اجرا و مدیریت پروژه به روش اصول ناب
(Lean Project Management)

فصل دوم: بکارگیری مفاهیم و اصول روش ناب در مدیریت پروژه (Lean Project Management)

بخش دوم: استفاده از اصول روش ناب در مرحله طراحی (Design) پروژه

ارائه دهندگان:

سید محمدرضا علوی‌پور

(PhD, PMP, CMIT)

کامبیز کردانی

(M.Sc., PMP)

ACEMI

What we will learn?

- Lean in design and construction
  - Concepts
  - Contract
  - Lean project delivery system (LPDS)
    - ✓ Life cycle
    - ✓ Definition phase
    - ✓ Design phase
      - o Some of tools and techniques

Lean in Design and Construction

(Concepts)

Lean design and construction

- **Lean design and construction** involve the **application of lean methods/techniques** to **design and construction processes**, in order to **derive the benefits** that have been clearly established in manufacturing operations.
  - Benefits include:
    - ✓ Lower costs,
    - ✓ Fewer delays,
    - ✓ Less uncertainty,
    - ✓ Less waste,
    - ✓ More efficient buildings/facilities, and
    - ✓ Higher user satisfaction.

Lean design and lean construction

- **Lean construction** much **like current practice** has the goal of *better **meeting customer needs** while **using less of everything**.*

But **unlike** current practice,

lean construction rests on **"physics"** of construction

That results in a **new project delivery system** that can be applied to **any kind of construction**

But particularly studied for complex, uncertainty, and quick projects

Goals?

Goals of Lean design and lean construction

- Achieve reliable **workflow**
- Minimize **waste**
- Optimize the **whole**, not the parts
- Develop a **discipline** of **learning** and **continuous** improvement
- Maximize **value** to the customer
  - Value includes:
    - ✓ Safer job sites (zero injuries)
    - ✓ Quality assurance (zero defects)
    - ✓ Sustainable (net zero efficiency)
    - ✓ Unique solution (pre-fabrication)

How?

Goals of Lean design and lean construction

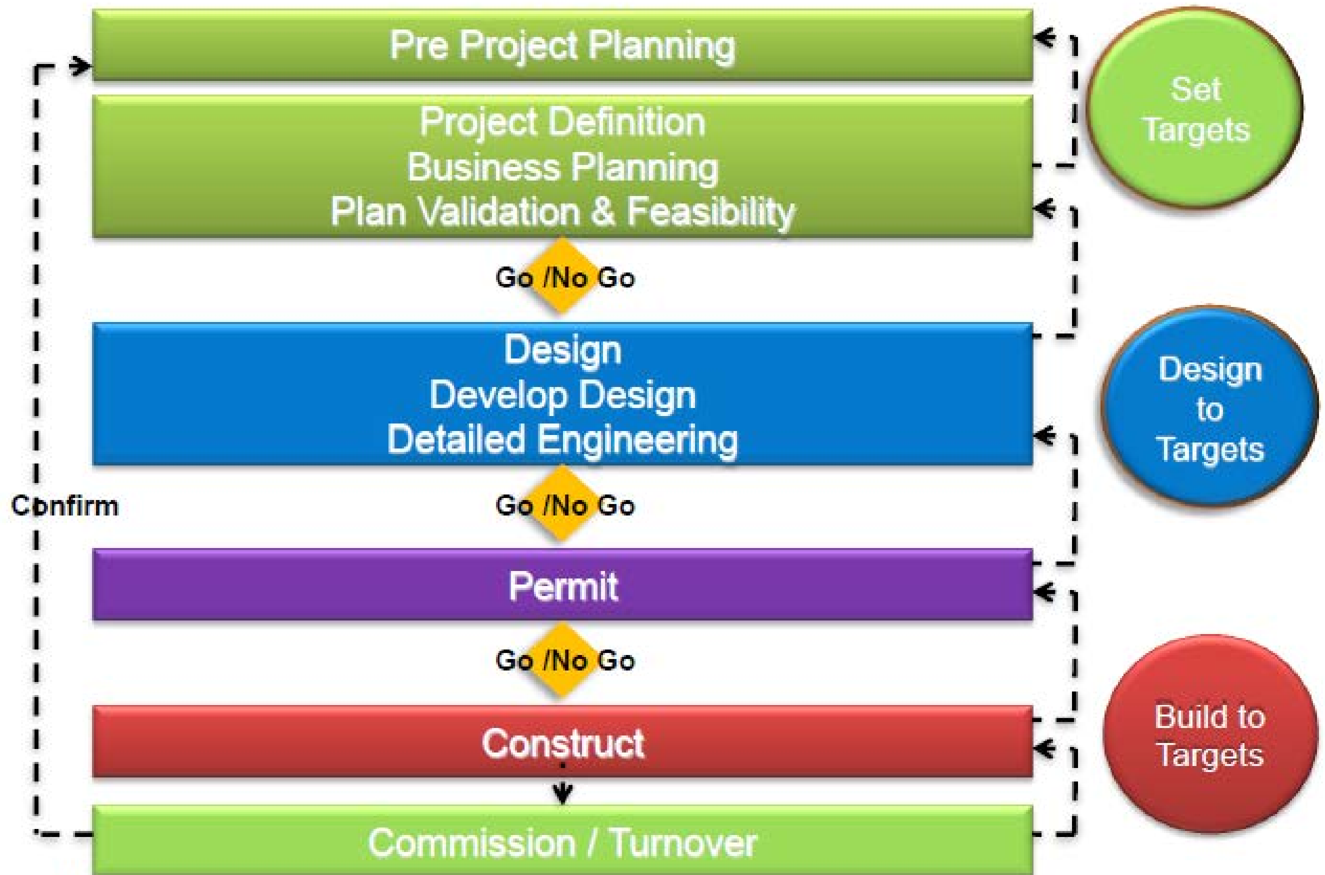
- **How?**
  - Start to develop an **awareness** about the **wastes**
    - We talked about this
  - As we get **better** at **identifying waste**
    - Practice **continuous improvement and learning**
    - Pursue **perfection**

Results?

Goals of Lean design and lean construction

- **Results:**
  - Reduce **time** to design and construct
  - Reduce **cost** to deliver projects
  - Improve **profitability**

Lean project work flow



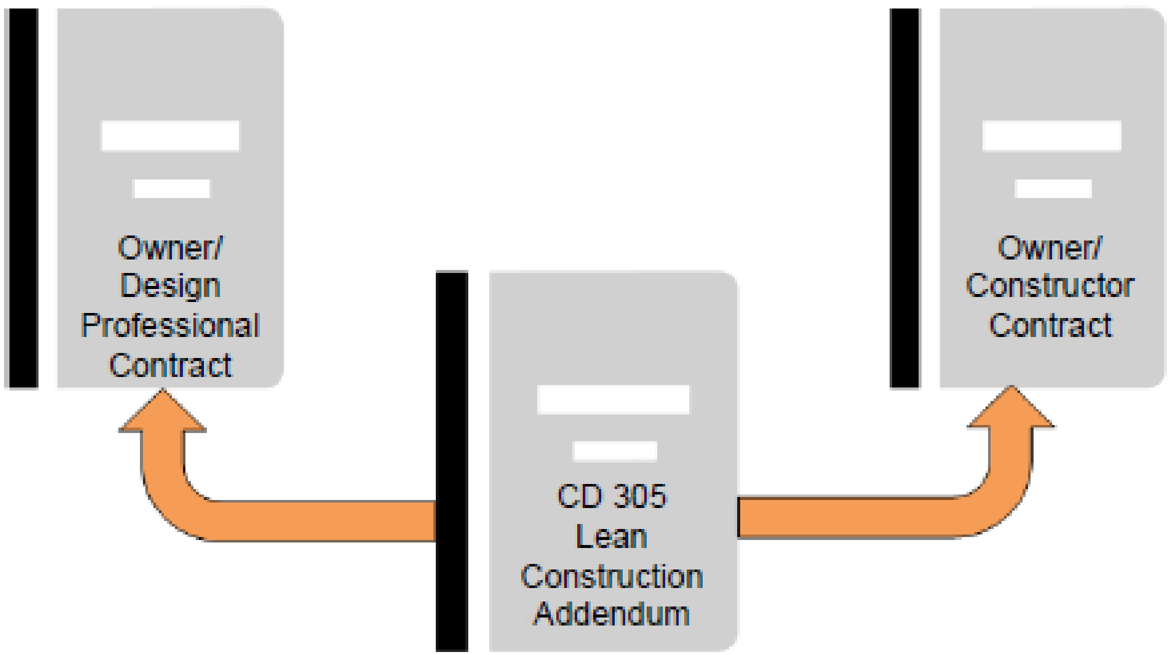
"Target Costing" Lean Construction Institute

Lean in Design and Construction

(Contract)

Ways to contract for lean design and construction

What is the ConsensusDocs 305?



Ways to contract for lean design and construction

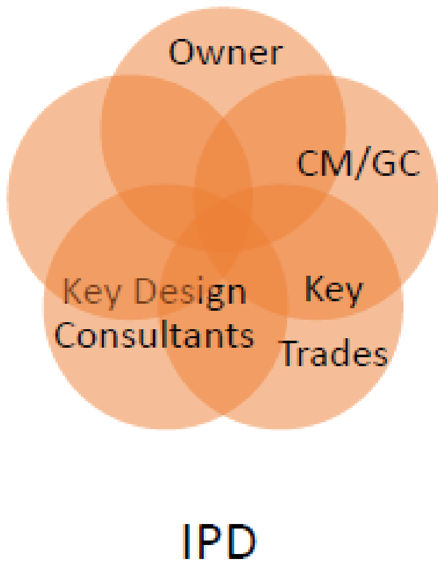
- **Integrated Project Delivery (IPD) agreement** (a/k/a IFOA)
  - e.g., CD 300 (2016 edition)
- **Custom-created** IPD-ish design & construction agreements
- **Vague references** to lean added to an owner's standard contract
- Now with CD305, an **industry standard form <u>outside</u> of IPD** that addresses a wide spectrum of lean practices

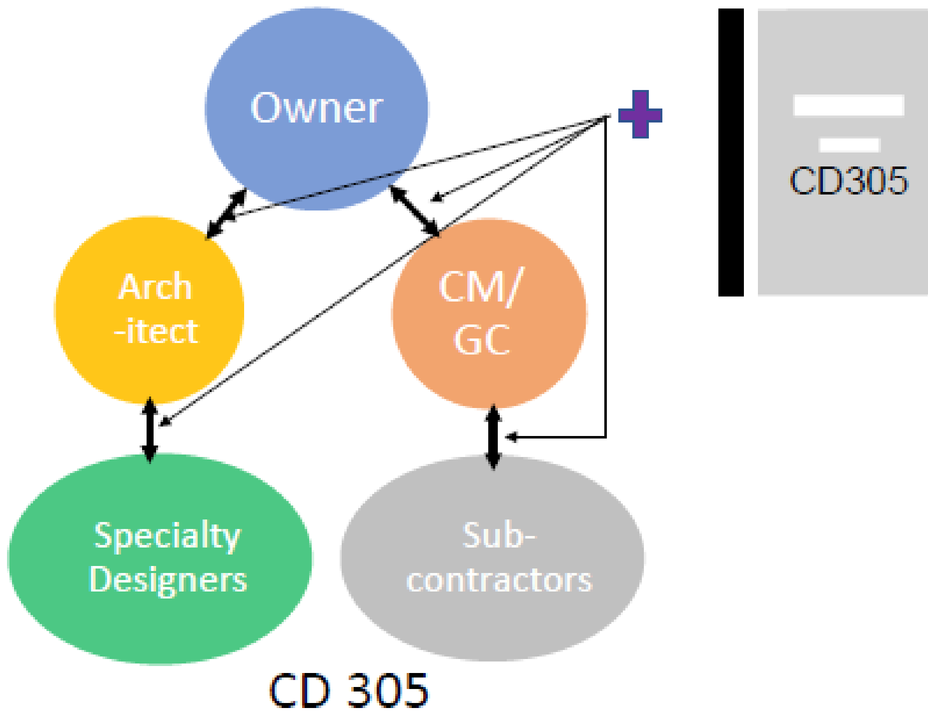
Addendum to what?

- **ConsensusDocs 305** can be used with:
  - consensusDocs 500 Agreement between **Owner & CM**
  - Other forms of **CM at Risk** contracts
  - Construction contracts under **Design-Bid-Build**
  - **Owner contracts** with **Design Professional**

Not intended for **Design-Build Prime Contracts**, but stay tuned

How is this different than IPD?





It is an addendum, not a full contract!

Addendum vs. silence

- Increase **alignment** among parties
- First **collaborative** act
- Parameters of **lean behavior and activities**
- Some lean methods will **conflict** with **standard contract language**, so **addendum overrides**
- Allows **enforcement** of lean requirements, but **take care**

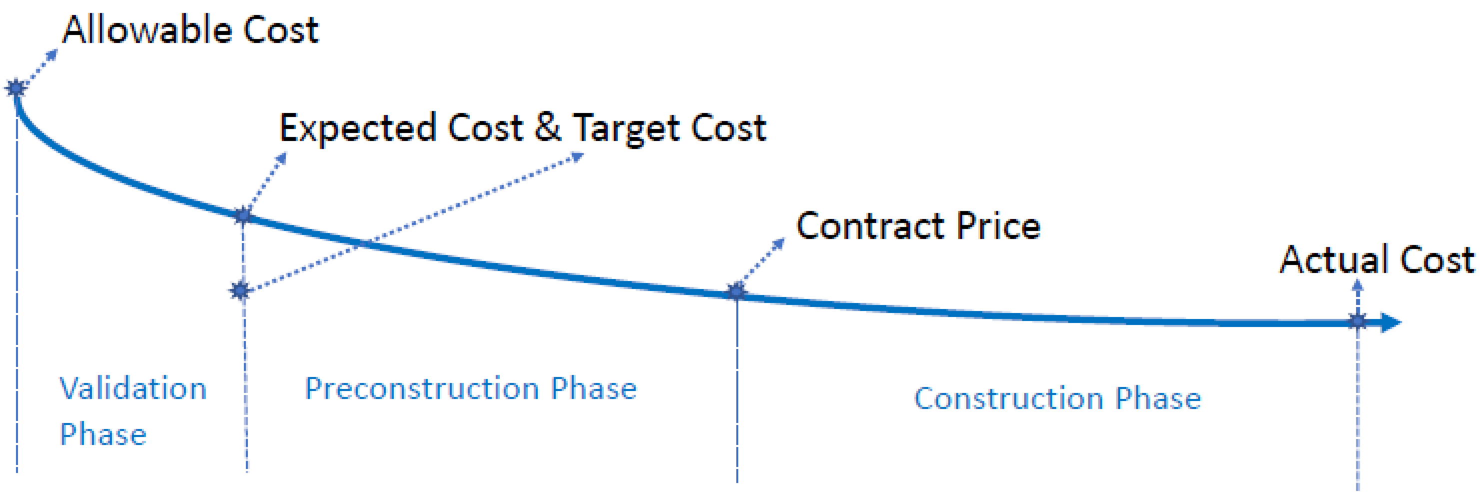
ACEMI

Using the CD 305

- **When?**
  - O/A/C are committed to lean, but one or more are not ready or able to enter an IPD agreement

