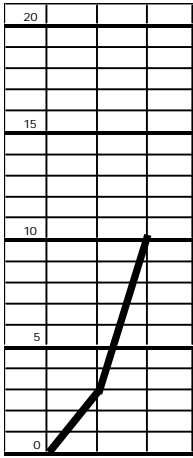
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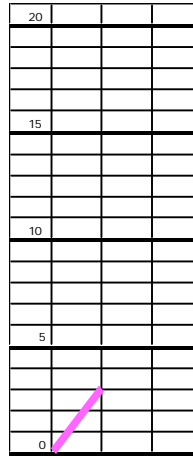
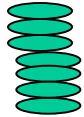
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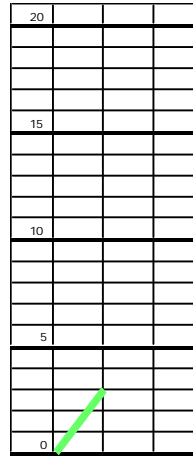
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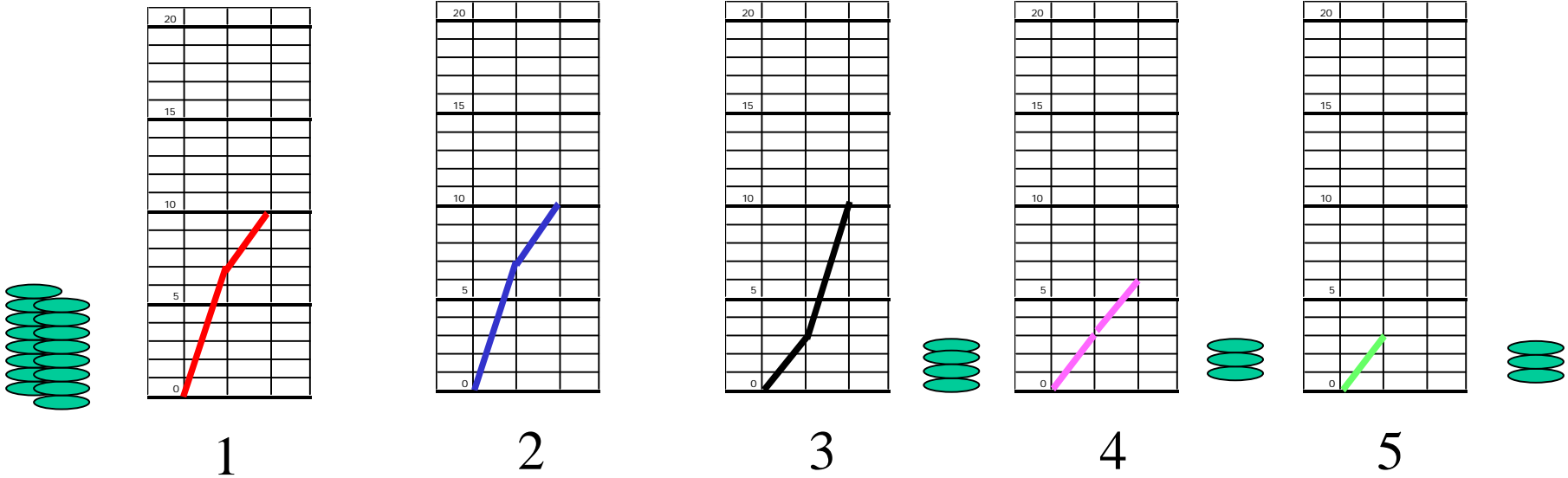


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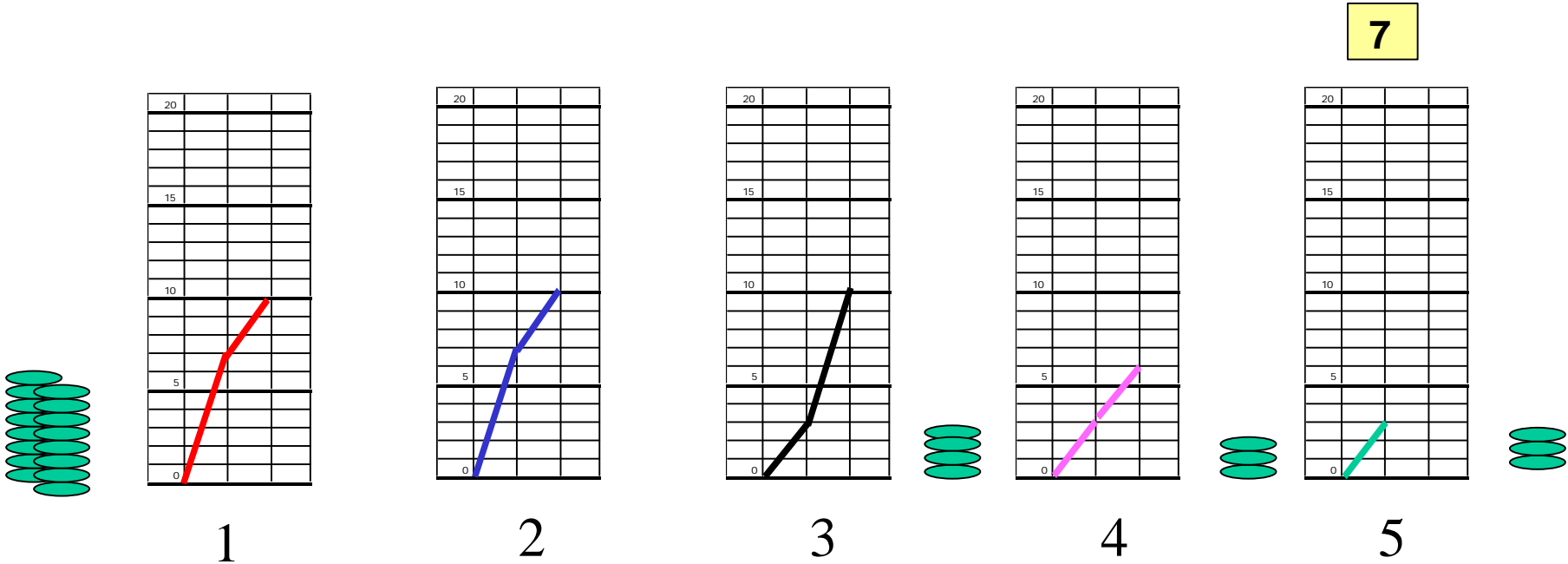


Sample Game

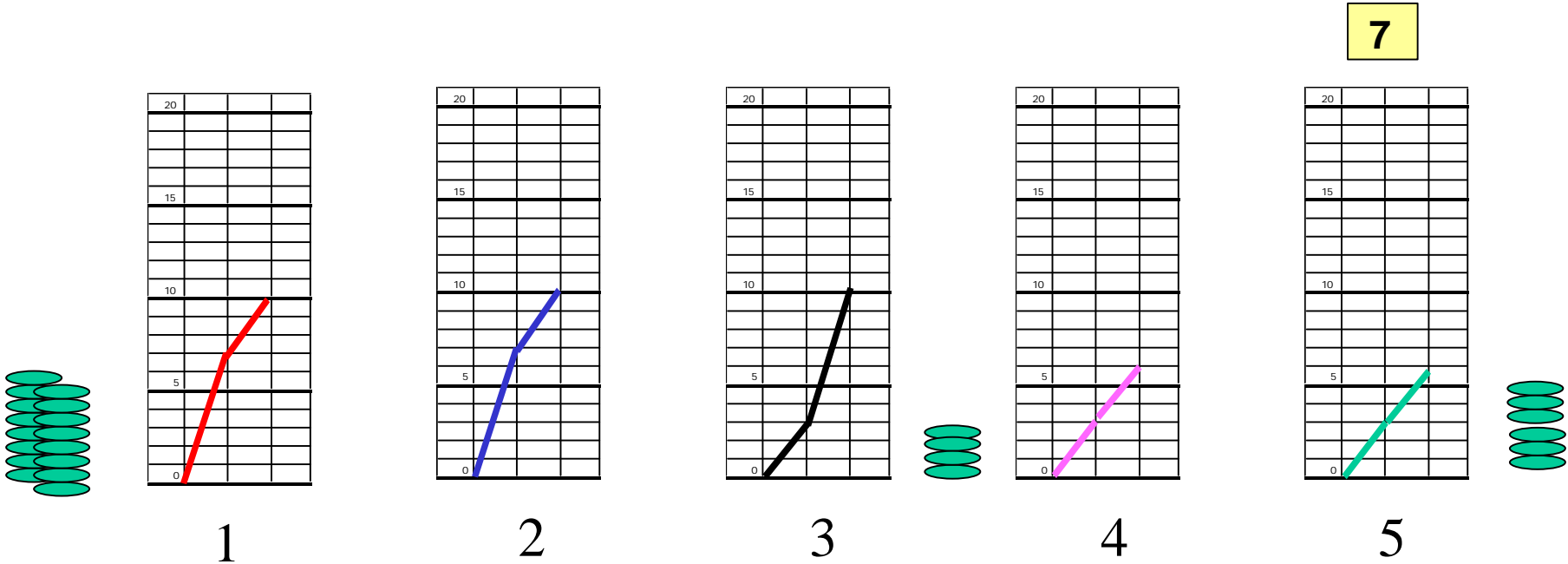
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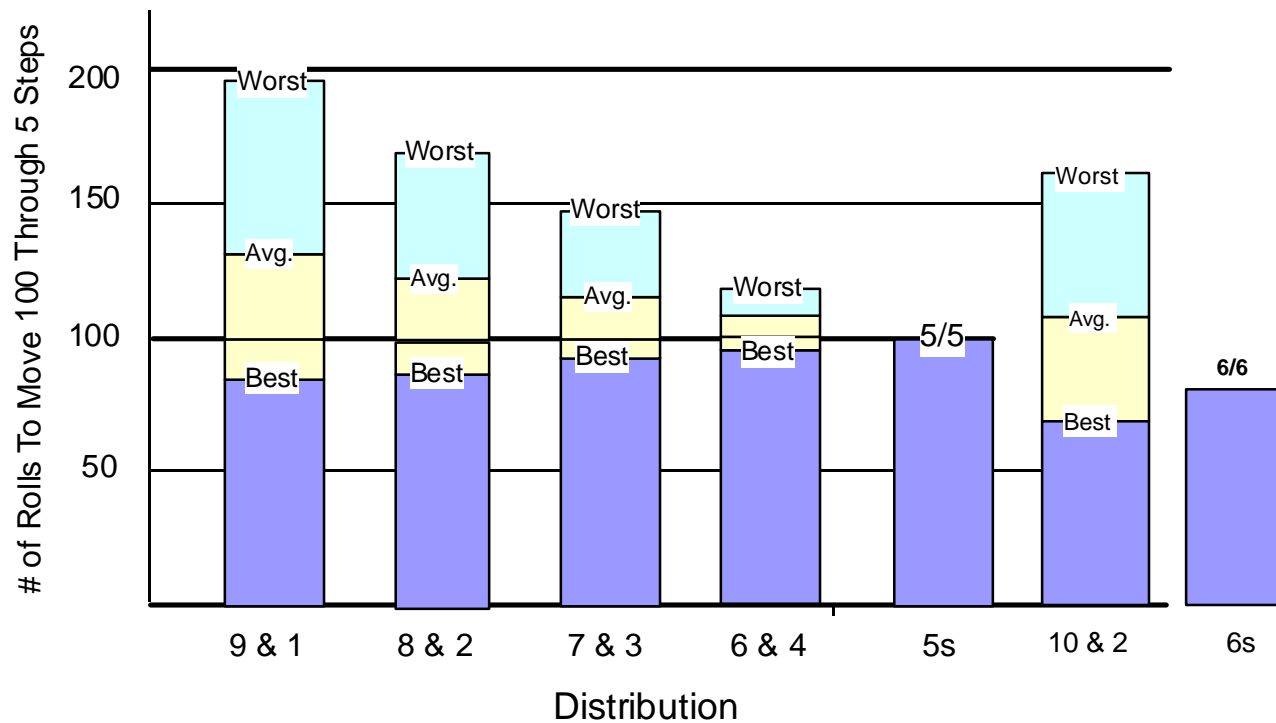
Sample Game