- **How?**
  - Jointly negotiated, separately attached
  - Check-the-box

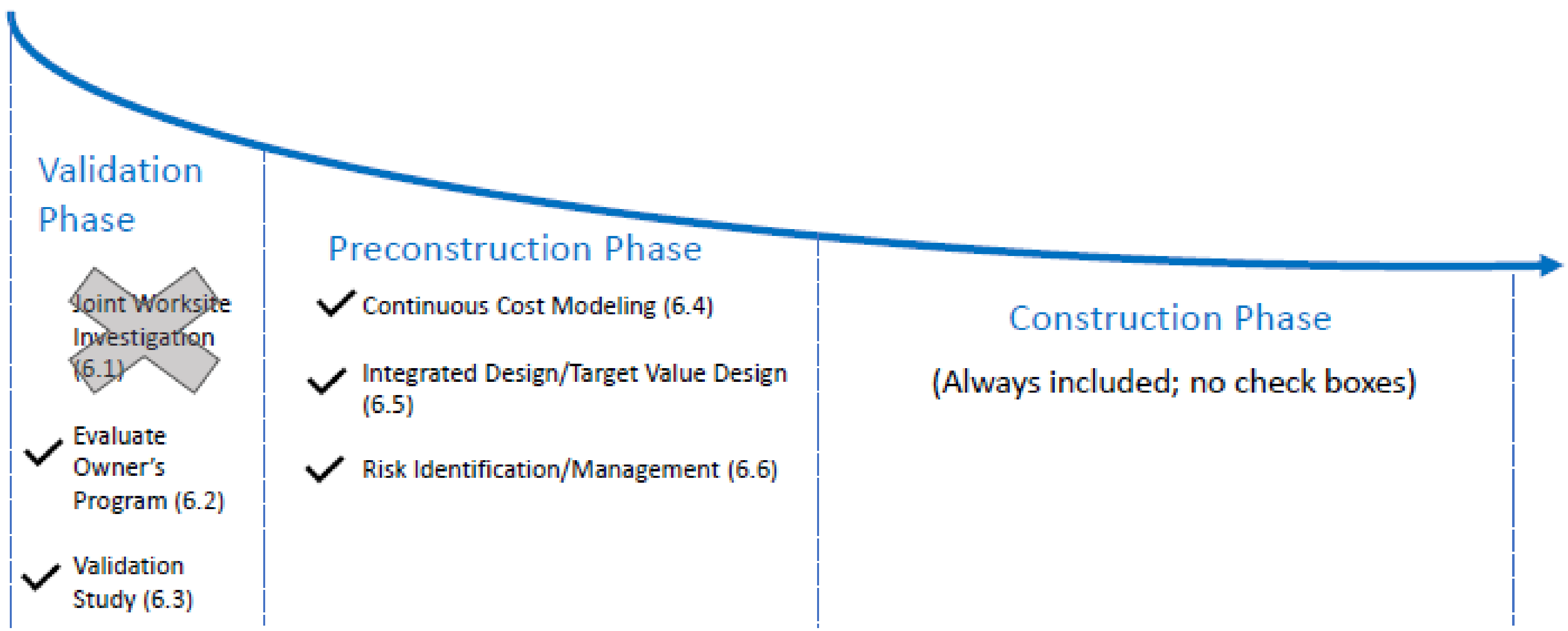
Typical chronology of IPD project



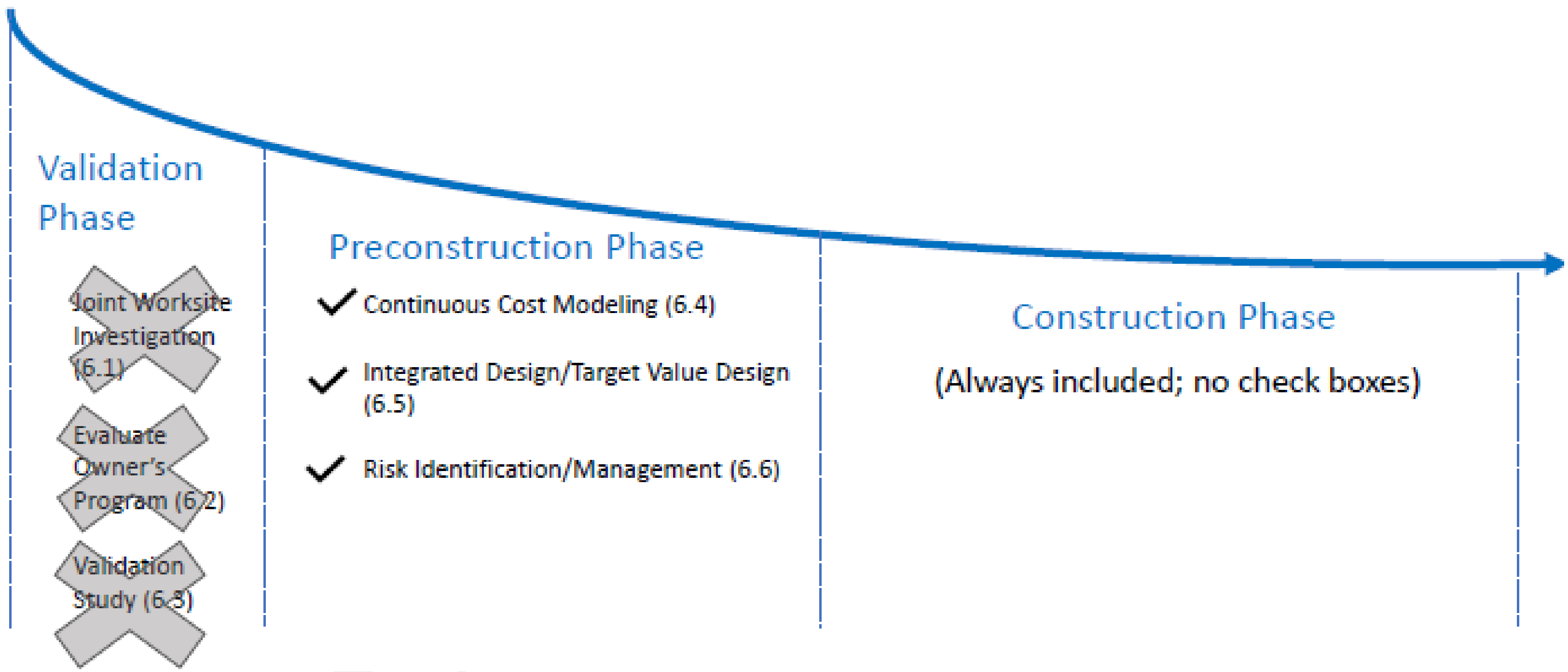
Expected Cost - An expression of the team's best estimate at the conclusion of the Validation Phase of what current best practice would produce as a price for the facility reflected in the accompanying basis of design documents. Typically, the Expected Cost will also be supported by benchmarking or other market data to calibrate the Expected Cost in light of the market context.

Target Cost - The cost goal established by the delivery team as the "target" for its design and delivery efforts. The Target Cost should be set at less than best-in-class past performance. The goal is to create a sense of necessity to drive innovation and waste reduction into the design and construction process.

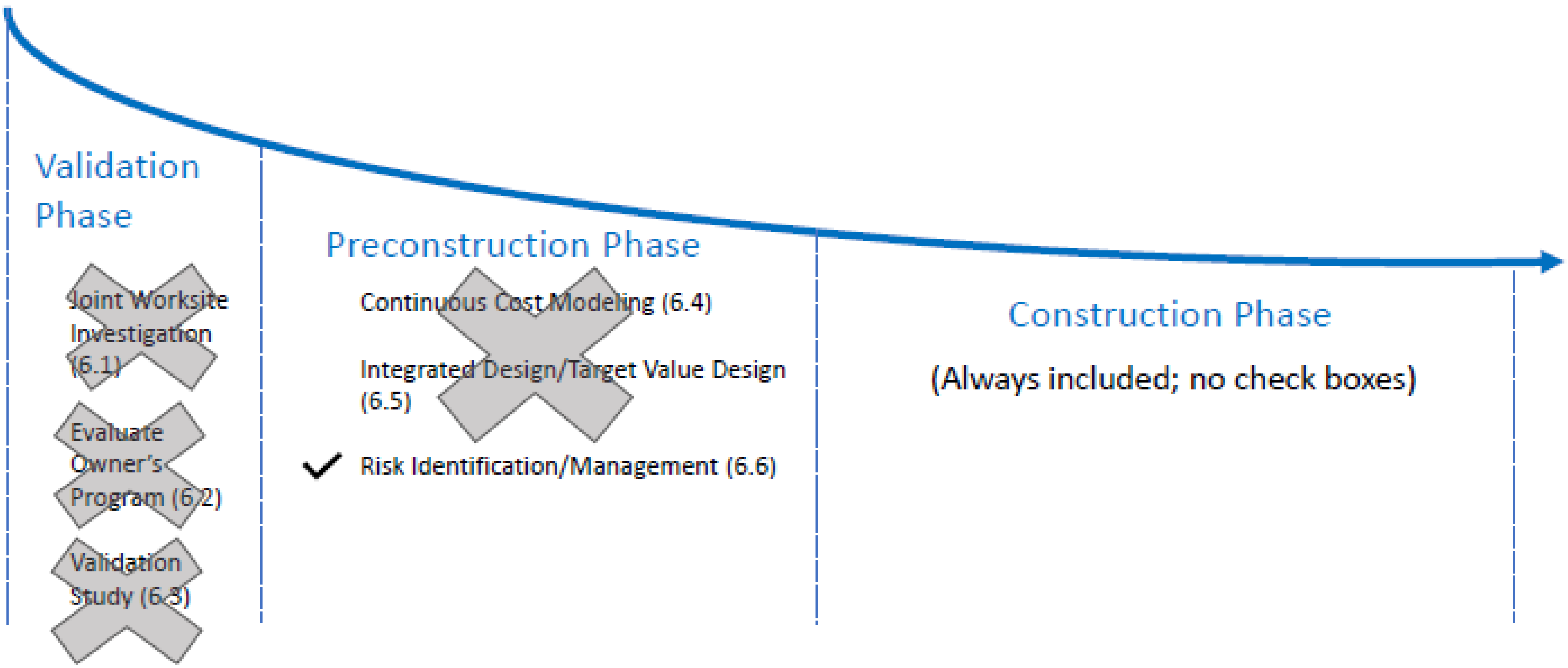
CD305 Check-the-Box Example 1



CD305 Check-the-Box Example 2



CD305 Check-the-Box Example 3



What about incentives?

- **CD 305** does **not itself provide** for incentive compensation.
- **Too much variability** to standardize **incentives**
- **CD305** does provide for **performance improvement program**,
  which individual projects could use as a platform for **incentive compensation**
- Provide for **incentives** through **amendment** to **owner contracts**

See files entitled "COD 305" and "COD 305-Guidebook"

Lean in Design and Construction

(Lean Project Delivery System)

Overview of lean project delivery system and its components

- **Poor design** and **documentation quality** have been identified as a **major factor** in **reducing** the overall performance and **efficiency** of construction projects.

- The **Lean Project Delivery System™ (LPDS)** provides a **means** of
  1. **Addressing** these shortcomings and
  2. **Improving** the entire design and construction process

(Ballard 2000; Ballard and Howell 2003a).

Who developed LPDS?

Overview of lean project delivery system and its components

- The **Lean Project Delivery System™ (LPDS)** was developed by **Glenn Ballard in 2000** and subsequently refined.
  - Whereas **traditional industry** practice has **separated** the roles of designers and constructors,

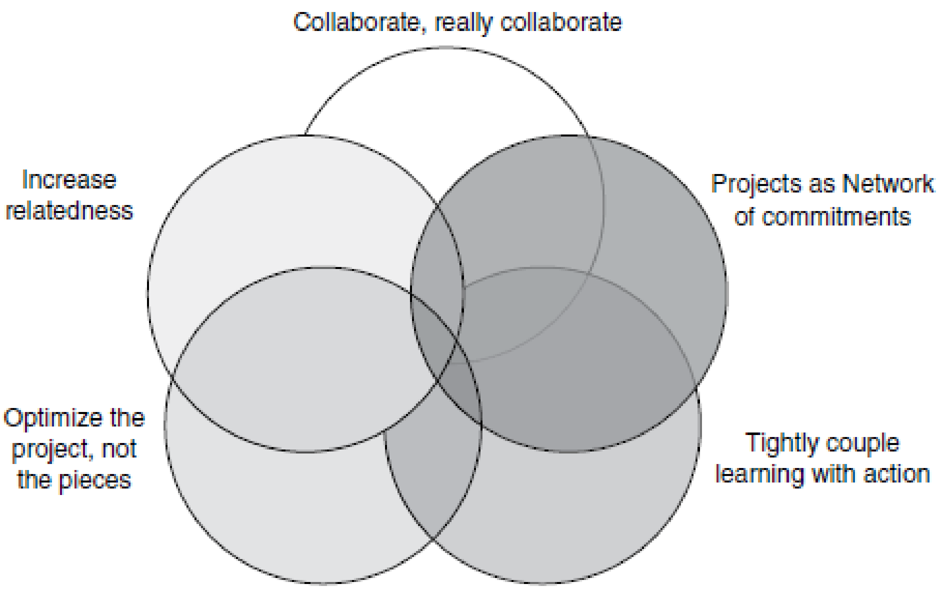
    LPDS sees the activities of these professionals as a **continuum for project management** to **achieve three fundamental goals** (Koskela 2000):

    1. Deliver the product,
    2. Maximize value, and
    3. Minimize waste.

What is the fundamental of LPDS?

Overview of lean project delivery system and its components

- **Fundamental to the LPDS** is the deployment of the **"Five Big Ideas":**
  1. Collaborate, really collaborate,
  2. Increase relatedness among all project participants,
  3. Projects as networks of commitments,
  4. Optimize the project, not the pieces, and
  5. Tightly couple learning with action.



Source: The Five Big Ideas are the intellectual property of Lean Project Consulting

- Set of **organizing concepts** that **support Lean Project Delivery.**

Structure of the lean project delivery system (LPDS)

- The **LPDS** comprises a **number of phases** that juxtaposes them in such a manner as to **apply production system design principles** to enhance **delivery of the entire project** from predesign to completion and use.
  - LPDS is structured to achieve the **Transformation, Flow, and Value (TFV) goals**.
    - ✓ The phases are:
      1. Project definition
      2. Lean design
      3. Lean supply
      4. Lean assembly
      5. Use/completion