Sample Game



Flow Variation and Project Outcomes



Key Points

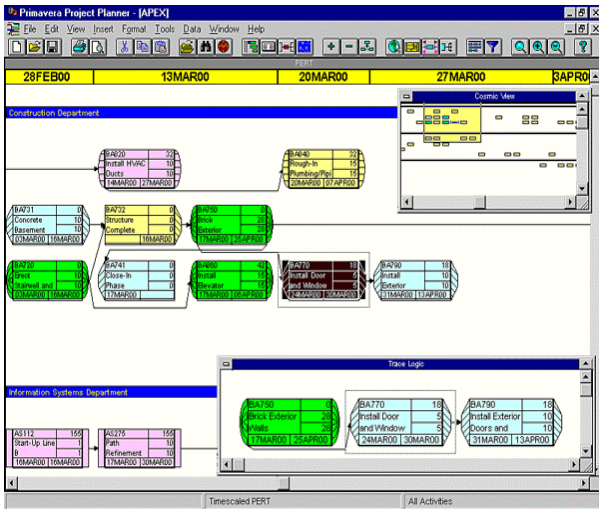
- Reducing workflow variability
 - Improves total system performance,
 - Makes project outcomes more predictable,
 - Simplifies coordination,
 - Reveals new opportunities for improvement.
- Point speed and productivity don't matter to the customer – throughput does.
- Strategy: Reduce variation then go for speed to increase throughput.

Key Terms

- **Work Flow** - The movement of work between interdependent specialists.
- **Release of work** - making work available to the next crew.
- **Dependence** - waiting on release of work.
- **Variation** - the range of work completed each day or week.
- **Buffer** - a verb: “to isolate one activity from the next.”
- **WIP** - Work in process.
- **Point Speed** - how fast each assignment or activity is completed.
- **Throughput** - the amount of the project completed each period.
- **Capacity** - amount of work that can be done by the crew, related to productivity.
- **Push** - Advancing work based on central schedule
- **Pull** - Signaling for components of work to arrive when they will be required.

What We Know for Sure about Last Planner Production Management

First - It Works!!!!!!



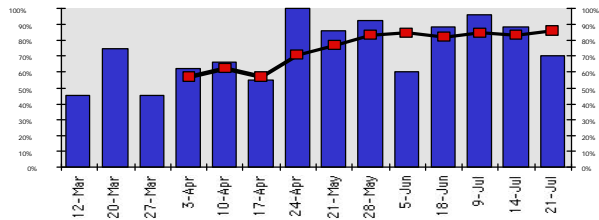
Master & Phase Schedules

Project Zonaca Ag Products - Building 196

Run Date: 2/21/00 12:57

ID	Activity Description	Start	Responsible	Criteria				Inputs			Resources			Other	Comments
				Contract	Design	Submittals	RFIs	Material	Prereq	Equipment	Labor	Weather			
	Demo CMU wall	28-Oct	Cal-Wrecking	X	X	X	X	X							Concrete at E-10 must be up to strength.
	Excavate footing	4-Nov	Cal-Wrecking												Possible delay caused by oversized footing.
	Install bottom rebar mat	9-Nov	McGrath	X	X	X	X	X	X	X	X	X	X	X	
	Install footing dowels	9-Nov	NLB	X	X	X	X	X	X	X	X	X	X	X	
	Plumbing rough-in	10-Nov	Perryman	X	X	X	X	X	X	X	X	X	X	X	
	Install top rebar mat and stirrups	11-Nov	McGrath	X	X	X	X	X	X	X	X	X	X	X	
	Rebar inspection	12-Nov	ICI, C of R	X	X	X	X	X	X	X	X	X	X	X	
	Place footing	16-Nov	NLB	X	X	X	X	X	X	X	X	X	X	X	
	Install 1st floor wall rebar	19-Nov	McGrath	X	X	X	X	X	X	X	X	X	X	X	
	Above sequence	2-Dec		X	X	X	X	X	X	X	X	X	X	X	
													Total Activities	27	
													Activities Ready	25	
													AMR Week - 1 Ratio	92.59%	