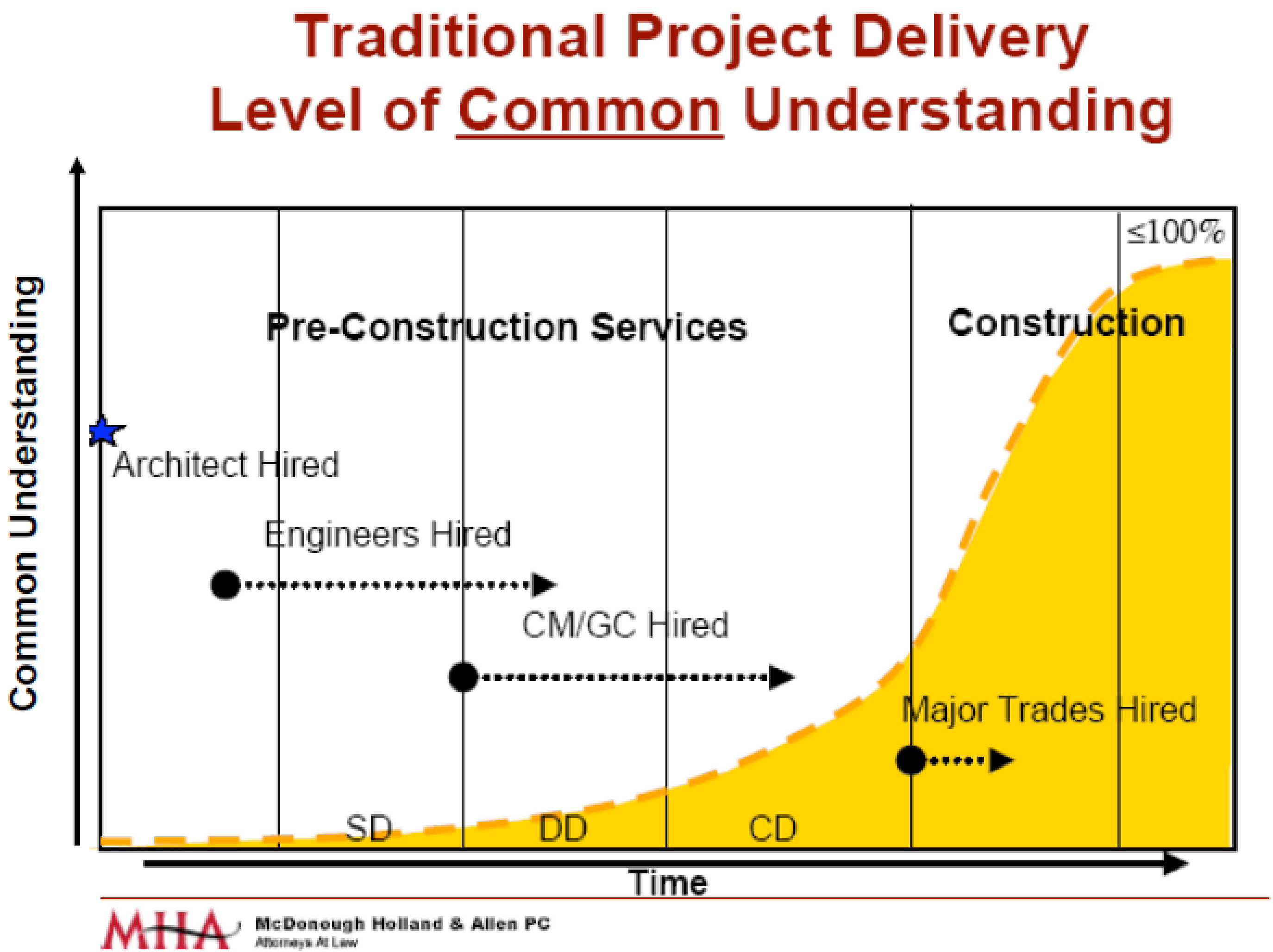
Structure of the lean project delivery system (LPDS)

Comparison of the LPDS with traditional systems

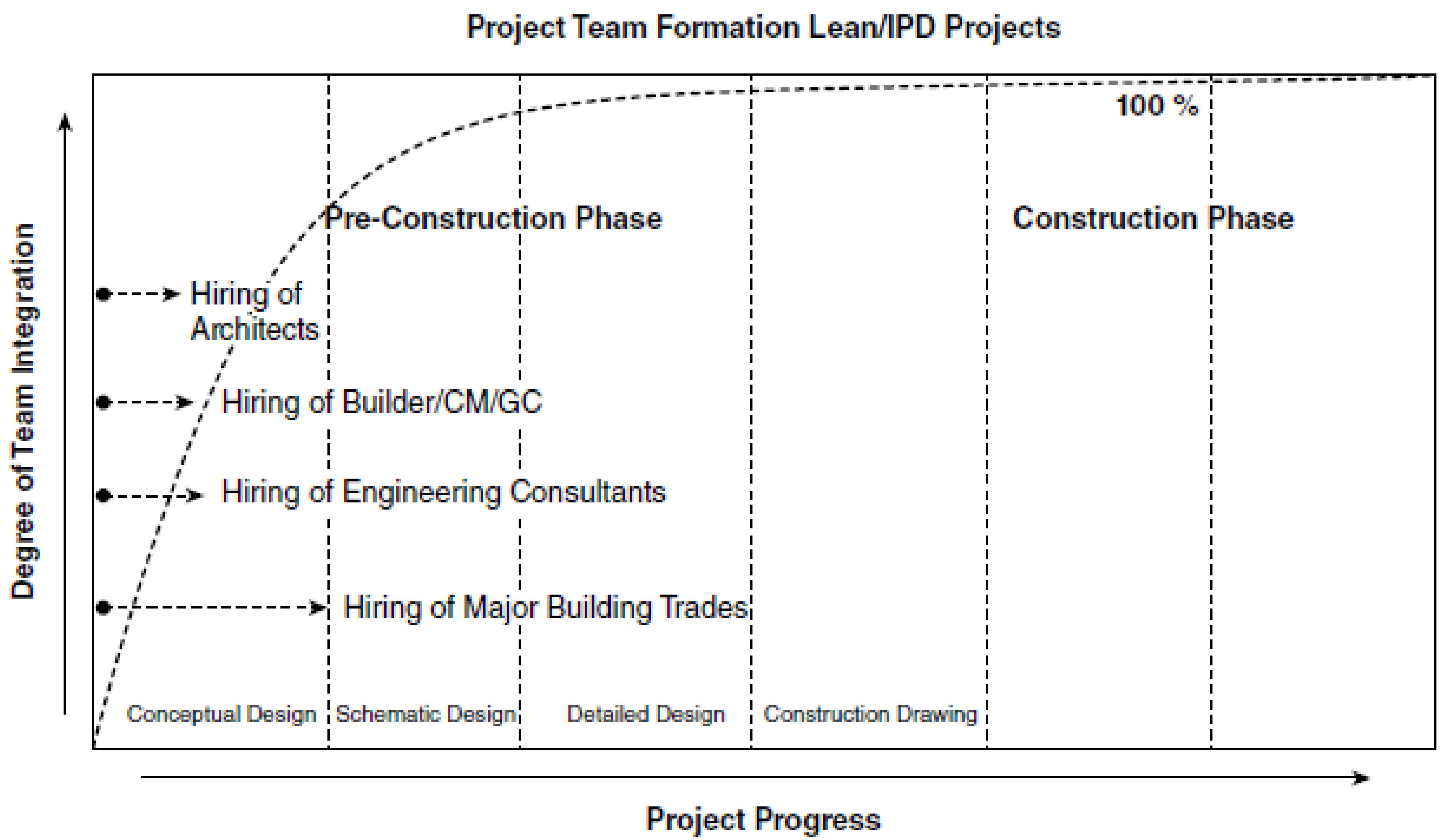
	Lean project characteristics	*Traditional project characteristics*
1	The focus is on the production system	The focus is on transactions and contracts
2	The TFV goal	The T goal
3	Downstream players are involved in upstream decisions	Decisions are made sequentially by specialists,
4	Design coordinates both the product and the process	Process design is done separately after product design
5	Design considers product life-cycle stages	Design does not consider life-cycle stages
6	Actions are taken at the last responsible moment	Actions are taken as soon as possible
7	Supply chain lead times are reduced systematically	Organizations accept market conditions, availability
8	Learning is included in projects, firms and supply chain management	Learning occurs sporadically
9	Stakeholder interests are aligned	Stakeholder interests are not aligned
10	Buffers are sized and located to absorb system volatility	Participants protect their interests with large inventories.