Lookahead Plan With Constraint Analysis

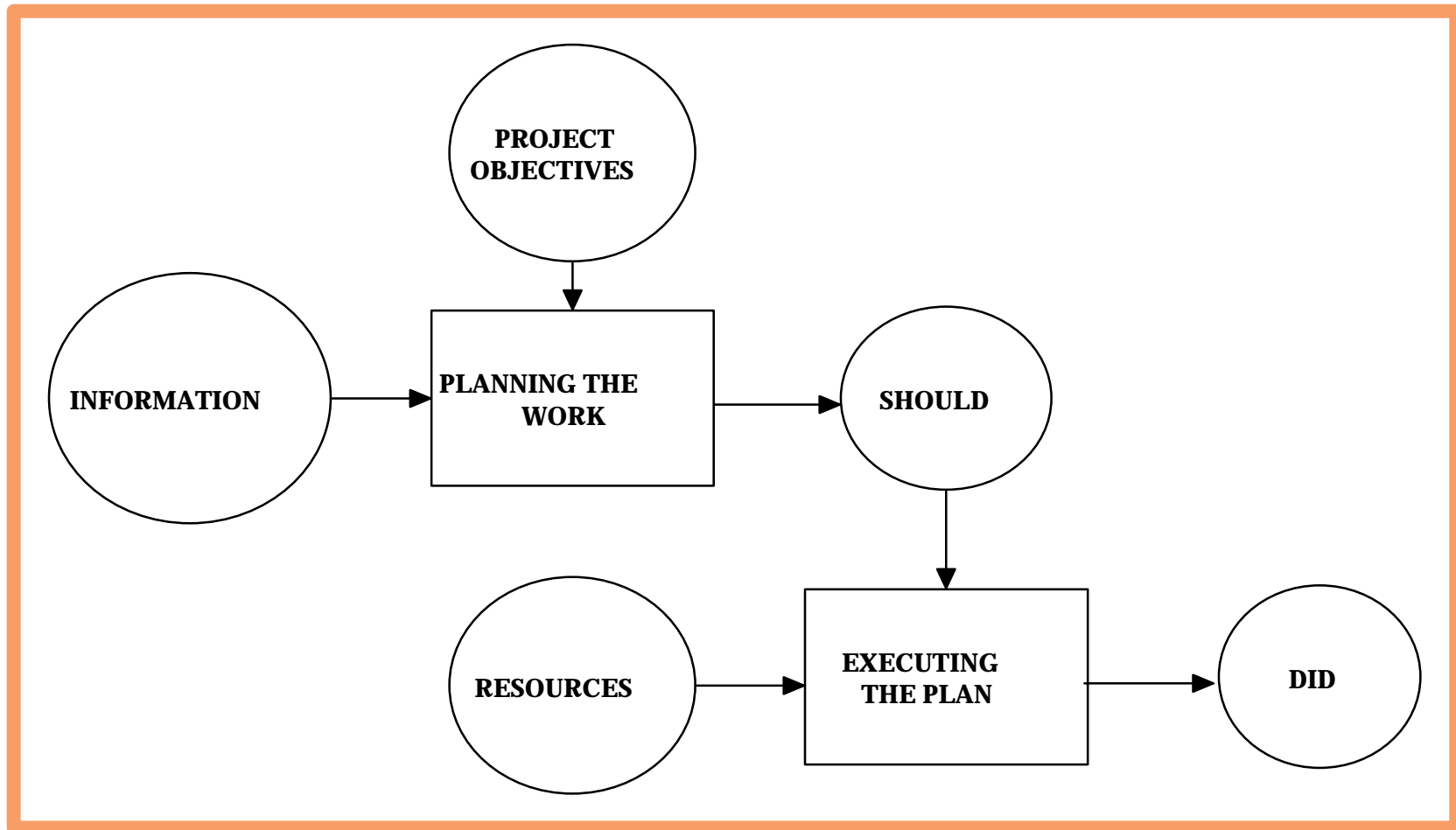


Planning System Measurement

1 WEEK PLAN											
PROJECT: Pilot						FOREMAN: PHILLIP					
ACTIVITY						DATE: 9/20/96					
	Est	Act	Mon	Tu	Wed	Thurs	Fri	Sat	Sun	PPC	REASON FOR VARIANCES
Gas/F.O. hangers O/H "K" (48 hangers)			XXXX	XXXX						No	Owner stopped work (changing elevations)
Gas/F.O. risers to O/H "K" (3 risers)					XXXX	XXXX	XXXX	XXXX		No	Same as above-worked on backlog & boiler shutdown
36" cond water "K" 42" 2-45 deg 1-90 deg			XXXX	XXXX	XXXX					Yes	
Chiller risers (2 chillers wk.)						XXXX	XXXX	XXXX		No	Mail from shop rovd late Thurs. Grooved couplings shipped late.
Hang HW O/H "J" (240'-14")			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
Cooling Tower 10" tie-ins (steel) (2 towers per day)			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
Weld out CHW pump headers "J" mezz. (18)			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
Weld out cooling towers (12 towers)			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX		No	Eye injury. Lost 2 days welding time
F.R.P. tie-in to E.T. (9 towers) 50%			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
WORKABLE BACKLOG											
Boiler shutdown-gas vents -rupture disks											

Weekly Work Planning

A Traditional (Push) Planning System



Traditional Management Increases Variability: Plan Reliability Data

Contractor 1	33 %
Contractor 2	52 %
Contractor 3	61 %
Contractor 4	70 %
Contractor 5	64 %
Contractor 6	57 %
<u>Contractor 7</u>	<u>45 %</u>
Average	54 %

Construction Weekly Work Plan

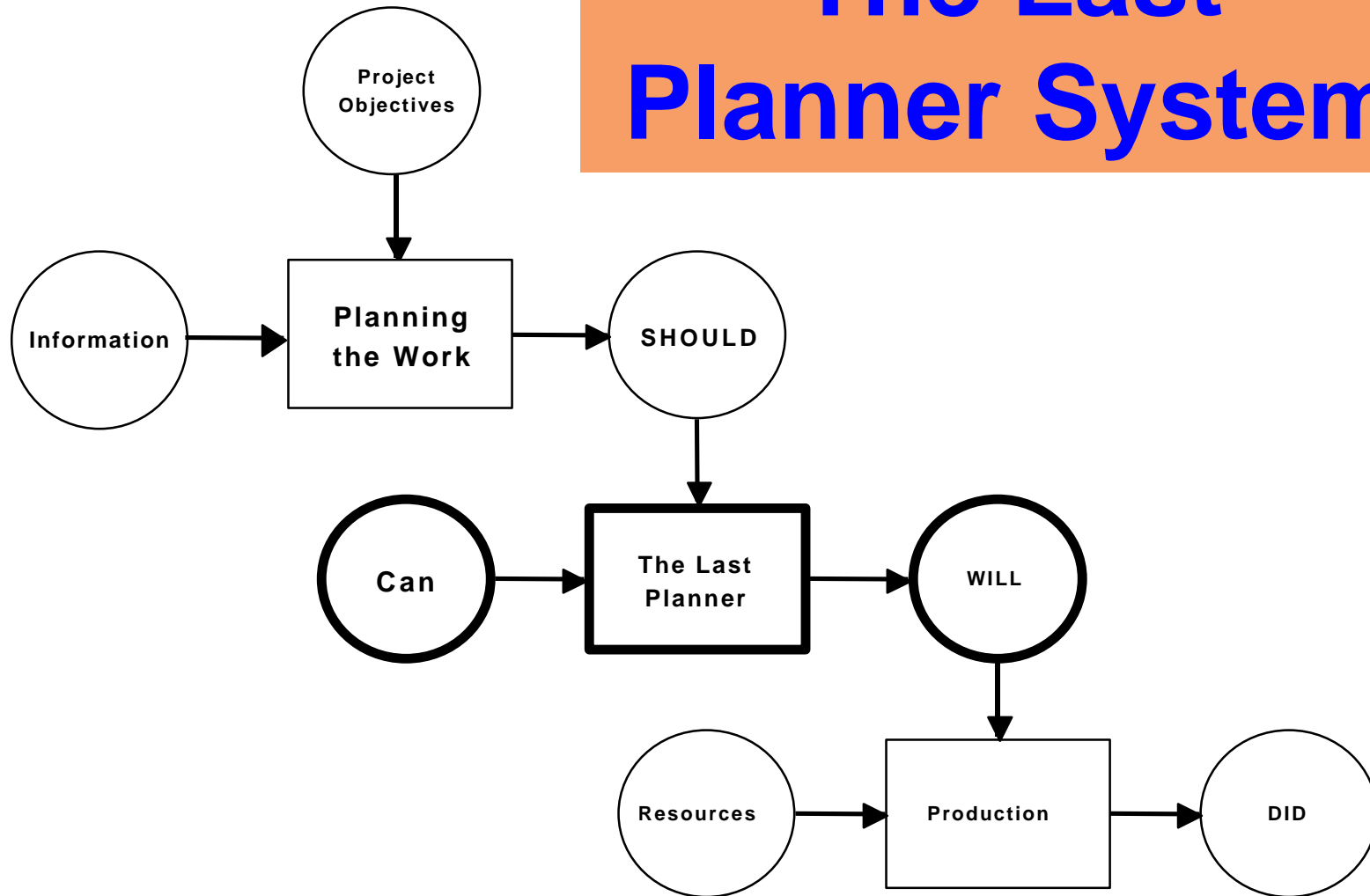
1 WEEK PLAN

PROJECT: Pilot
ACTIVITY

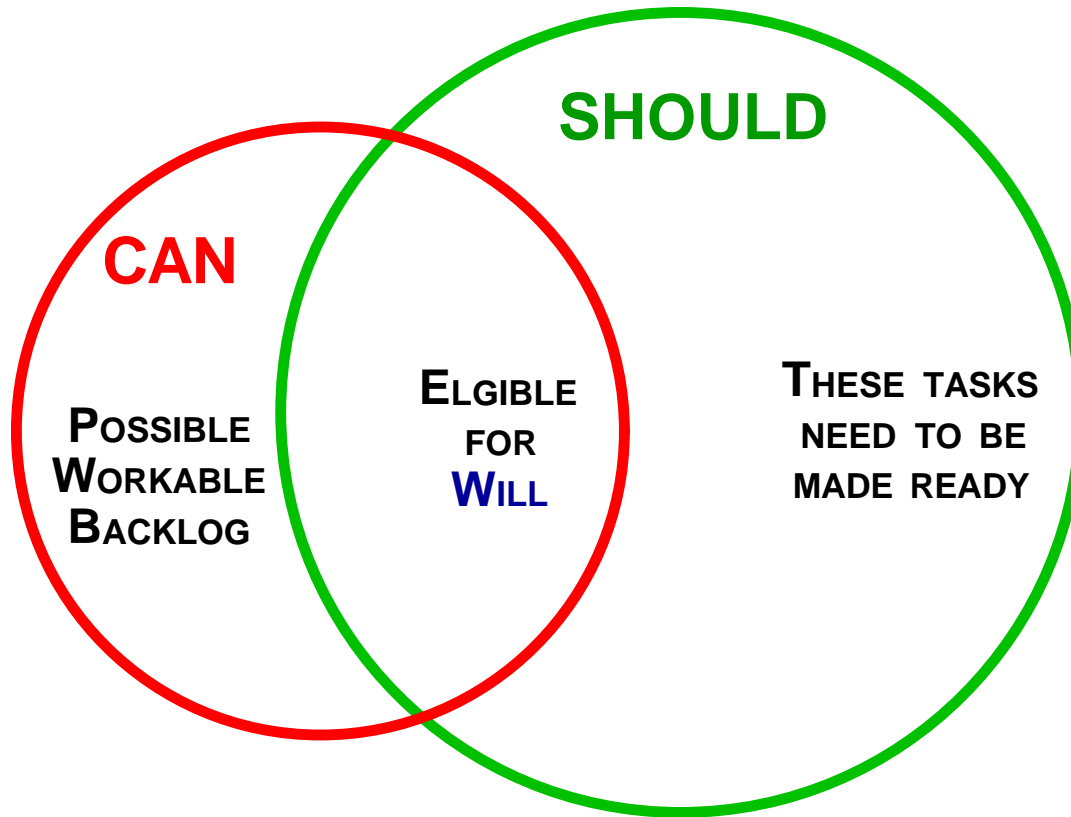
FOREMAN: PHILLIP
DATE: 9/20/96

	Est	Act	Mon	Tu	Wed	Thurs	Fri	Sat	Sun	PPC	REASON FOR VARIANCES
Gas/F.O. hangers O/H "K" (48 hangers)			XXXX Sylvano, Modesto, Terry	XXXX						No	Owner stopped work (changing elevations)
Gas/F.O. risers to O/H "K" (3 risers)					XXXX Sylvano, Mdesto, Terry	XXXX	XXXX	XXXX		No	Same as above-worked on backlog & boiler blowdown
36" cond water "K" 42' 2-45 deg 1-90 deg			XXXX Charlie, Rick, Ben	XXXX	XXXX					Yes	
Chiller risers (2 chillers wk.)						XXXX Charlie, Rick, Ben	XXXX	XXXX		No	Matl from shop rcvd late Thurs. Grooved couplings shipped late.
Hang H/W O/H "J" (240'-14")			XXXX Mark M., Mike	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
Cooling Tower 10" tie-ins (steel) (2 towers per day)			XXXX Steve, Chris, Mark W.	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
Weld out CHW pump headers "J" mezz. (18)			XXXX Luke	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
Weld out cooling towers (12 towers)			XXXX Jeff	XXXX	XXXX	XXXX	XXXX	XXXX		No	Eye injury. Lost 2 days welding time
F.R.P. tie-in to E.T. (9 towers) 50%			XXXX Firt, Packy, Tom	XXXX	XXXX	XXXX	XXXX	XXXX		Yes	
WORKABLE BACKLOG Boiler blowdown-gas vents -rupture disks											