Source: Adapted from Table 14.2 of Koskela *et al.* 2002

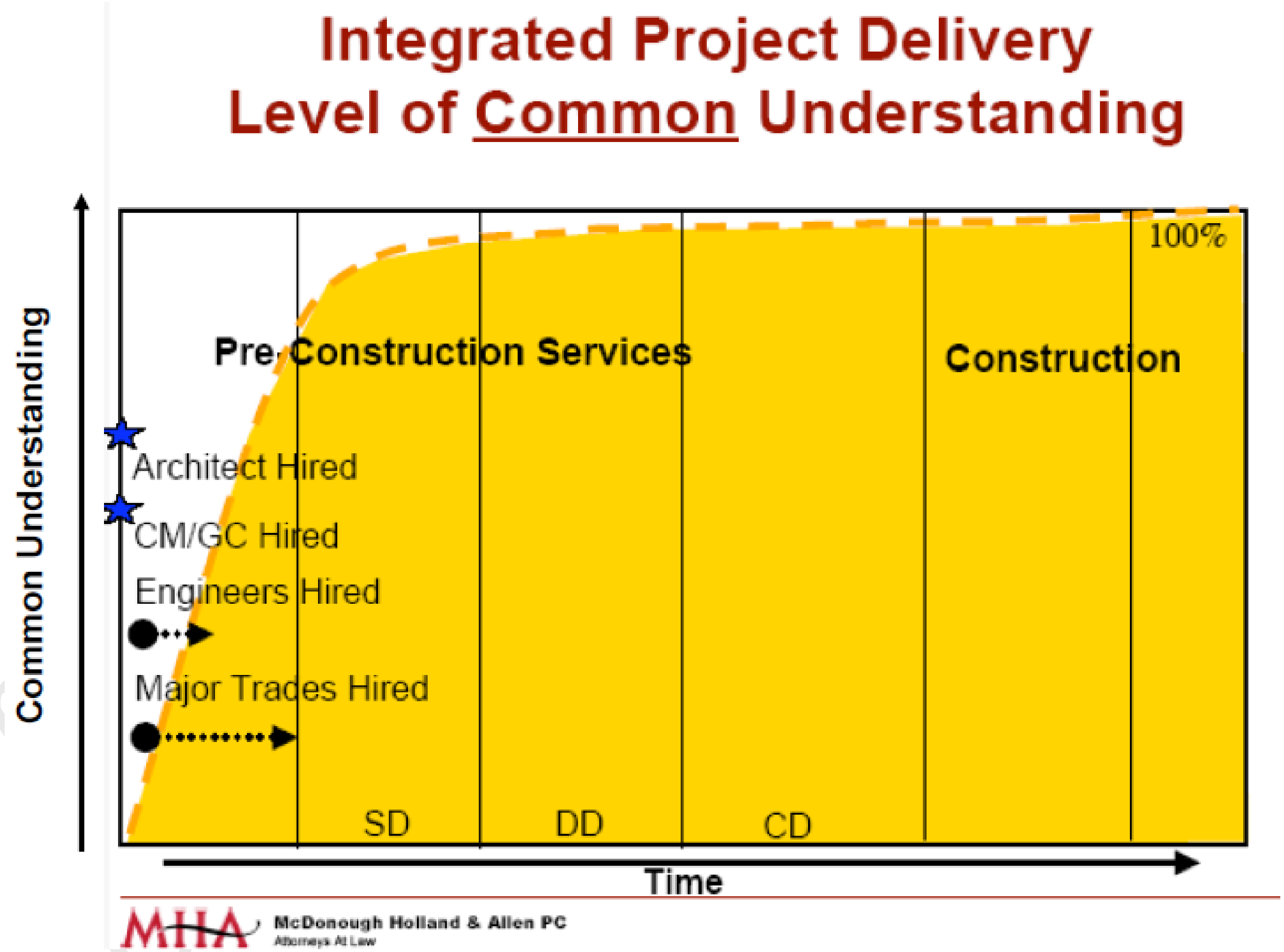
Traditional project delivery



Lean project delivery and team formation

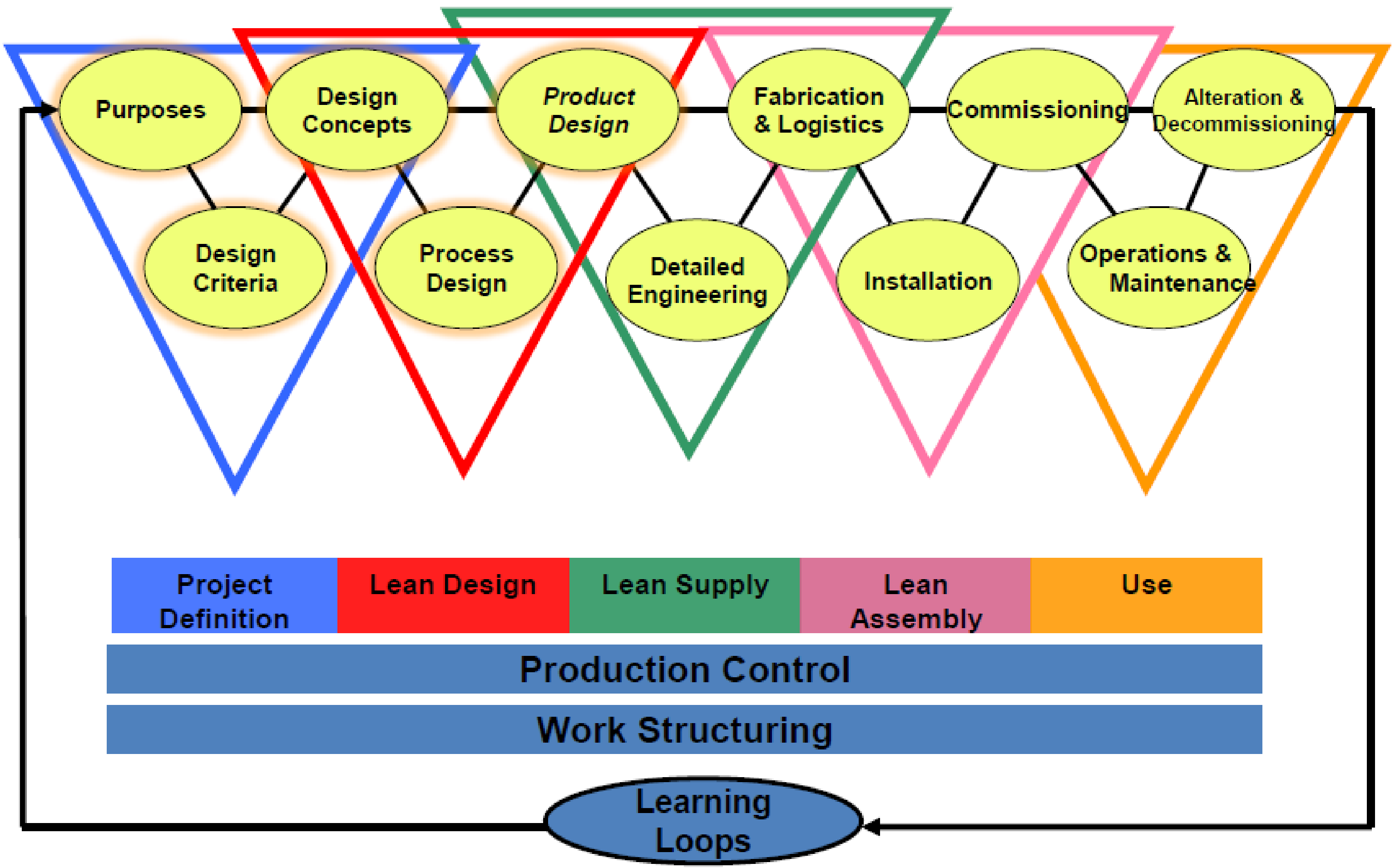


Lean team formation



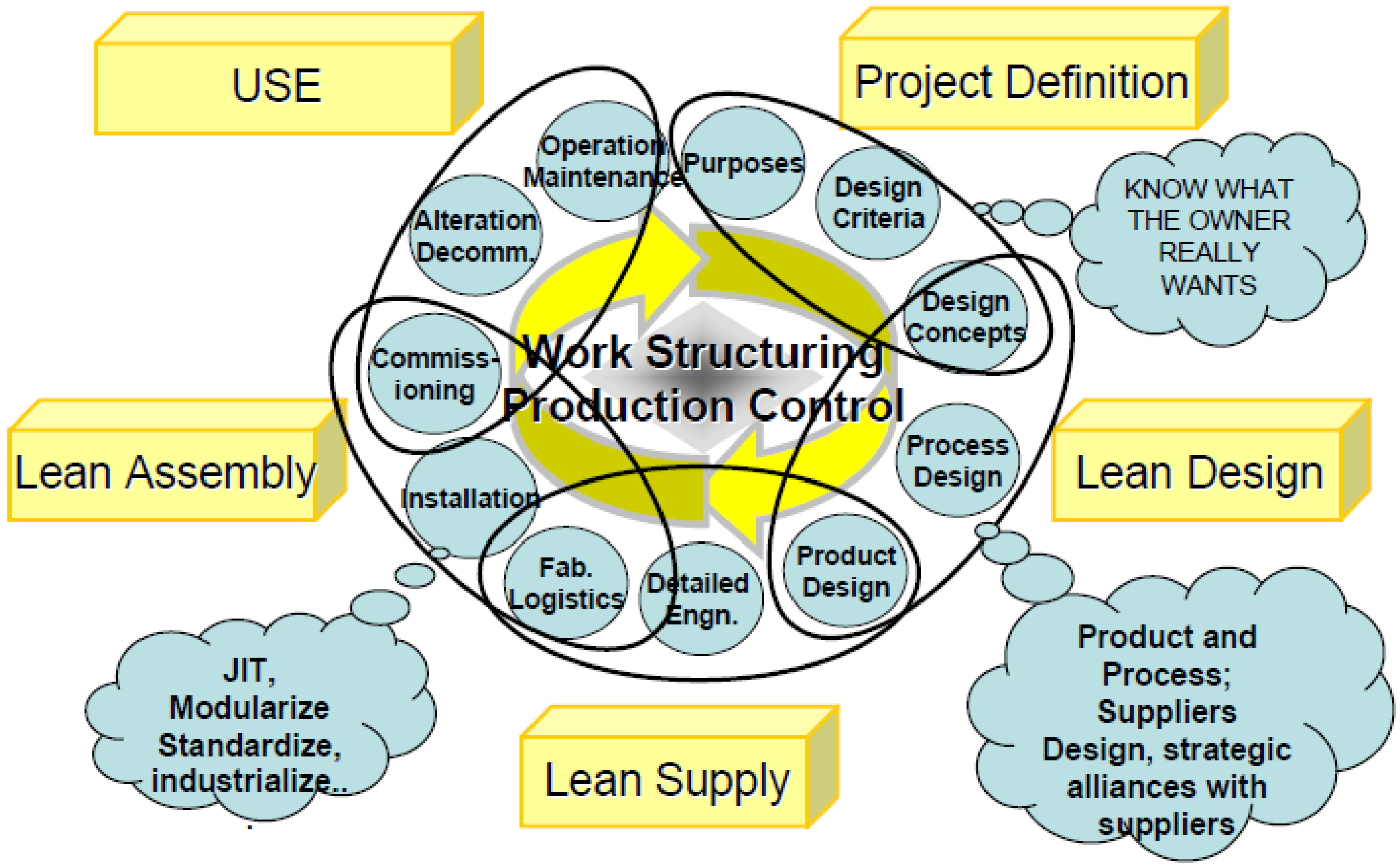
Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



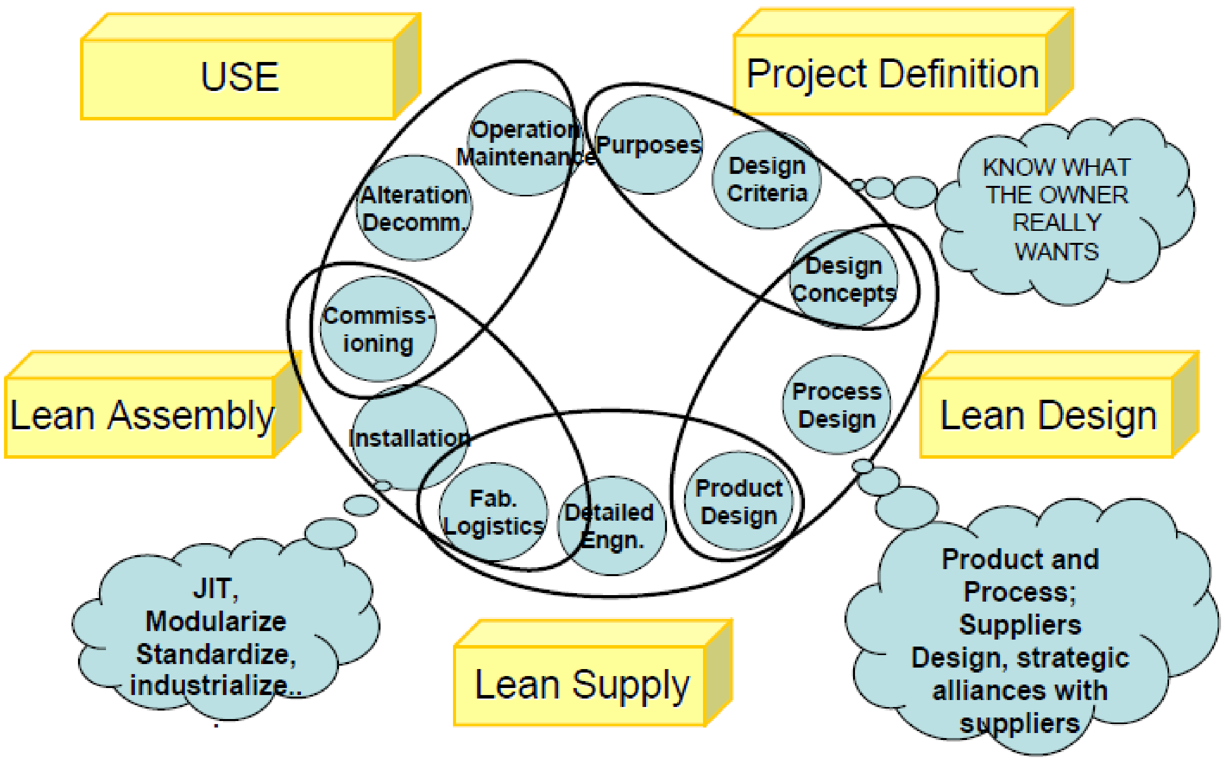
Structure of the lean project delivery system (LPDS)

Ballard (2000); Adapted by T. Abdelhamid



Structure of the lean project delivery system (LPDS)

We will discuss the components: Project Definition, Lean Design, Lean supply, Lean Assembly, and Use.



Ballard (2000); Adapted by T. Abdelhamid

Project definition phase

- **Project definition** typically involves
  - Developing **project alternatives** at a conceptual level,
  - Analyzing **project risks** and the economic payoff, and
  - Developing a **financial plan**.

A decision is **made to proceed** if the owner considers conditions to be **favorable**;

a **plan is developed** for the organization and control of the project.

What is the difference between LPDS and traditional project definition?

ACEMI

Project definition phase

- **Traditionally**,

  project definition has been **established by the architect** (or engineer for non-building projects) **working alone** with the owner.

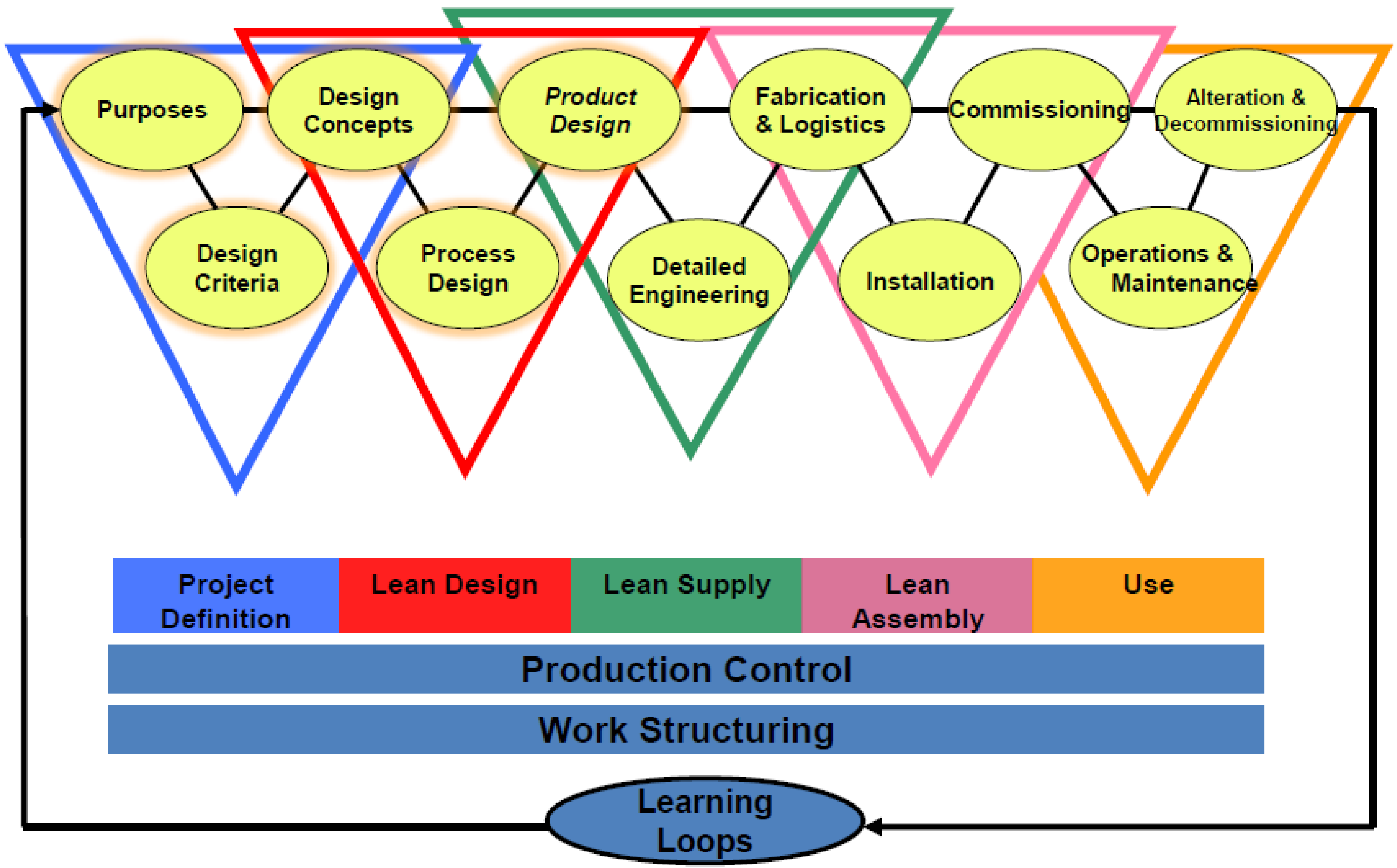
- In **lean project definition**,

  representatives of every stage in the life cycle of a facility are **involved**, including members of the production team that will design and build it.

  (Koskela et al. 2002).

Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



Lean design phase

- The lean design phase comprises:
  1. Conceptual design,
  2. Process design, and
  3. Product design.

*It builds on the **output** from the **project definition phase**,*

*but with a **deviation from traditional design** practice.*

What is the difference between lean design and traditional design?

Lean design phase

- In **D-B-B projects**,

  architect provides preliminary drawings to the **other disciplines** at various stages in the design process and

  engineers apply their respective design parameters to the architectural framework.

  Although this ***work may benefit*** *from the* ***cost efficiencies of 3-D CAD*** *(or more advanced versions),*

  process is ***not generally interactive!***

Lean design phase

- In **design-build (DB) projects**,

  a **single entity contracts** with the owner/client;

  there is an **interplay between designers and builders**, but

  1. **Owner/client** is **not generally included** in this process
  2. **Owner/client** does **not have a fiduciary relationship** with the designer of record.

Lean design phase

- In **<u>CM@ Risk</u>** the **builder** is brought on board

  with the **primary motive of becoming familiar** with the project and its environment;

  the **risk of unforeseen** conditions is reduced.

Lean design phase

- With **lean projects**,

  design is done with **both** the **construction product** and the **process** in mind.

  - **Constructability reviews** and **value engineering** are **not seen as tools** to apply in a problem-solving mode,

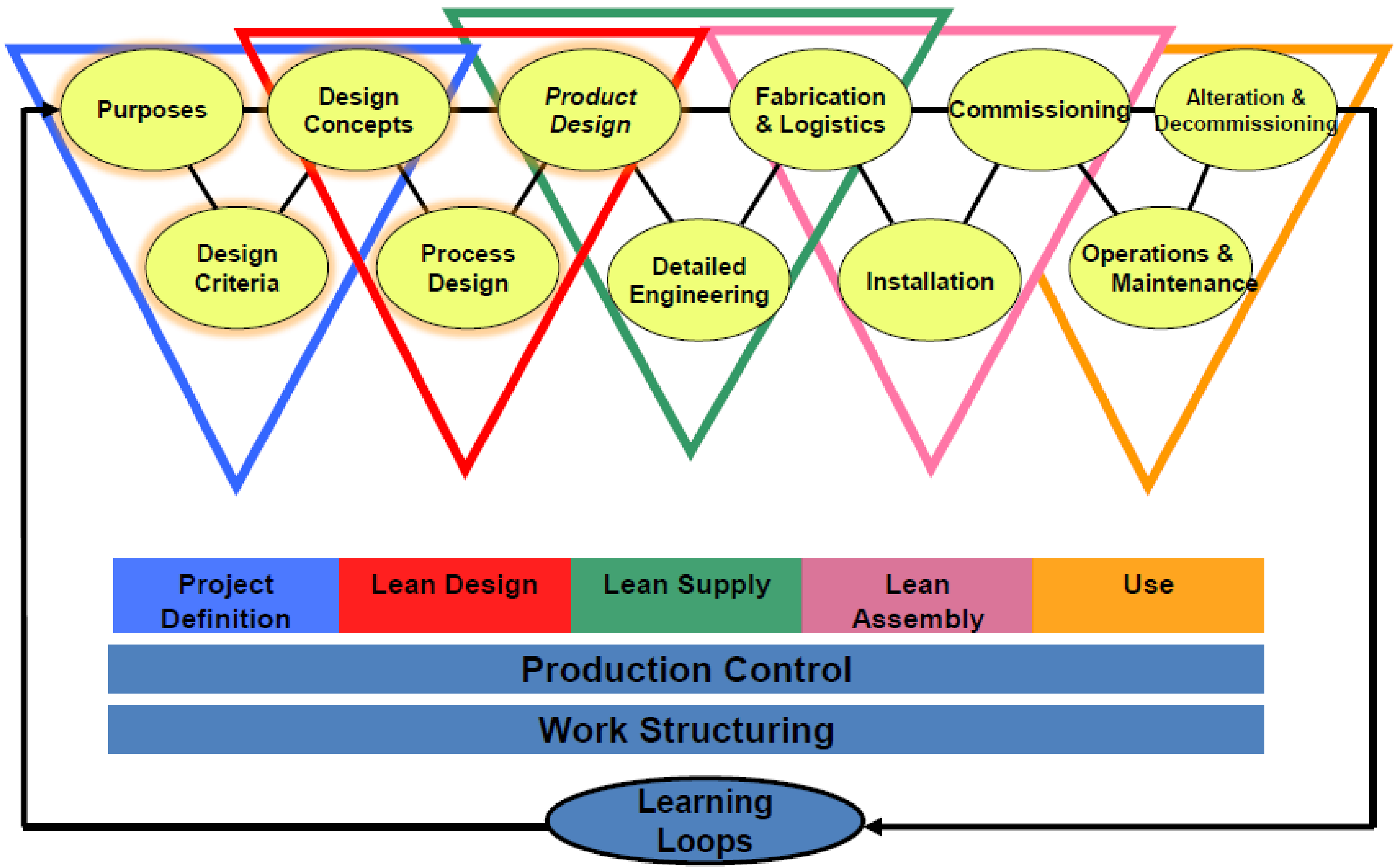
    but rather, are **continually integrated with decision-making** in the design process.

    - ✓ This is **accomplished with cross-functional teams** that include *architects, engineers, contractors, subcontractors, and various specialists*

      who **collaborate with each other and interactively** make decisions that are optimal for the product and the process.

Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



Lean supply phase

- The third triad, **lean supply**,

  requires **up-front product** and **process design** to define

  1. What is needed and
  2. When it should be delivered.

- **Lean supply** also includes **reducing the lead time** for project information requirements.

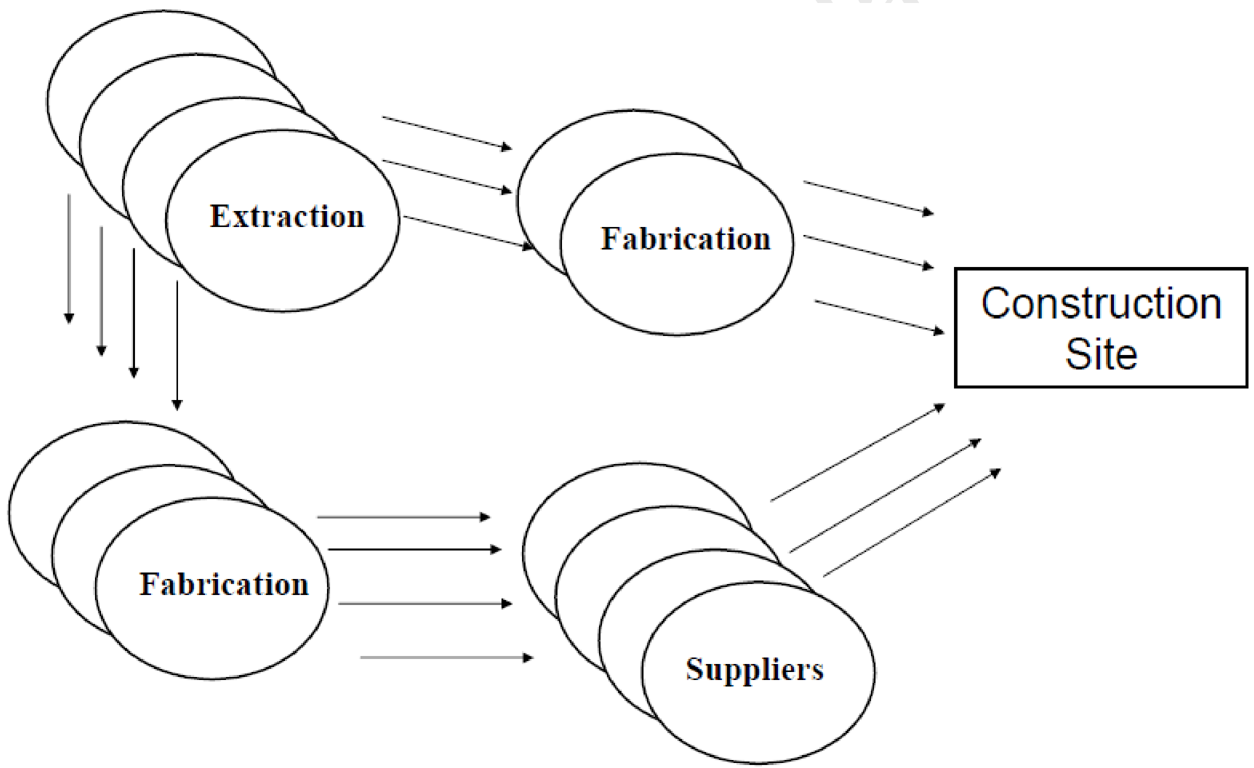
- It involves the use of **supply chains** to **optimize the delivery** of materials, components and major building sub-assemblies

Lean supply phase

- **Lean supply** to Do's
  - **Early applications of JIT** in construction should focus on **reducing on-site waste** and **operations variation** by:
    1. Selecting location and size of **material** - **inventory buffers** (Use Computer Simulation)
    2. Performing **risk analysis** - **schedule buffers** (Use Computer Simulation and Last Planner)
    3. Creating alternative work for **crews** - **capacity buffers** (Use Last Planner)
  - **Shift** detailed engineering to fabricators and installers.
  - **Structure** logistics so materials can be **pulled** to site in **small batches**.

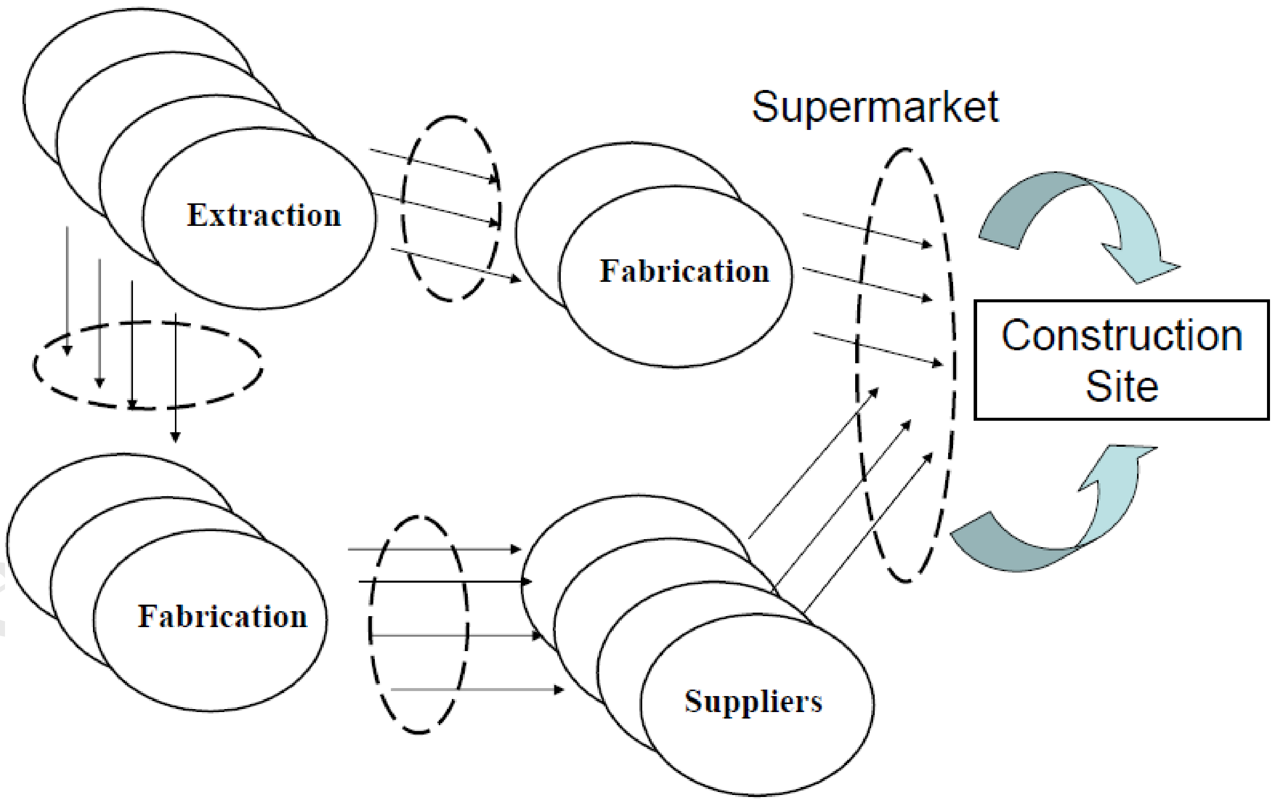
Lean supply phase

- Map the supply chain



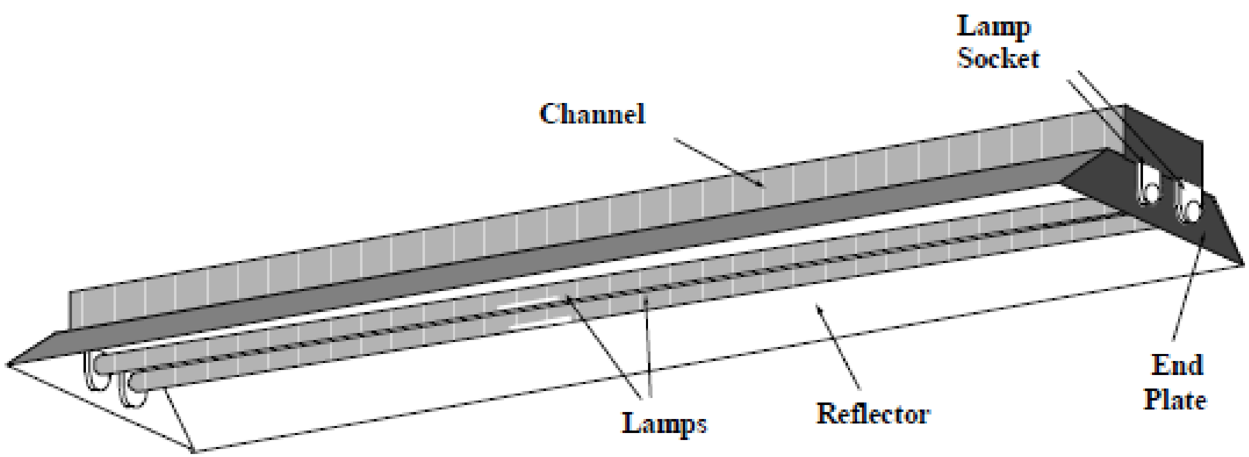
Lean supply phase

- Map the supply chain



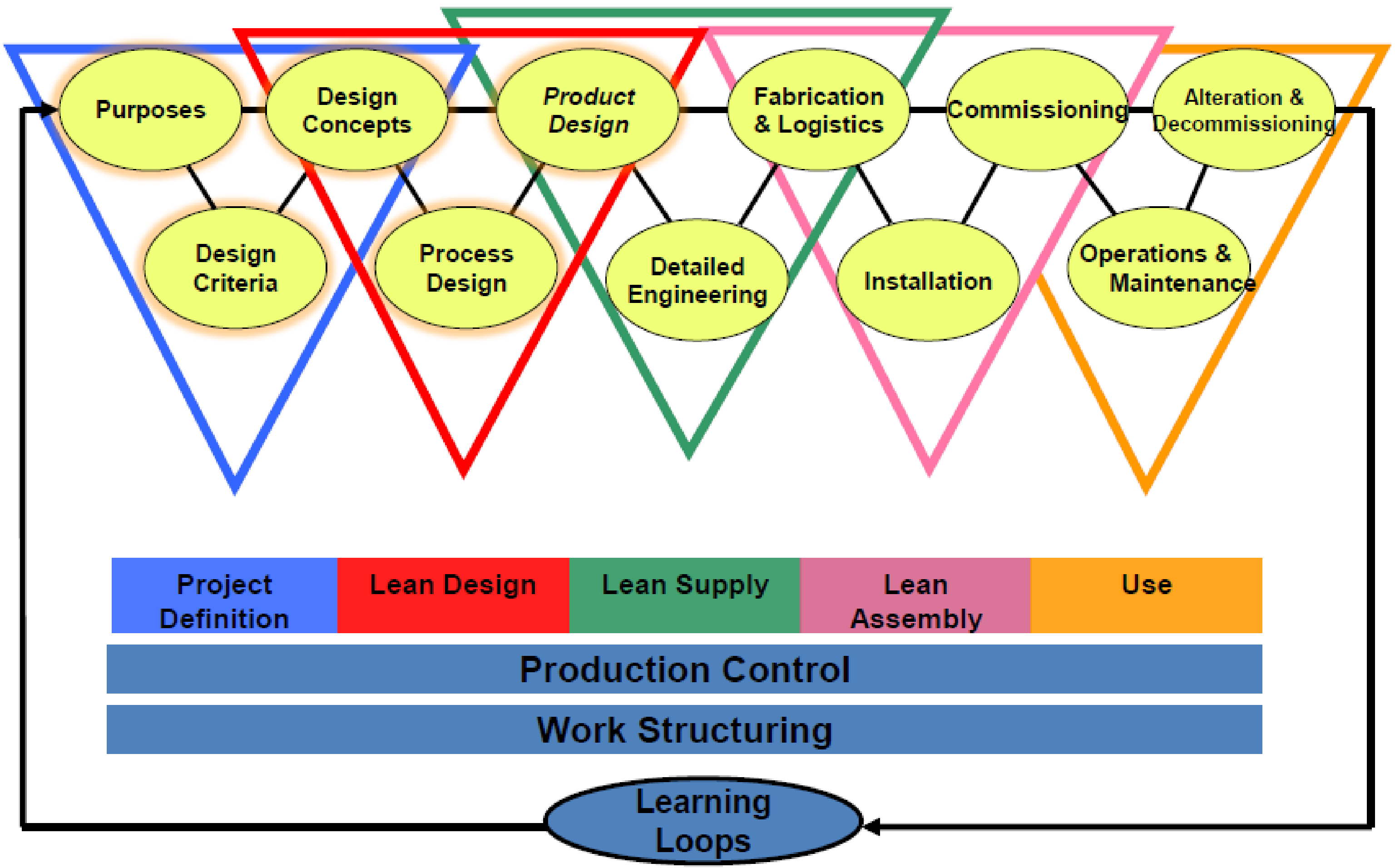
Lean supply phase

- At some point move to complete off-site assembly



Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



ACEMI

Lean assembly phase

- **Lean assembly** is practiced in the **actual construction** of a project, putting

  1. Materials,
  2. Systems, and
  3. Components

  in place to create a completed facility.

Lean assembly phase

- **Lean assembly** to Do's
  - **Standardize** and **industrialize**
    - Standardize the ingredients, not the recipe
  - Use **5S**
  - **Simplify site installation** to final assembly and test
  - " **Flow** where you **can**, **Pull** where you **must**"
    - Strive for **one-touch material handling**
    - Pull from **off-site suppliers**

What is the difference between prefabrication and field work?

ACEMI

Lean assembly phase

- **Prefabrication** is a **production technique** that can **enable a contractor** to **operate in a lean manner** by **reducing** the many **nonvalue-added steps** that are required in field fabrication.

Whereas

- **Field work** contends with **uncertain conditions** such as weather, and limitations in the availability of skilled labor, material, and equipment, shop fabrication benefits from a **predictable, controlled environment**.