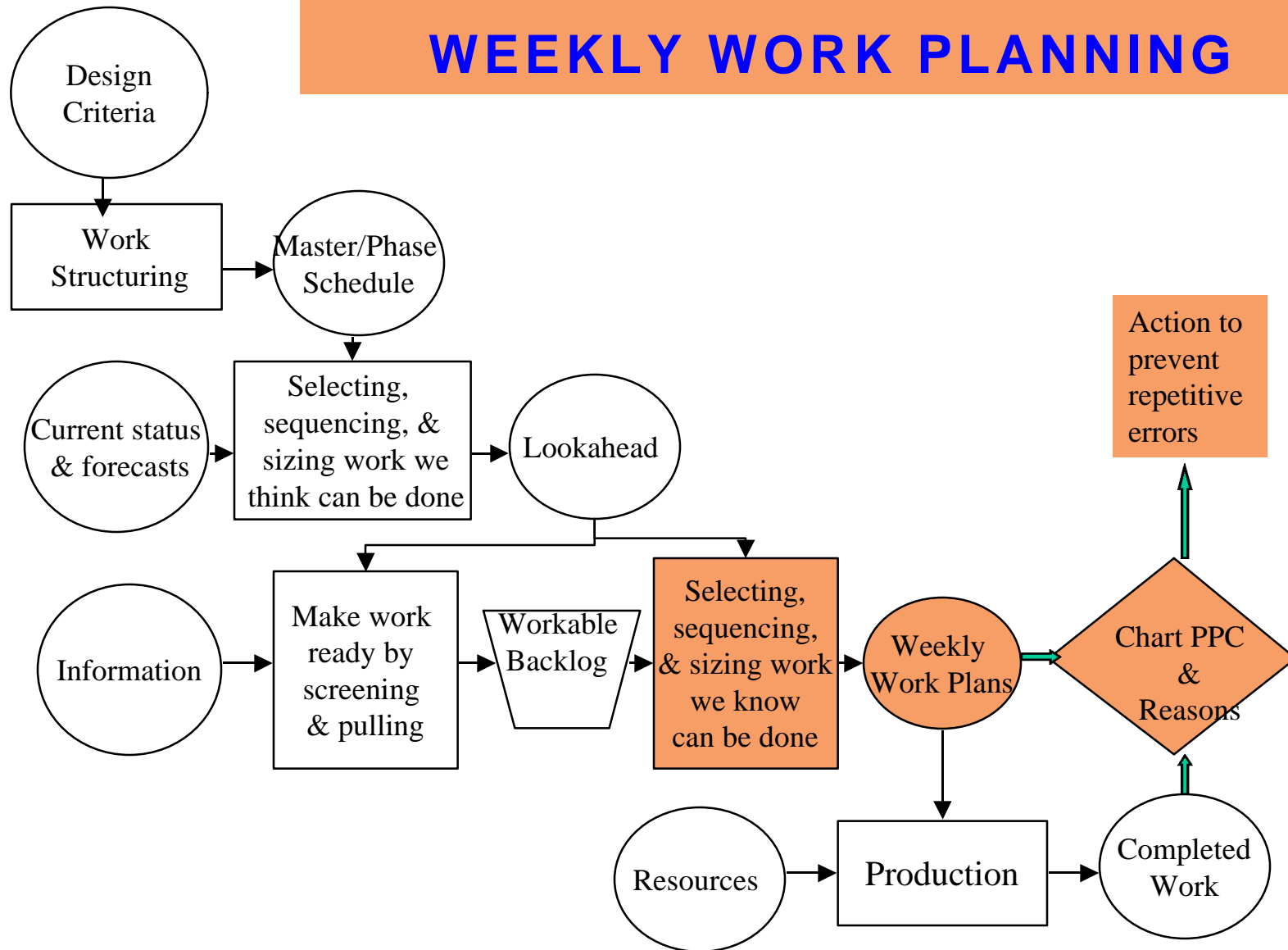
The Last Planner System



Forming the Weekly Work Plan



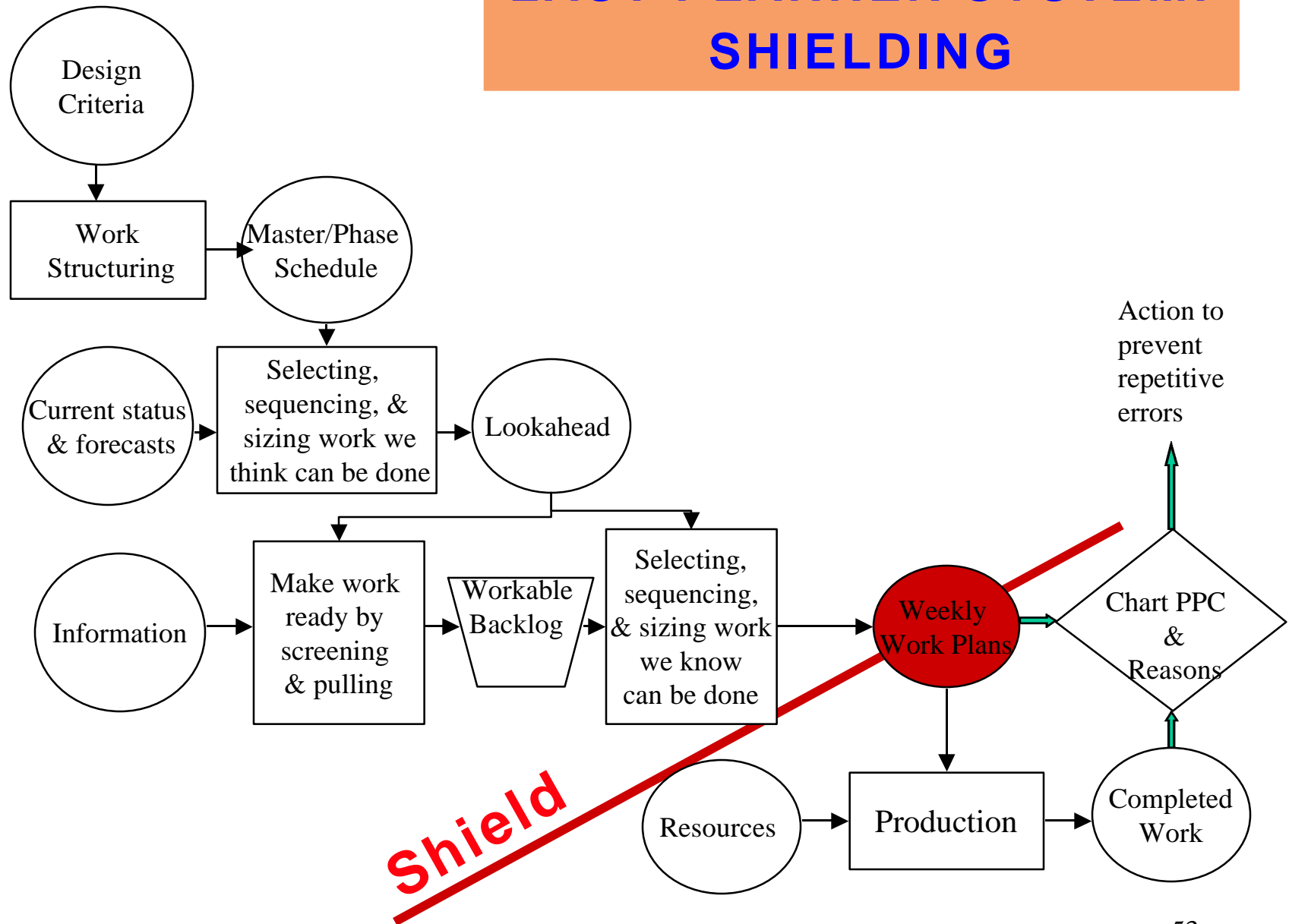
LAST PLANNER SYSTEM: WEEKLY WORK PLANNING




Quality Characteristics of Weekly Work Plans

- Definition
- Soundness
- Sequence
- Size
- Learning


LAST PLANNER SYSTEM: SHIELDING



Weekly Planning

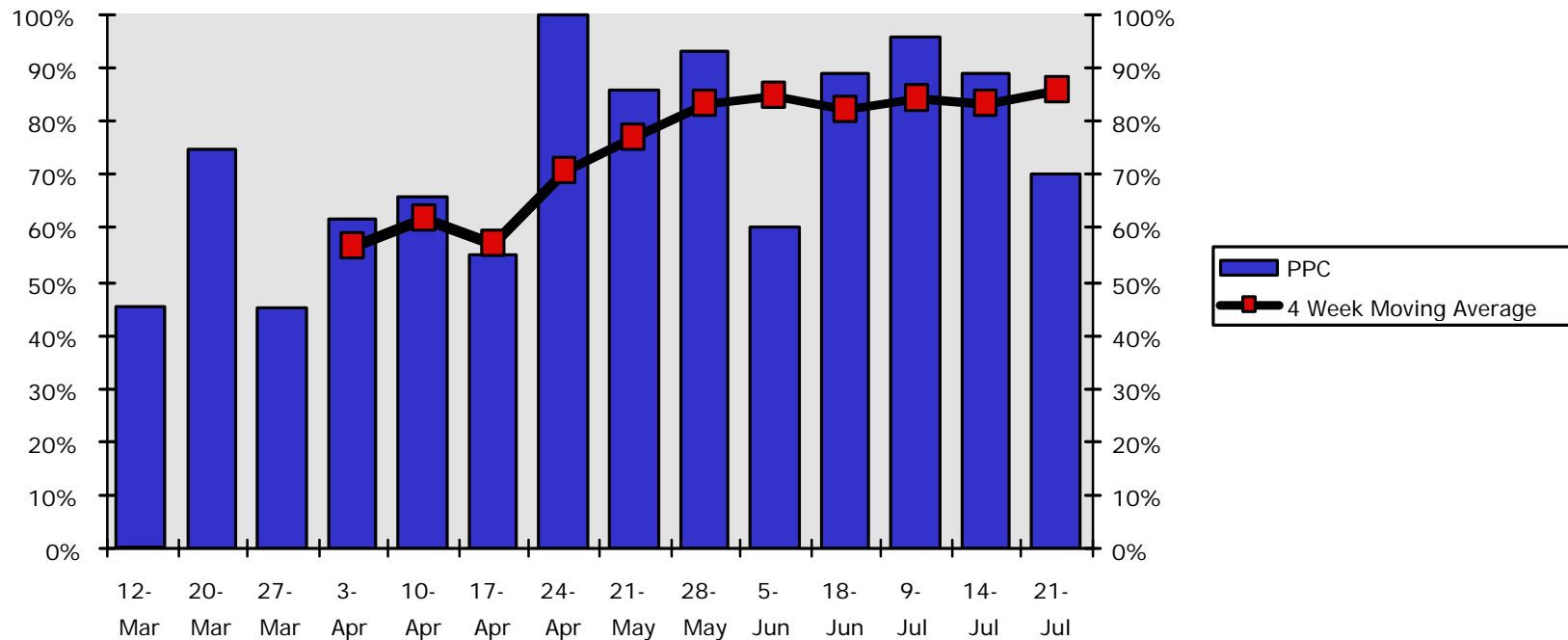
 OSCAR J. BOLDT CONSTRUCTION COMPANY USA Project: Same Day Surgery Planner: Dena Deibert				Week of 10/23/00													
Weekly Work Plan																	
Assignment Description				Make Ready Needs										Done?		Comments	
Division	Meet	Repeat	Remember the Five Criteria for Release of Assignments Defined - Sound - Proper Sequence - Right Size Able to Learn	Responsible Party	Work that Must and Can Be Performed Prior to Release of this Assignment	M	T	W	T	F	S	Y	N				
1		<input checked="" type="checkbox"/>	Issue vibration study	Brad/STS		x	x	x	x								
1			Award Bid Pack 3	Dena/Brad		x	x	x	x	x							
1			Reissue construction documents	Jose	Coordinate with Ring & DuChateau	x	x	x	x								
2			Test Glycol Mains	Jarosz		x	x	x	x	x							
3			Pour Roof	Randy					x								
4			Confirm brick is ready	Roger Spahr		x											
4			Stone production	Rossi		x	x	x	x	x				Week 1 of 8			
5			Complete roof framing	Bob Brue		x	x	x									
5			Begin roof detailing	Bob Brue					x	x							
5		<input checked="" type="checkbox"/>	Re-submit curtainwall support shops	Dick		x	x	x	x								
5			Issue penthouse curb ASK's	Jose		x	x	x	x								
6			Submit Phase 2 millwork shops	Precision		x											
6			Deliver mock-up millwork	Precision						x							
7			Submit additional roofing shops	Scott Harms		x	x										
8		<input checked="" type="checkbox"/>	Resubmit curtainwall shops	Jim L				x									
8		<input checked="" type="checkbox"/>	Submit curtainwall Struct. Calcs	Jim L				x									
8			Order Glass	Jim L	ARC verbally confirm dimensions	x											
10			Fab. Louvers	Air Flow		x	x	x	x	x				Week 1 of 6			

Measuring PPC

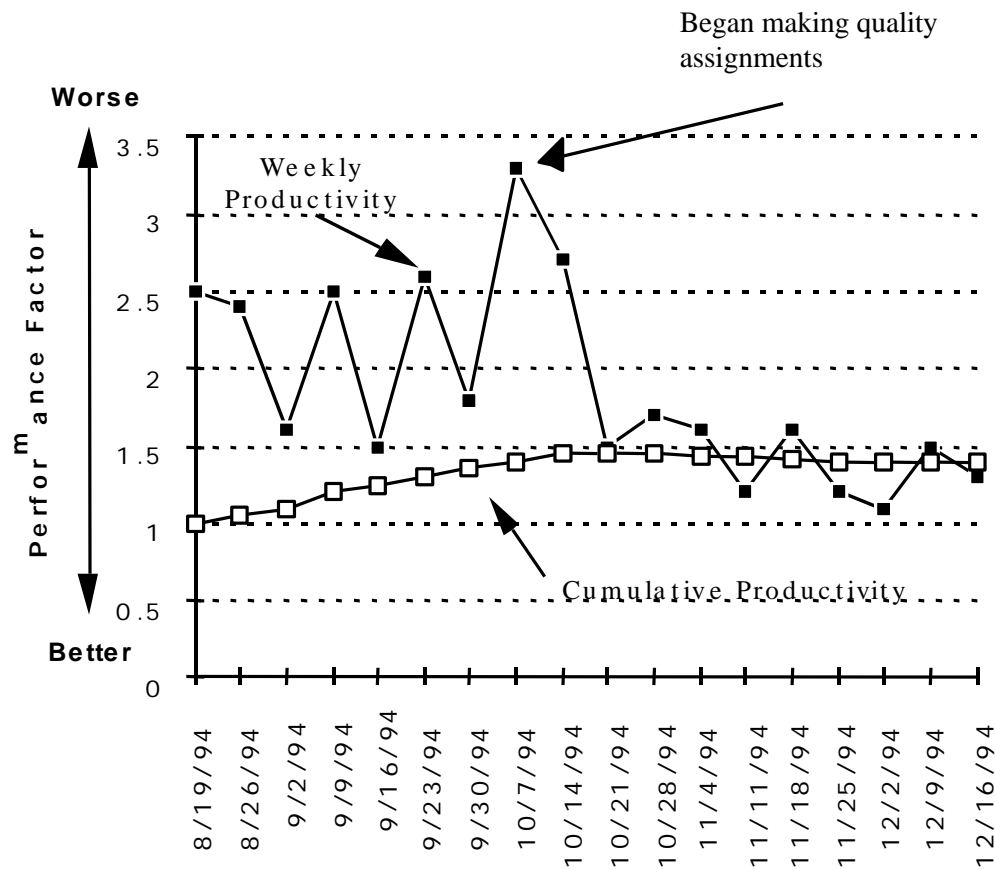
 OSCAR J. BOLDT CONSTRUCTION COMPANY USA Project: Same Day Sugery Planner: Dena Deibert												Week of 10/16/00	
Assignment Description												PPC = 69%	
Repeat	Remember the Five Criteria for Release of Assignments Defined - Sound - Proper Sequence - Right Size - Able to Learn	Responsible Party								Done?		PPC Analysis	
			M	T	W	T	F	S	Y	N	Reasons For Variance / Comments		
	Review mock-up drywall dimensions	Randy	x	x	x	x	x				Y		Wardrobe dimensions changed
	Review microscope vibration Study	David	x	x	x	x	x					N	
	Review bids - Bid Pack 3	Dena/ Brad	x	x	x	x	x				Y		Will award next week.
	Review roofing shops	Jose'	x	x	x	x	x				Y		Week 1 of 2
	Complete concrete haunches	Randy	x	x	x						Y		
	Releae order on limestone	Dena	x								Y		
	Re-submit curtainwall support shops	Dick	x	x	x	x	x					N	Waiting for curtainwall shop drwg.
	Roof framing: 75% complete	Bob Brue	x	x	x	x	x				Y		
	Submit Phase 2 Millwork Shops	Precision	x	x	x	x						N	
	Fabricate mock-up millwork	Precision	x	x	x	x	x				Y		Week 2 of 3
	Re-submit curtainwall shops & structural calcs	Jim Leicht	x	x	x							N	Middle of next week
	Finalize review of louver shops	Tony/ David	x	x	x	x					Y		
	Review GL-1 and GL-2	ARC/Jim Leight	x	x	x						Y		

Percent Plan Complete (PPC) Chart

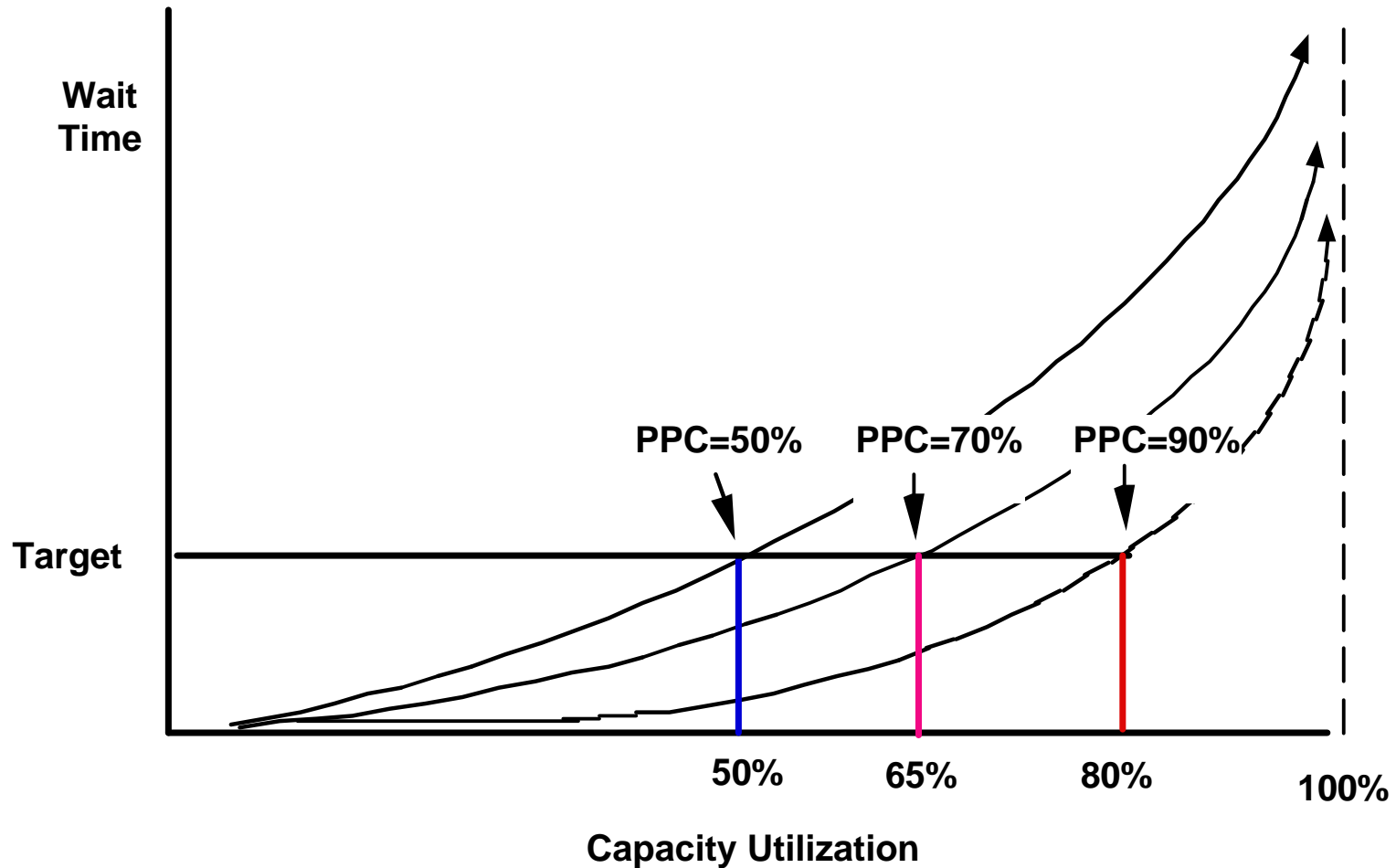
Rasacaven: Electrical Power Distribution