Lean assembly phase

- The **commissioning process** **overlaps** in the last two triangles;

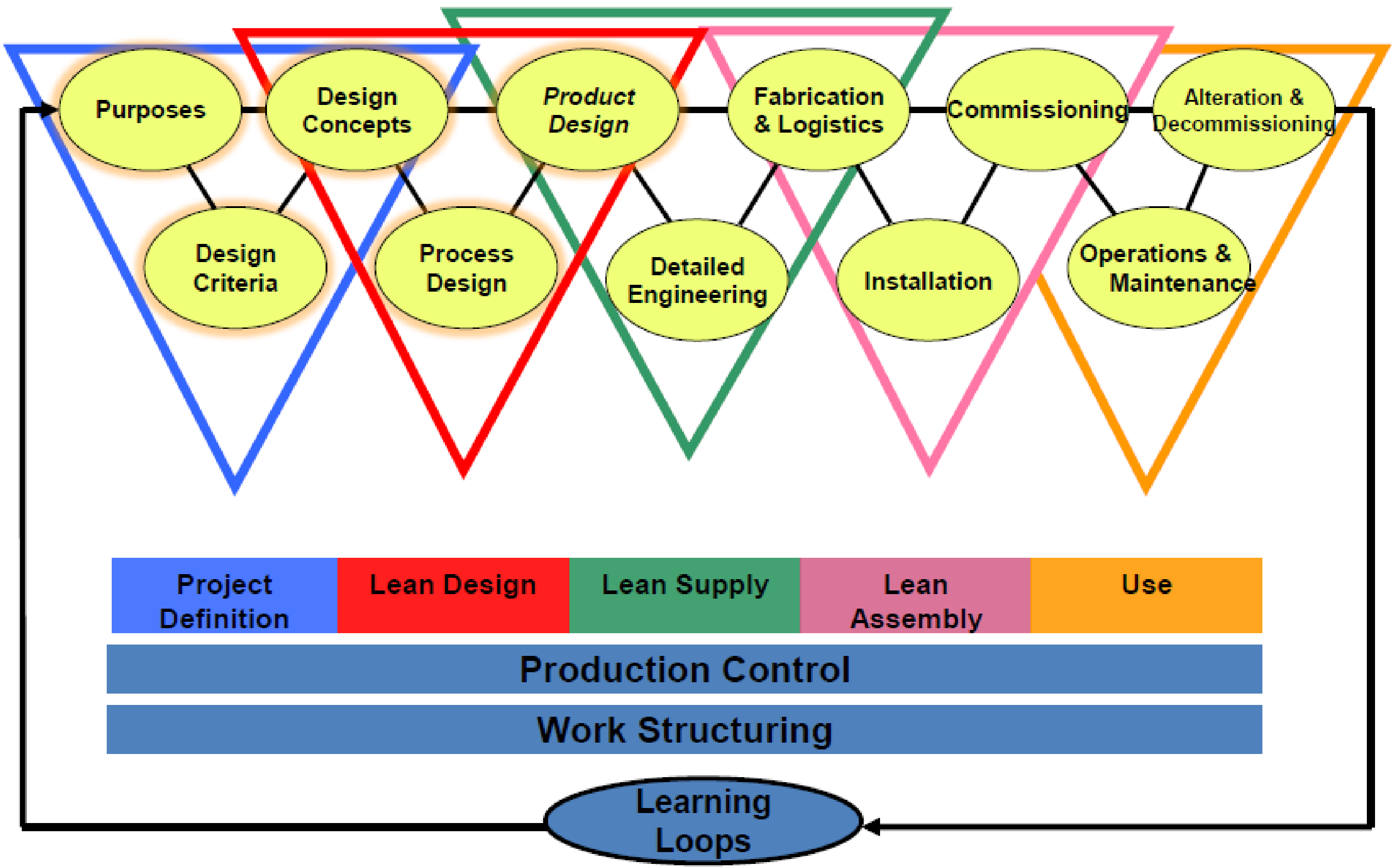
  it provides **quality assurance** before a facility is completed and accepted by the owner.

  - It **improves** the **probability** that the facility will meet the **owner's project requirements (OPR)** and

    performs as expected, to provide user satisfaction.

Structure of the lean project delivery system (LPDS)

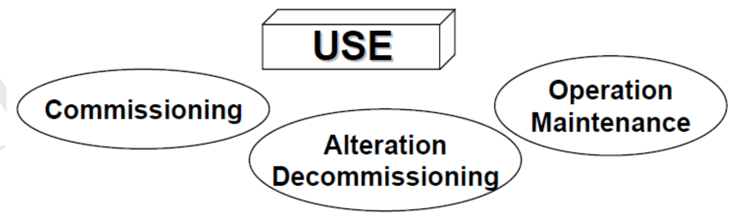
- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



ACEMI

Lean use phase

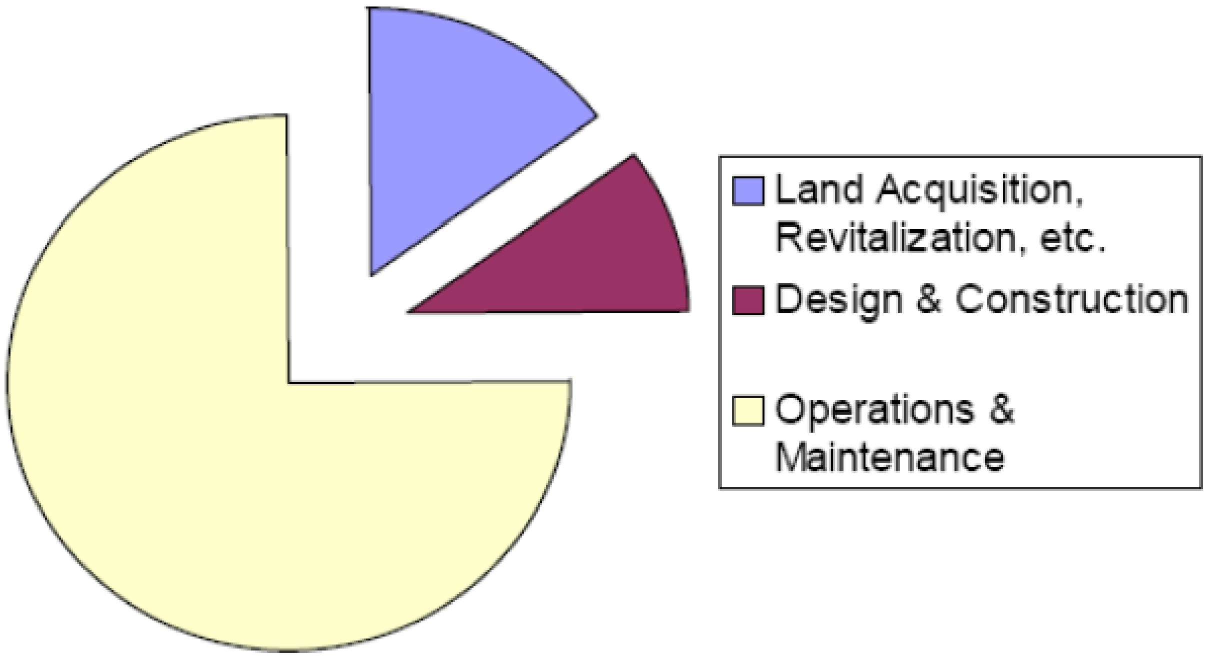
- The fifth triad, <u>**“Use,”**</u> refers to a **completed facility**.



- Following <u>**successful commissioning**</u>, **facility** should undergo a **protracted operations** and **maintenance phase** as it is used.

- <u>**“Alteration and Decommissioning”**</u> refer to a **future activity** when the facility may be
  1. Repaired,
  2. Renovated, or
  3. Taken out of service.

Lean use phase



U.S. Federal Facilities Council. (2001). "Sustainable Federal Facilities: a guide to integrating value engineering, life cycle costing, and sustainable development." Federal Facilities Technical Report No. 142. National Academy Press. Washington, DC.

Lean use phase

"Operating expenses represent over 95 percent of building life cycle costs, yet operations and maintenance personnel are usually the last to be consulted during programming and design" (NIBS 2003)

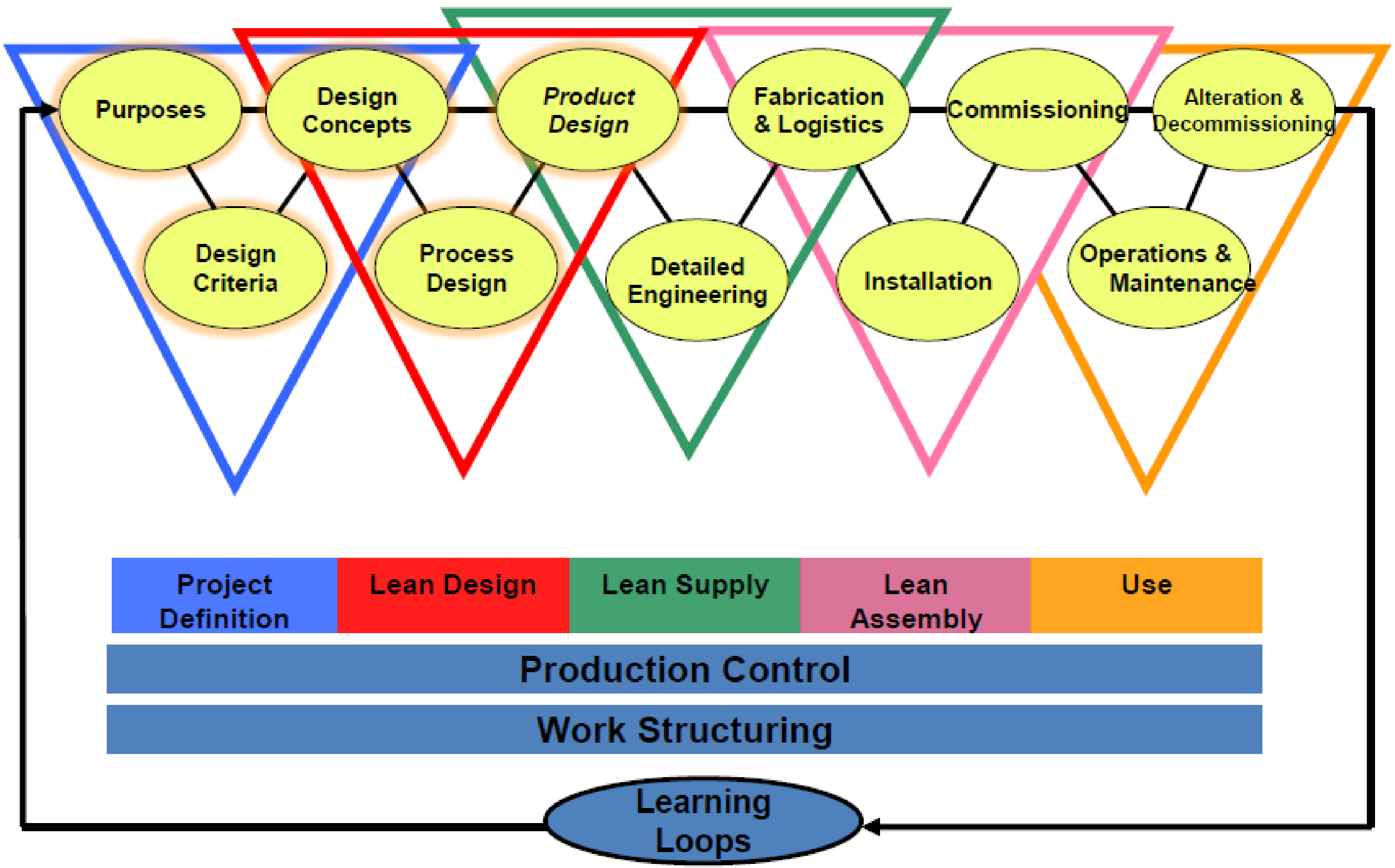
- When **1% of upfront cost** are spent, 70% of the life cycle cost of a bldg. may have been committed (Romm 1994)

National Institute of Building Sciences. (2003). "Annual Report to the President of the United States."

Romm, J. (1994). Lean and Clean Management. Kodansha America Inc., New York.

Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



Learning loops

- **"Learning loops"**
  1. Span **all the activities** in the **five triads**, and
  2. Refer to the application of **root cause analysis** to the **Last Planner® System** on a **weekly basis** to review **Percent Plan Complete (PPC) values** and **commitment reliability**.

- **Learning** is also accomplished through **ongoing retrospectives** as well as the process of **post occupancy evaluation (POE)**.
  - In POE reviews a facility is **surveyed after occupancy/acceptance** to **review the consequences** of **decisions** made during the execution of the project.

Production control

- **Production control** is represented as a **horizontal bar** that extends from the very inception of the project to its conclusion.

- **Lean production control** is achieved through
  1. **Systematic process** for making **assignments ready** to be performed,
  2. **Combined with explicit commitments by people** at the production level to what work will be released to **their customer processes** in the next plan period.
     - This is typically **"one week"**
     - It consists of **work flow control** and **production unit control**.

Work structuring

- **Work structuring** and **production control** are used **throughout a project** to manage production.

- The term **work structuring** was developed by the **Lean Construction Institute** (Ballard 1999) to describe **construction-related process design**.

- It is a **process** of **subdividing work** so that
  1. **Pieces are different** from **one production unit** to the next to promote flow and throughput, and
  2. **Have work organized** and **executed** to benefit the **project as a whole**.
     - Work structuring is used as a part of the **Last Planner System (LPS).**

Work structuring

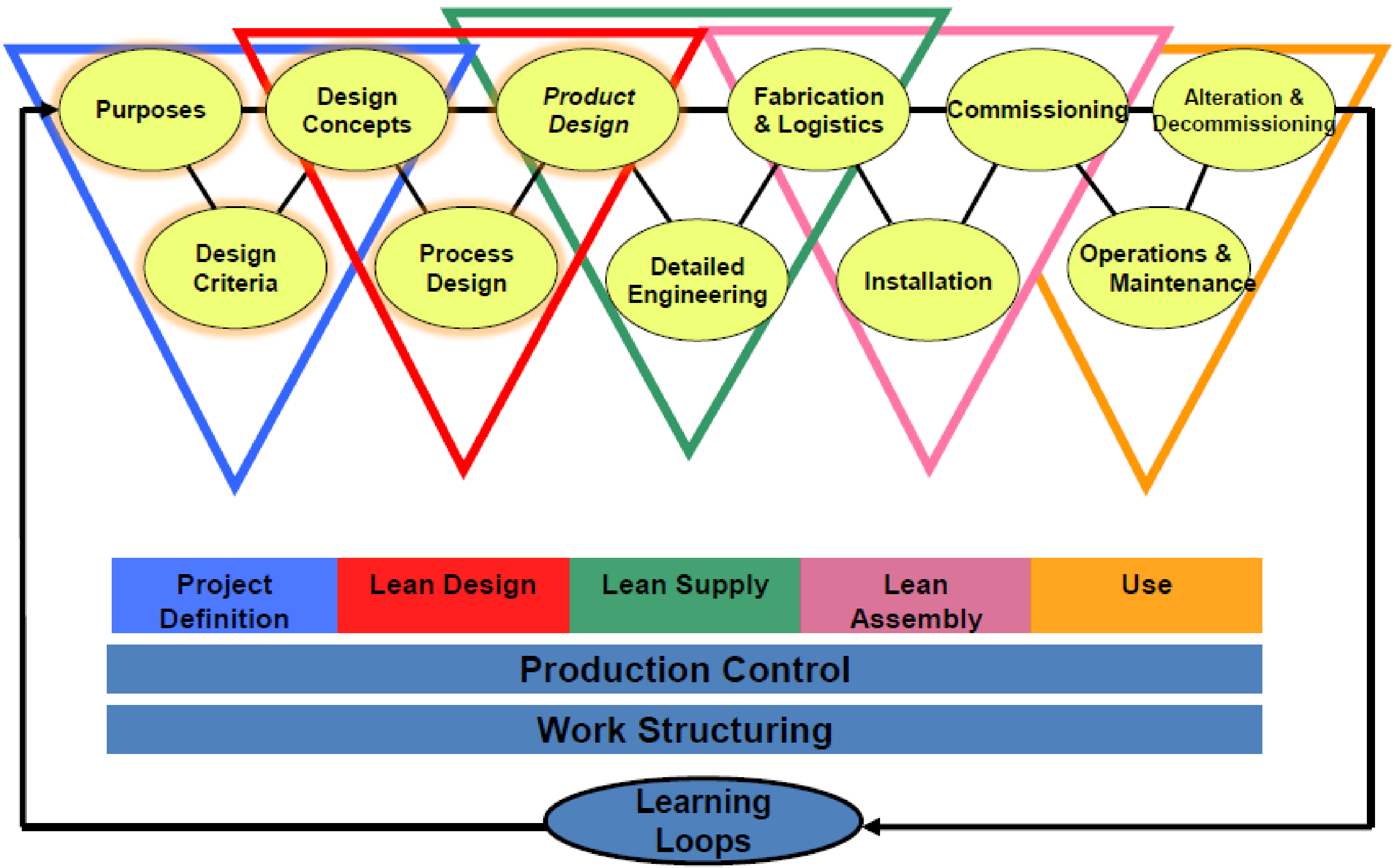
Work Structuring - Designing the production system to determine who does what, when, where and how, usually by breaking work into pieces, where pieces will likely be different from one production unit to the next. The purpose of work structuring is to promote flow and optimize system throughput by focusing on handoffs and opportunities for moving smaller batches of work though the production system.

Lean Project Delivery System

(Project Definition and Design Phases)

Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003

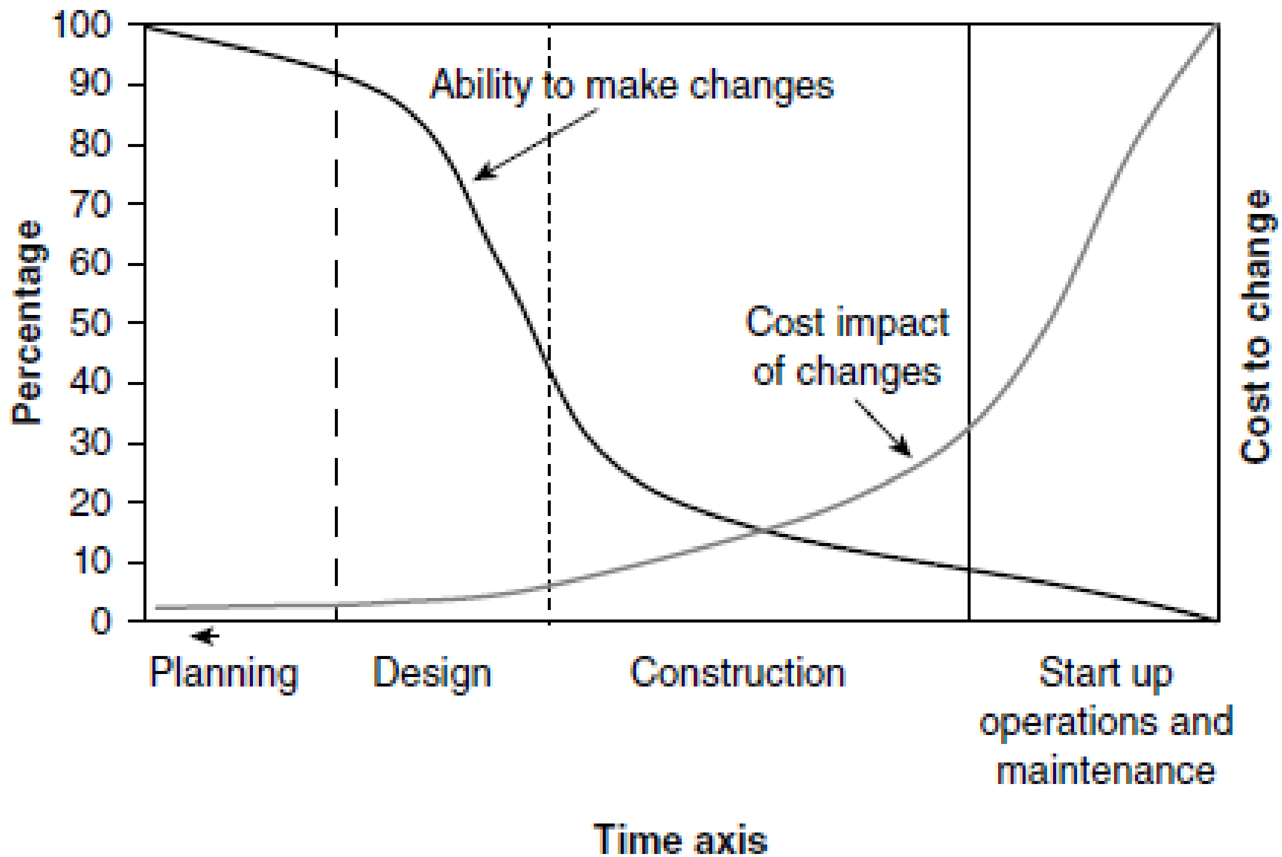


Importance

- The **purpose of this section** is to
  1. Discuss **project definition** and **lean design** as the **first two triads** of the lean project delivery system (LPDS)
  2. Explain how the **related activities affect** the delivery of lean projects.

- **Traditional projects** do **not generally have a clear line of communication** between designers and builders – **except** for
  1. **Design-build** projects, and
  2. **Some** applications of **CM at risk**.

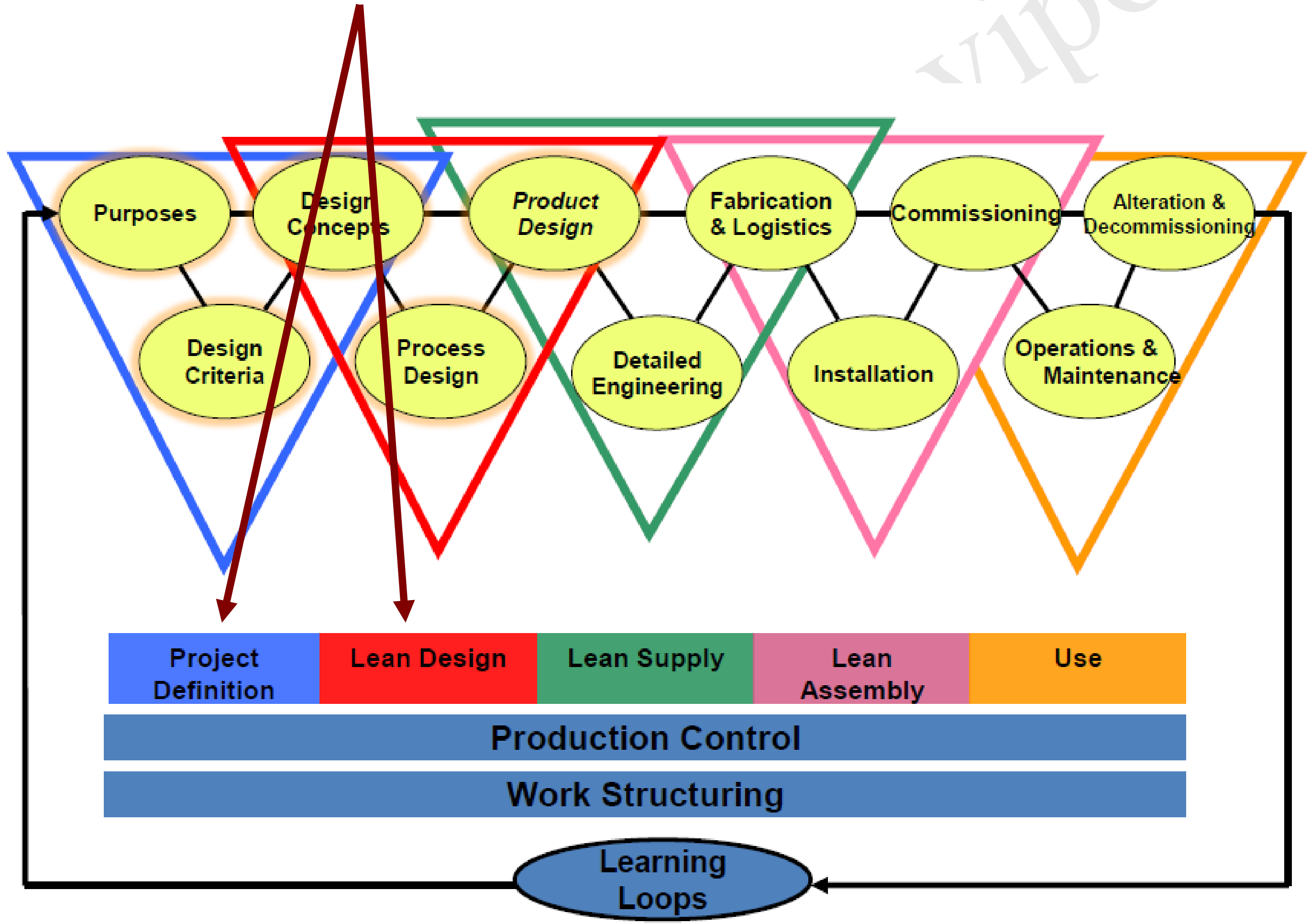
Importance



The relationship between time and the impact of design changes

Structure of the lean project delivery system (LPDS)

- We will discuss this part at this section

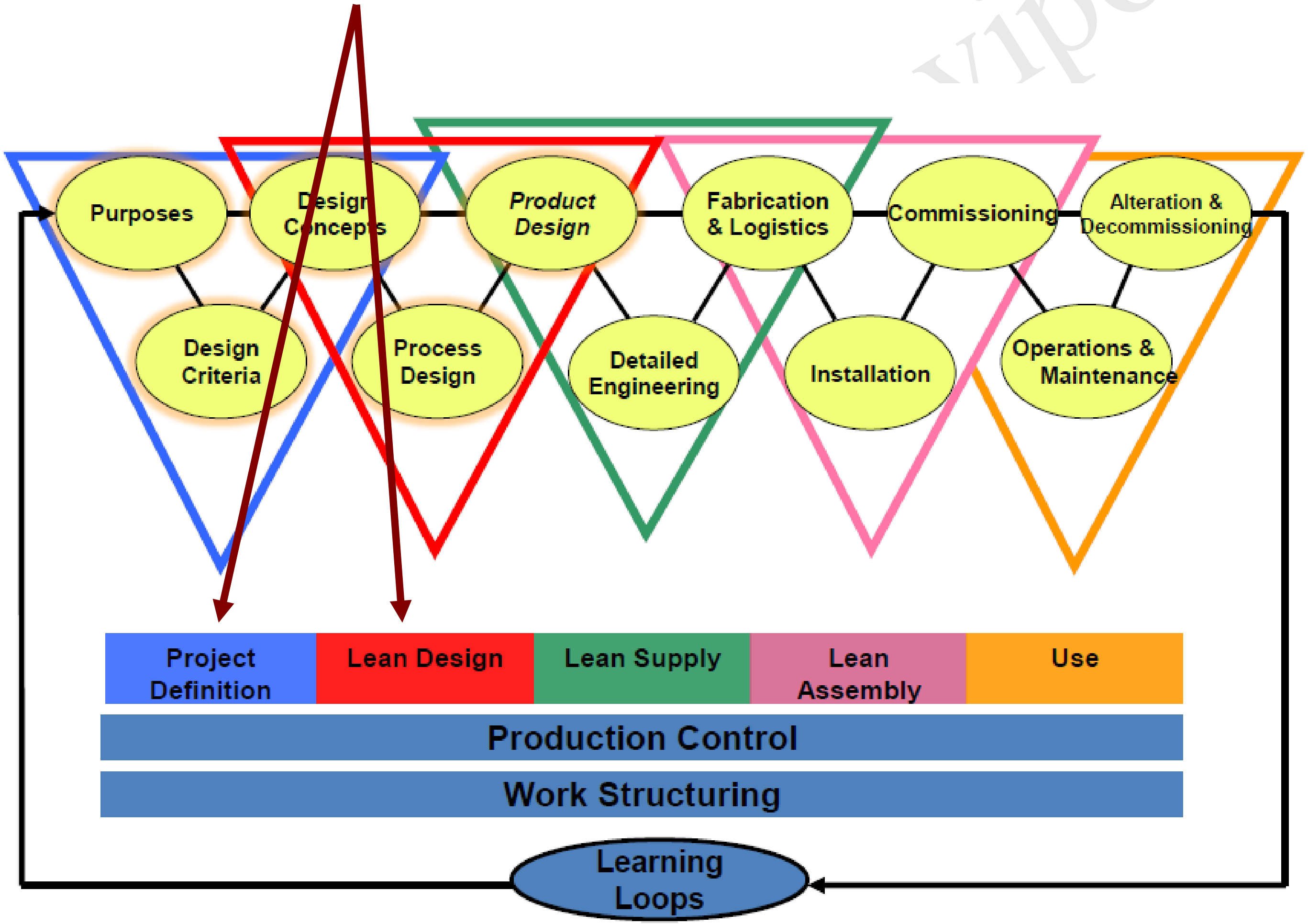


Lean Project Delivery System

(Project Definition Phase)

Structure of the lean project delivery system (LPDS)

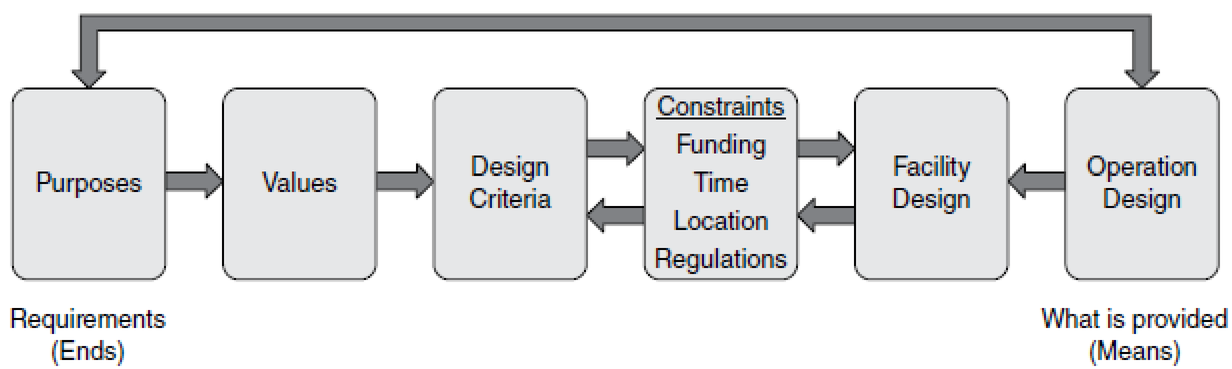
- We will discuss this part at this section



Project definition phase – Definition & steps

- The **first triad** of the LPDS contains **three important attributes** – purposes, design criteria, and design concepts.
- **Project definition** provides valuable information on:
  - The owner’s needs and values
  - The owner’s business plan and its value proposition
  - Project alternatives and their associated risk
  - Target values and constraints for lean design

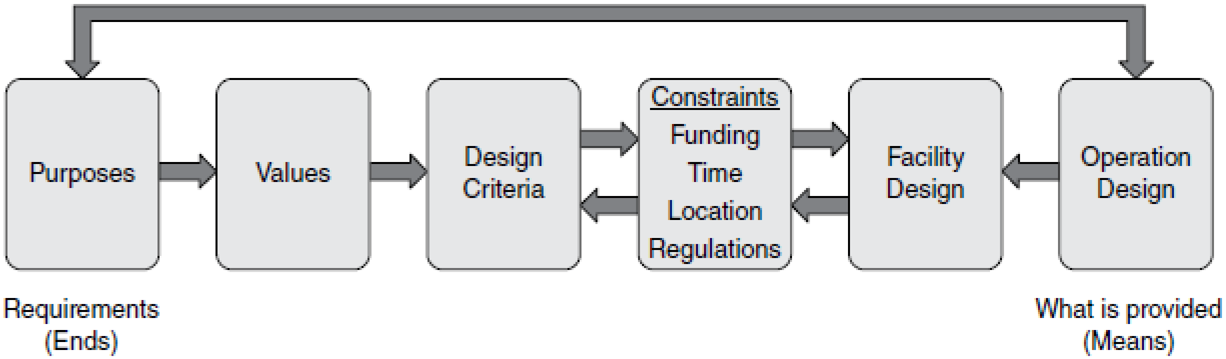
A representation of the lean project definition process



Project definition phase – Definition & steps

What are three major variables here?