The Impact of Last Planner



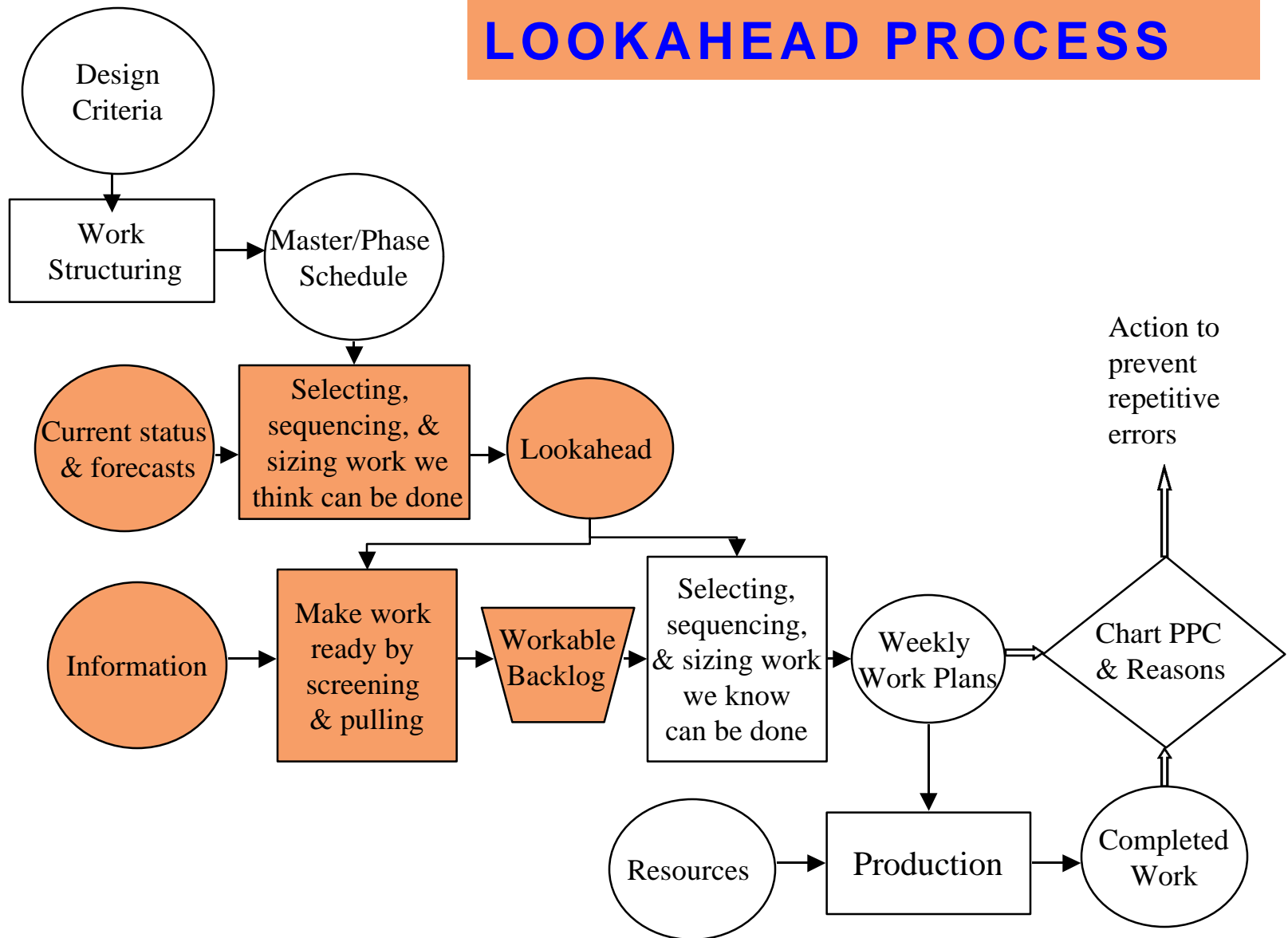
PPC and Capacity Utilization



Uncertainty and Variability Can Be Managed

- **Reduce variability then go for speed.**
- **The place to start is by shielding production from flow variability by making only 'quality' assignments.**
- **Managing the remaining variability involves thoughtful location and sizing of inventory and capacity buffers.**

LAST PLANNER SYSTEM: LOOKAHEAD PROCESS



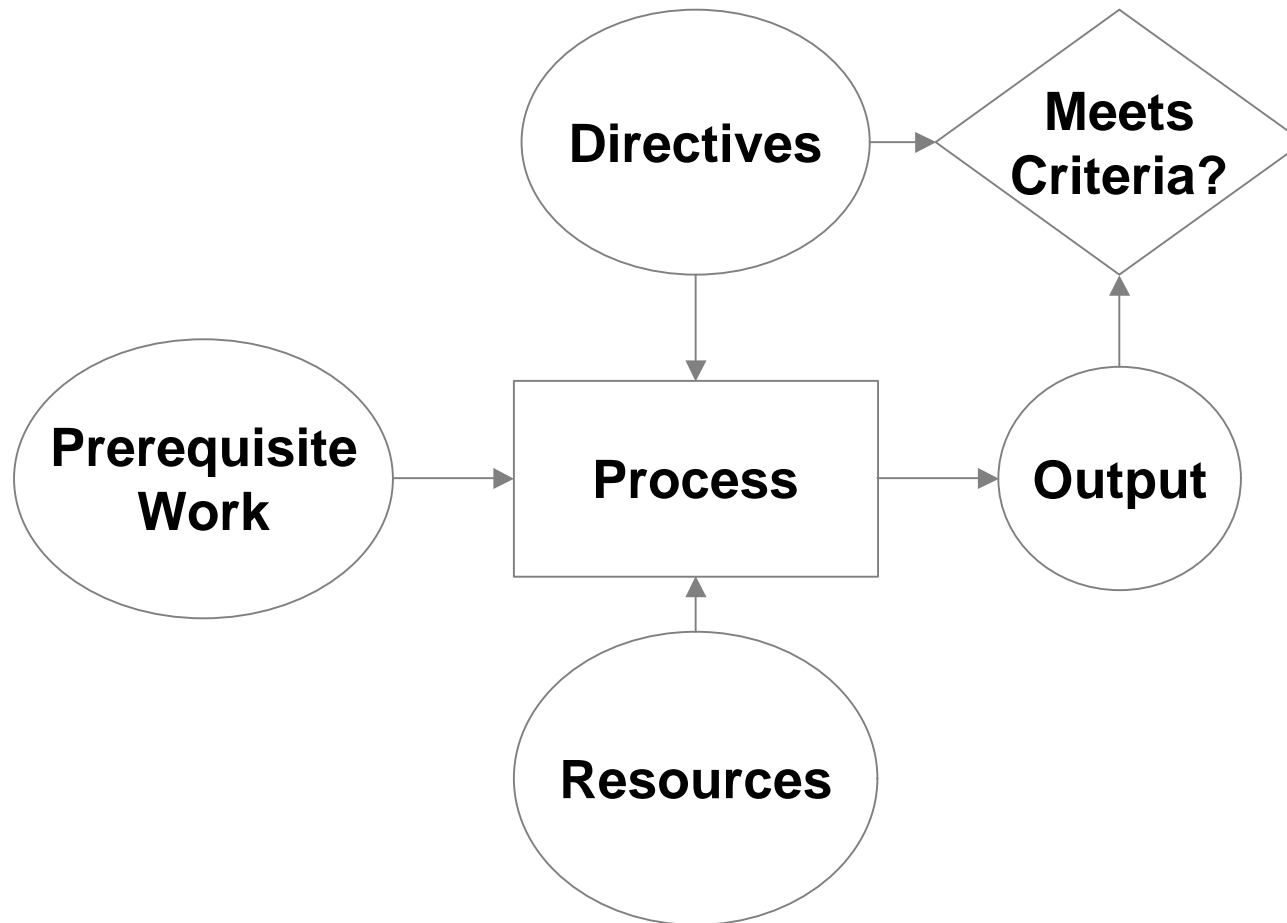
Purposes of the Lookahead Process

- Shape work flow sequence and rate
- Match work flow and capacity
- Maintain a backlog of ready work
- Develop detailed plans for how work is to be done
 - Safety, environmental, quality issues

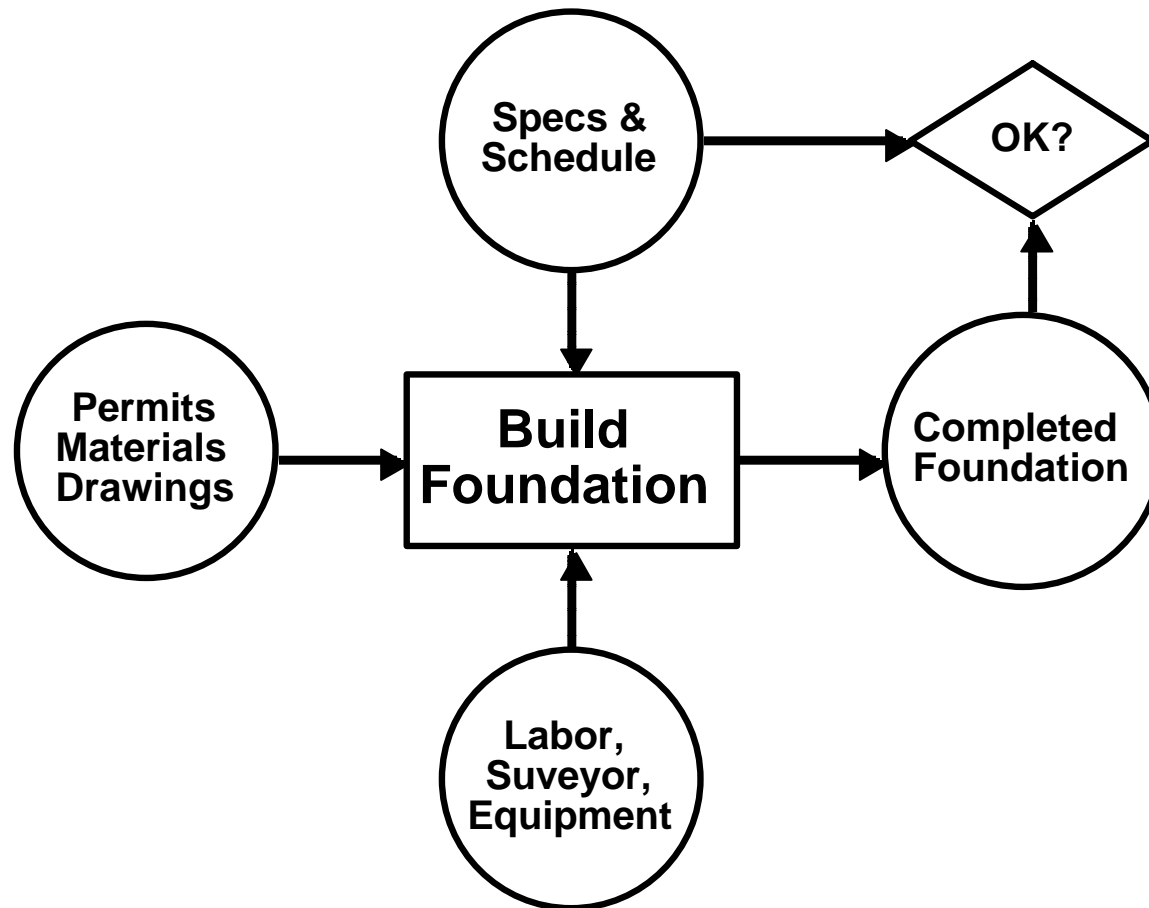
Lookahead Process

- **Explode** scheduled activities into assignment-level detail, using the Activity Definition Model and First Run Studies.
- **Screen** the constraints on each assigned task within the lookahead window.
- **Make** assigned tasks **ready** by removing constraints.
- **Balance** load and capacity by advancing/retarding scheduled work, increasing/decreasing capacity, or deciding how to invest excess capacity.
- **Adjust** phase or master schedules as needed.
- **Learn**: measure and improve performance.

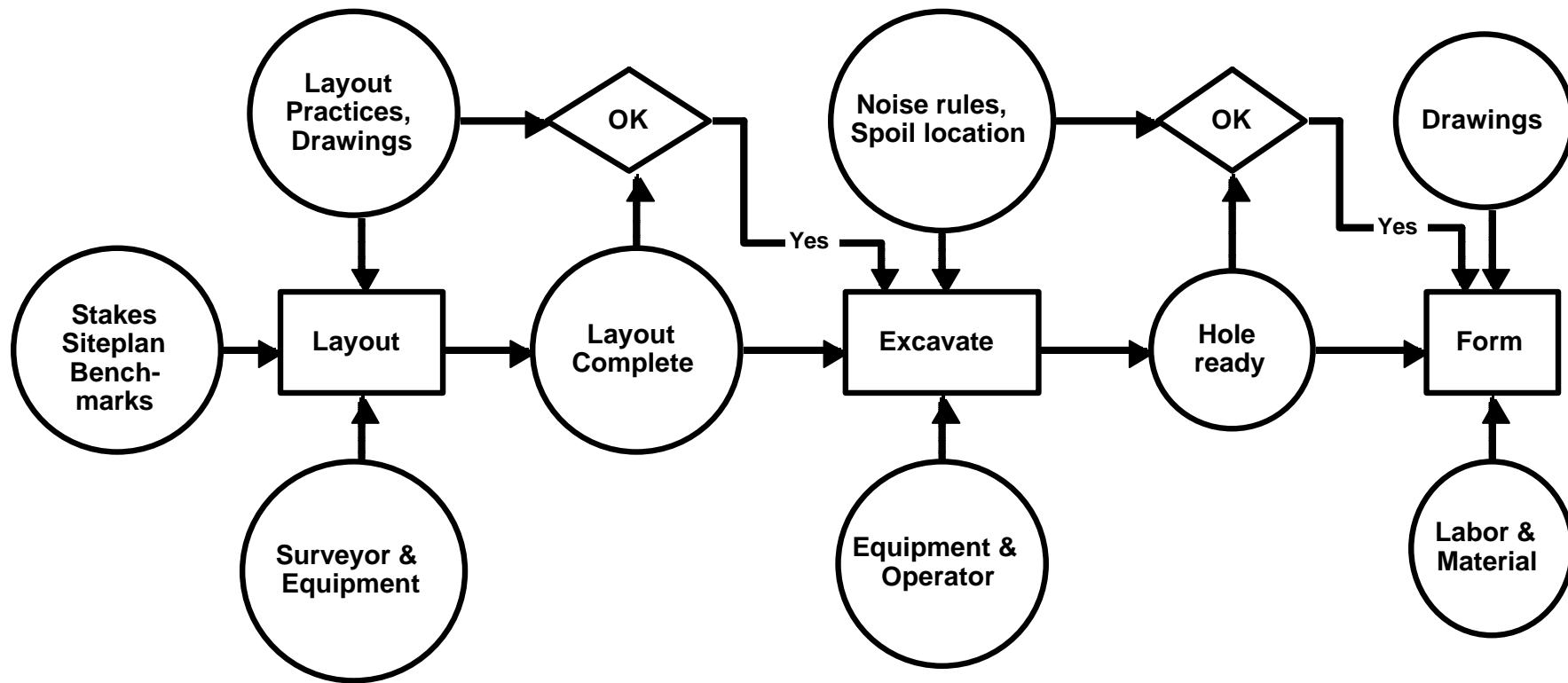
Mapping Language: Activity Definition Model



Using the Activity Definition Model



Task Explosion



Screening and Constraints

- Activities are made ready to be assigned by removing constraints.
- Screening is the process of analyzing the activities for constraints and evaluating if they can be removed in time for the planned start.

Constraints Analysis: Design

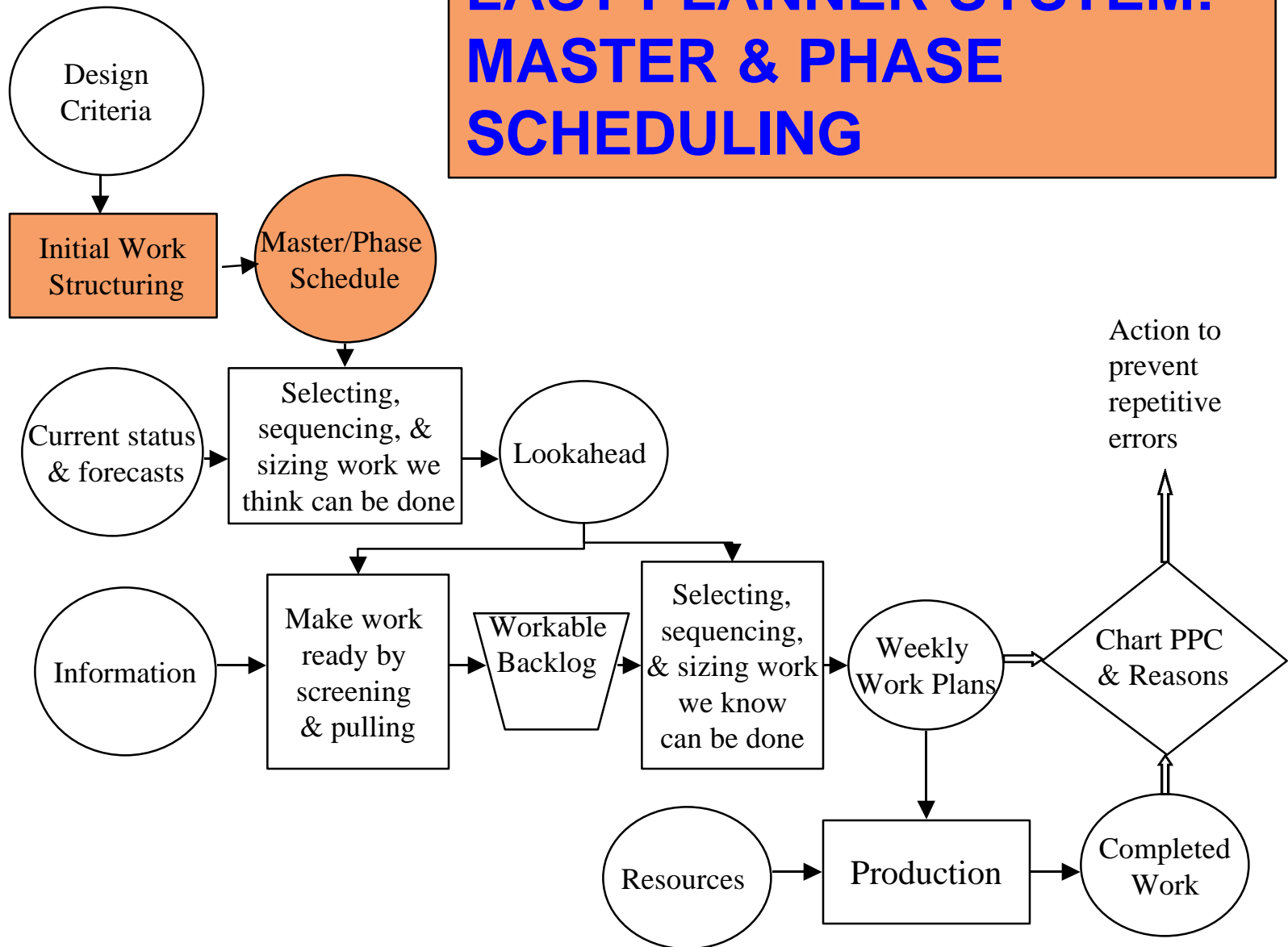
Project: Mega Bldg

Report Date: 3 Nov

C o n s t r a i n t s

Activity	Responsible Party	Scheduled Duration	Directives	Pre-requisites	Resources	Comments	Ready?
Design slab	Structural Engineer	15 Nov to 27 Nov	Code 98 Finish? Levelness?	Soils report	10 hours labor, 1 hr plotter		No
<i>Get info. from client re floor finish & level</i>	<i>Structural Engineer's gofer</i>	<i>3 Nov to 9 Nov</i>	OK	OK	OK		Yes
<i>Get soils report from Civil</i>	<i>Structural Engineer</i>	<i>By 9 Nov</i>	OK	OK	OK		Yes
Layout for tool install	Mechanical Engineer	15 Nov to 27 Nov	OK	Tool configurations from mfger	OK	May need to coord. w/ HVAC	No

LAST PLANNER SYSTEM: MASTER & PHASE SCHEDULING



Products of Work Structuring

- Global sequencing
- Project Organizational/Contractual Structure
- Supply Chain Configurations (how the project hooks to external production systems)
- Master Schedule & Phase Schedules
- Rough Cut Operations Designs; e.g., decision to cast-in-place vs precast, or use a tower crane vs rolling stock
- Detailed Operations Designs; e.g., how to form-rebar-pour basement walls

Purposes of Master Schedules

- Demonstrate the feasibility of completing the work within the available time.
- Develop and display execution strategies.
- Determine when long lead items will be needed.
- Identify milestones important to client or stakeholders.

Phase Scheduling: Purposes and Actions

- Produce the best possible plan by involving all with relevant expertise and by planning near action.
- Assure that everyone in a phase understands and supports the plan by developing the schedule as a team.
- Assure the selection of value adding tasks that release other work by working backwards from the target completion date to produce a pull schedule.
- Publicly determine the amount of time available for 'contingency' and decide as a group how to spend it.

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

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Photo - JPEG decompressor
are needed to see this picture.

Entry Rules

- Rule 1: Allow activities to remain in the Master/Phase schedule unless positive knowledge exists that it should not or cannot be executed when scheduled.
- Rule 2: Allow activities to remain in the lookahead window only if the planner is confident that it can be made ready for execution when scheduled. (Screening)
- Rule 3: Allow activities into weekly work plans only if all constraints have been removed. (Shielding)

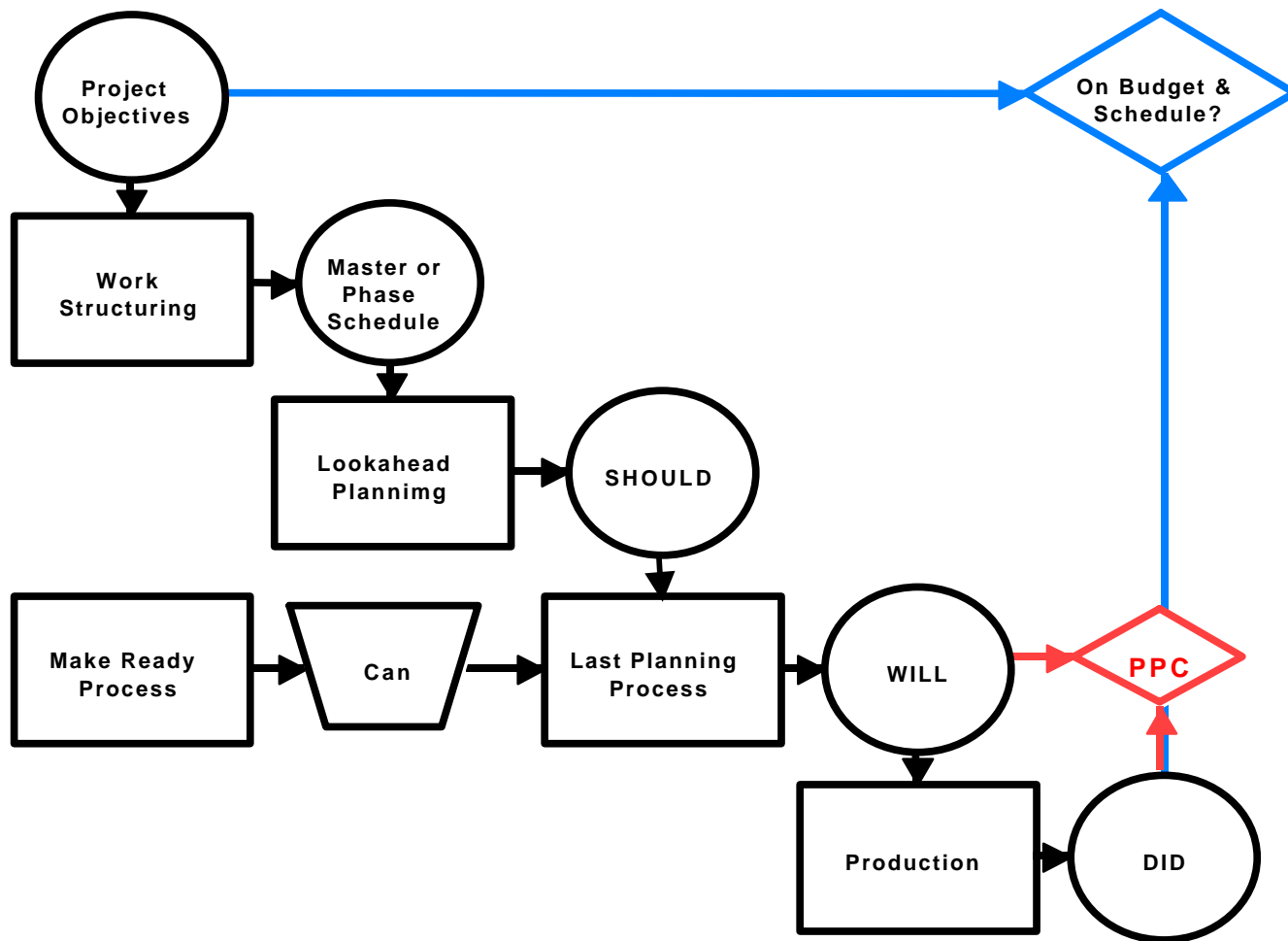
Summary Recommendations for Production Control

- **Limit master schedules to milestones and long lead items.**
- **Produce phase schedules with the team that will do the work, using a backward pass, and making float explicit.**
- **Drop activities from the phase schedule into a 6 week lookahead, screen for constraints, and advance only if constraints can be removed in time.**
- **Try to make only quality assignments. Allow assignments to be rejected.**
- **Track PPC and act on reasons for plan failure.**

Project and Production Controls

Project control in the *Last Planner System* is principally the practice of securing reliable promises and declarations of completion of those activities that releases work to others. This allows the project work to stay in the desired sequence. Hal Macomber, Good2Great

Project and Production Controls



Current Practice vs Lean

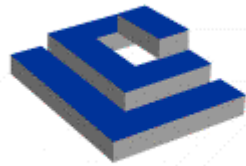
	Current	Lean
Planning	Knowing	Learning
Uncertainty	External	Internal
Control	Tracking & React	Steering & ?
Coordination	Following Orders	Making and Keeping Commitments
The Goal of Supervision	Point Speed	Reduce Variation Increase System Throughput
Commercial Contracts	Trades Production System Efficiency for Apparent Security	Aligns Production System Objectives with Interests

What is happening now.

- **Lean Project-based production systems are coming into construction.**
- **Specialty contractors make the most money soonest. Construction Users get better projects sooner.**
- **Leading edge of significant change in the industry flying under the radar of current thinking.**
- **Need to develop and extend theory & technique.**

A Path forward for Construction Education

- Develop an Explicit Theory Base
- Teach it
- Do research to continuously refine and extend it.



Lean Construction Institute
Building knowledge in design & construction

Seminars & Meetings

- March 14/15 Production Control Research Meeting - Chicago***
- March 27/28 LCI Academic Forum - Michigan State***
- April 18/19 Introduction to Lean Construction - Washington DC***
- May 16/17 Design Management Research Meeting - Denver***
- July 31-Aug Introduction to Lean Construction - Berkeley***
- Aug 2 4th Annual Lean Congress - Berkeley***
- Aug 5/9 10th Annual IGLC Meeting - Brazil***

**** Member/CLIENT Only Meetings***

Questions?