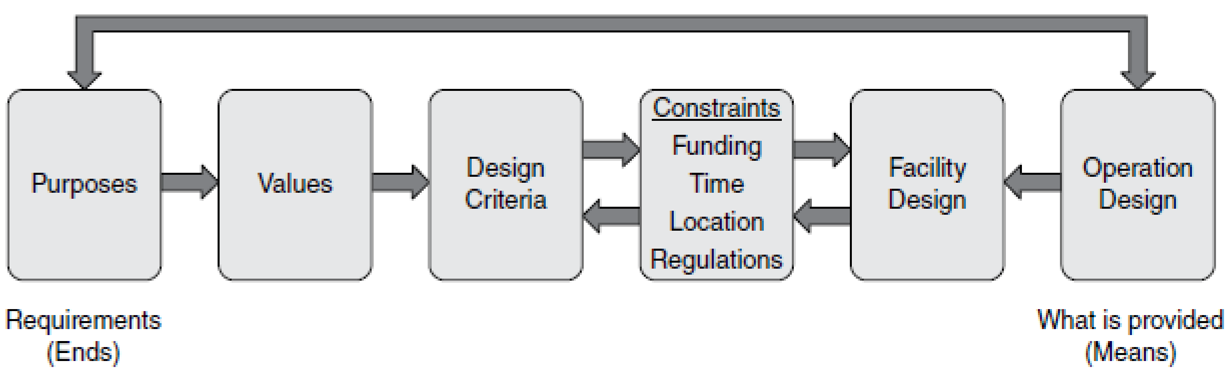
A representation of the lean project definition process



Project definition phase – Definition & steps

- The **team members** determine **three major variables**
  1. Ends,
  2. Means, and
  3. Constraints
- Overall, the **collaboration of many stakeholders** in the **project definition process** provides a **common understanding** of the project.

A representation of the lean project definition process



Project definition phase – Definition & steps

- For **customer/stakeholder satisfaction** with the overall project to be achieved,

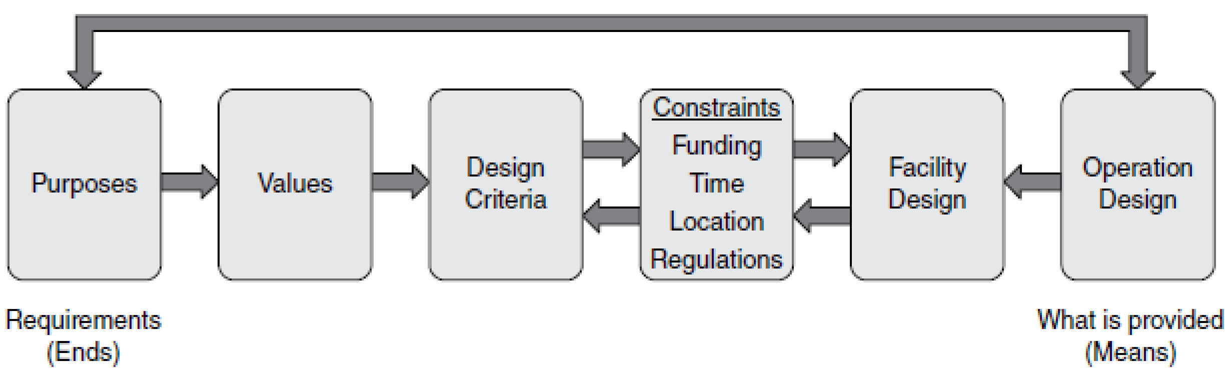
  value must be defined and agreed upon at the **very beginning**.

  Value - What the Customer wants from the process. The customer defines value.

- While **flow, pull, and striving for perfection** may take **different forms** during the **lean supply and lean assembly phases**,

  early clarification in the **project definition phase** sets the stage for **how** well a **facility serves its users** during its **entire life cycle**.

A representation of the lean project definition process



Project definition phase – Establishing design criteria

- The **design criteria** define the **owner's basis of design (BOD).**
- It reflects the **owner's needs and wants** that must be satisfied by the design of the project.

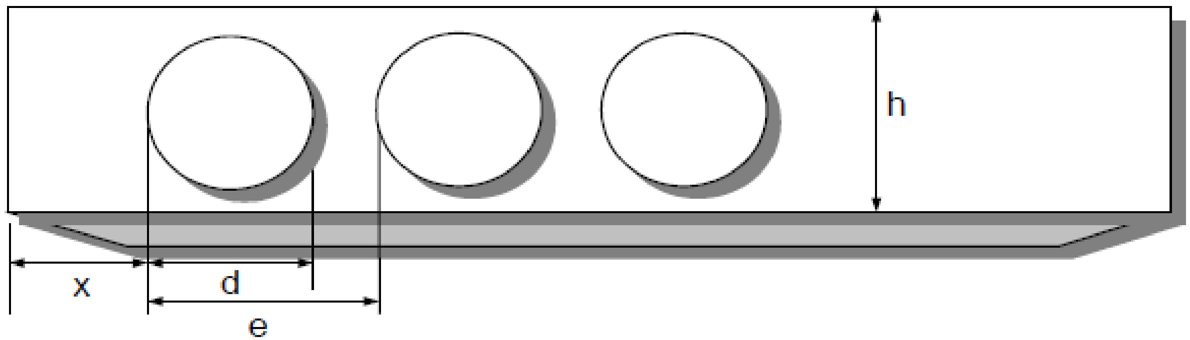
Voice of the Client	Voice of the Designer
"I don't want people to be disturbed by sounds other than those from the stage."	"Design to a decibel level of 17."
"We're going to operate this facility, so we need to keep energy costs low."	"Select HVAC equipment for low energy consumption."
"We're in a race with a competitor. We think we're ahead, but don't know how much."	"Accelerate project delivery within the bounds of safety, quality, and spending limits."

Project definition phase – Establishing design criteria

Make Team Communication Visual

Project definition phase – Establishing design criteria

- Waste in design needless (negative) iterations



Project Partner	d (mm)	e (mm)	h (mm)	x (mm)
Architect	550	650	650	500
Steel Fabricator	550	**900**	650	**1100**
Engineer	**200**	900	650	1100
Architect	200	900	650	**1000**
HVAC Subcontractor	**450**	**800**	650	**600**
Engineer	**400**	**900**	**730**	**700**
Steel Fabricator	400	900	730	**800**
.....	.....	.....	.....	.....

From Lottaz, et al. "Constraint-Based Support for Collaboration in Design and Const." Jrnl of Computing in Civ.Eng., 1/99

Project definition phase – Sustainability

- Fischer et al. 2017 describe a **sustainable building** as one that works in **harmony** with its **natural**, **social**, and **economic** contexts.

- **Other definitions** include concepts of
  - **Green building** design and construction,
  - **Reuse and recycling** of materials,
  - **Reduced use** of material and
  - **Energy resources** for building construction and operation, **water conservation** and responsible stewardship of the surrounding environment.

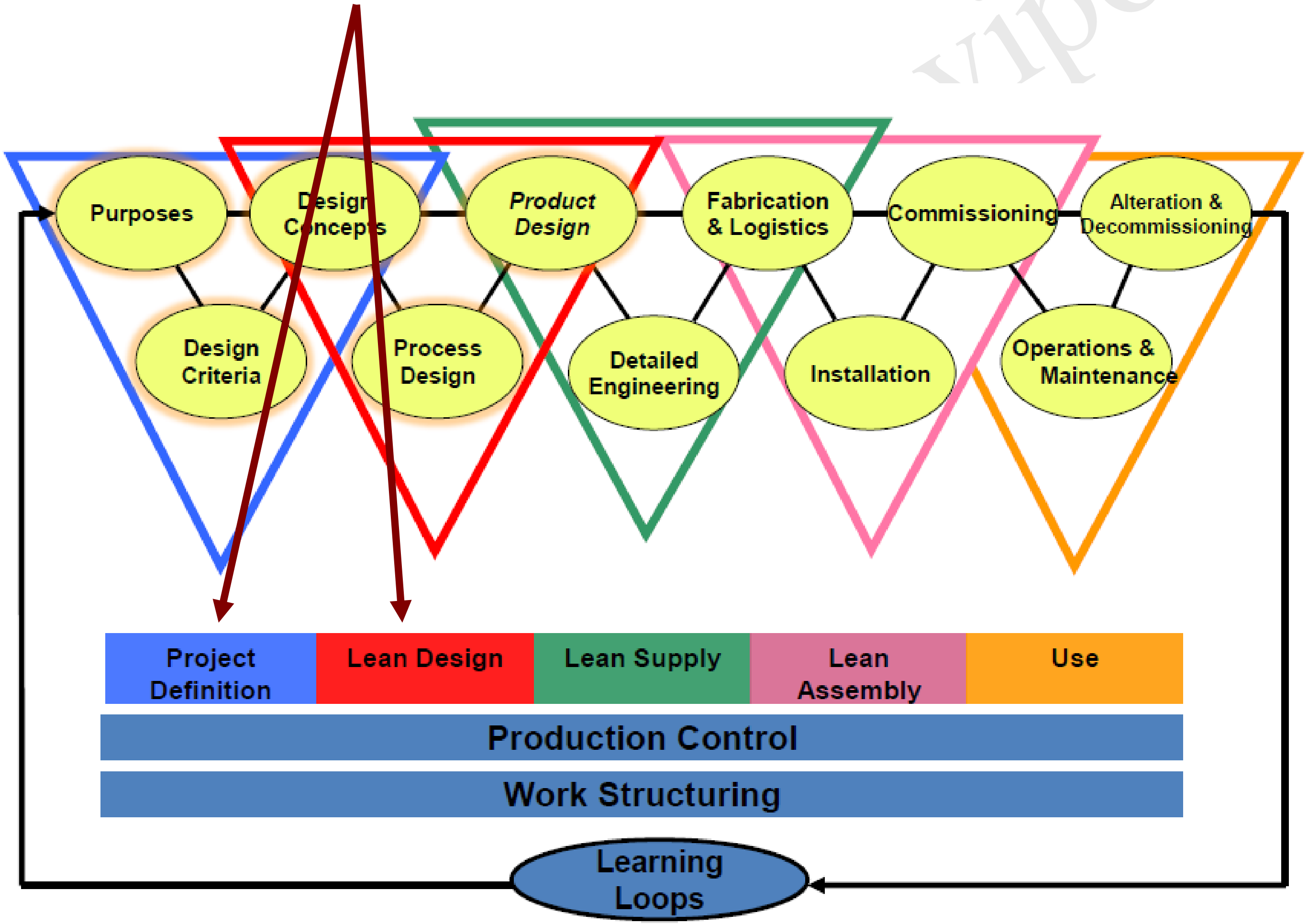
A green building (or "sustainable building") is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner.

Lean Project Delivery System

(Lean Design Phase)

Structure of the lean project delivery system (LPDS)

- We will discuss this part at this section



Lean design phase – Definition

- The **lean design phase** builds on the **output** from the **project definition phase**.
- It is represented by the **second triad** of the lean project delivery system.
- It is absolutely important to have **value defined** at the **beginning of the design process**.
- **Some definitions of value** are at conformance to **design and specifications**, **fitness for use**, and the **fundamental lean principle** that drives the value stream, flow, pull, and striving for perfection.
- **Without a clear definition** there is a **risk** that some actions taken may actually **reduce customer value.**

Lean design phase – Steps

Organize in Cross Functional Teams	* Involve downstream players in upstream decisions * Alternate between all-group meetings and task force activities * Create and exploit opportunities to increase value in every phase of the project
Pursue a set based strategy	* Select from alternatives at the last responsible moment * Share incomplete information * Share ranges of acceptable solutions
Structure design work to approach the lean ideal	* Simultaneous design of product and process * Consider decommissioning, commissioning, assembly, fabrication, purchasing, logistics, detailed engineering, and design * Shift detailed design to fabricators and installers
Minimize Negative Iteration	* Pull scheduling * Design Structure Matrix * Strategies for managing irreducible loops
Use Last Planner System of Production Control	* Try to make only quality assignment * Make work ready within a look ahead period * Measure PPC * Identify and act on reasons for plan failure
Use technologies that facilitate lean design	* Shared geometry; single model * Web based interface

Lean design phase – Factors

- The **primary factors** considered are:
  - **Designing** the **design process** itself (design work structuring)
  - **Obtaining** **collaborative inputs** from specialists
  - **Assigning** **detailed designs** to specialty contractors
  - **Conducting** **cross-functional discussions** to optimize product and process design
  - **Utilizing** **BIM** for unified modeling based on the inputs and needs of stakeholders
  - **Designing** for **usability with owners' facilities** maintenance staff
  - **Using** the **Last Planner® System** to reduce negative iterations and optimize delivery of design tasks meet schedules and commitments

Lean design phase – Tools and techniques

- **Some tools and techniques** suggested for **lean design** are:
  1. **Organize cross-functional teams**, involve downstream players in upstream decisions.
  2. **Use Set-based design** as concurrent engineering, to increase value via decisions at the last responsible moment.
  3. **Minimize negative iteration** even though design is not a linear process.
     - Use **pull scheduling** and a **design structure matrix**.
  4. **Apply production control**:
     - Utilize a **small design batch approach**, evaluating against project requirements purpose.
  5. **Use technologies** that facilitate lean design with a web-based interface such as BIM.

Lean Design Phase

(Some of Tools and Techniques)

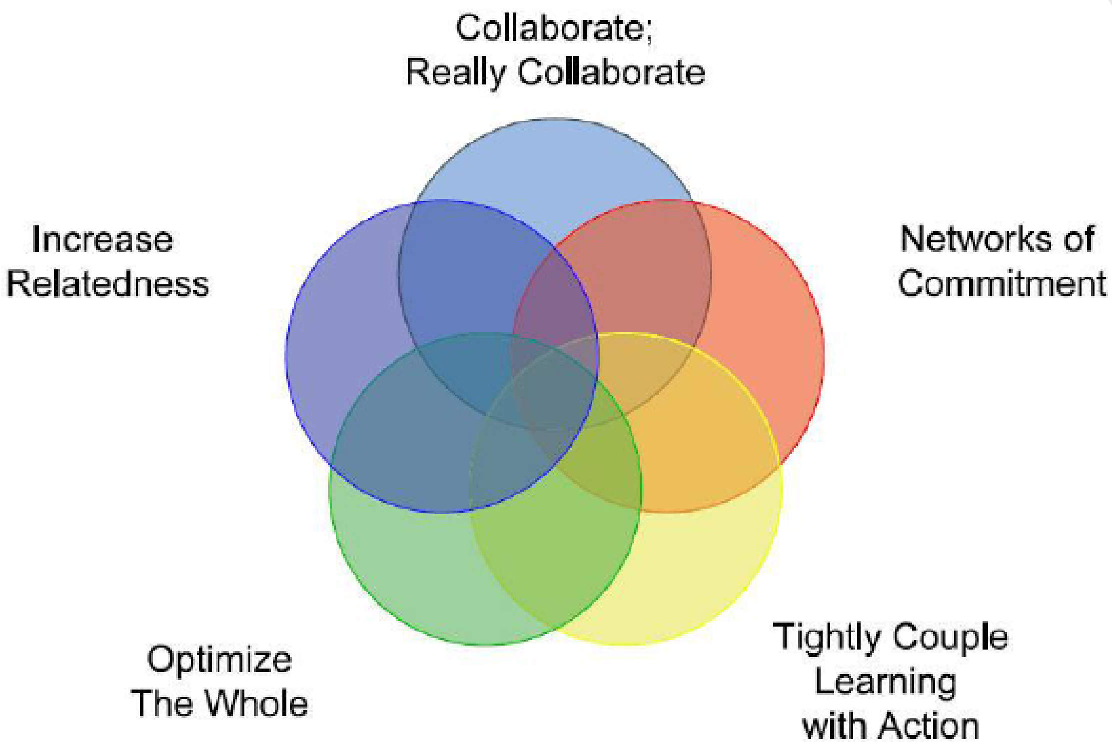
Building information modeling (BIM)

- **Building information modeling (BIM)** is a highly **productive tool** for carrying out lean design.
- It generally uses **3-D, real time, dynamic building modeling software** to increase productivity.
- **A building information model** is created for each facility, representing it in terms of **building geometry**, **spatial relationships**, **geographic information**, and **quantities and properties** of building components.

Building information modeling (BIM) and lean

Integrated VDC-BIM & Lean

FIVE BIG IDEAS OF LEAN PROJECT DELIVERY



Building information modeling (BIM) in design phase

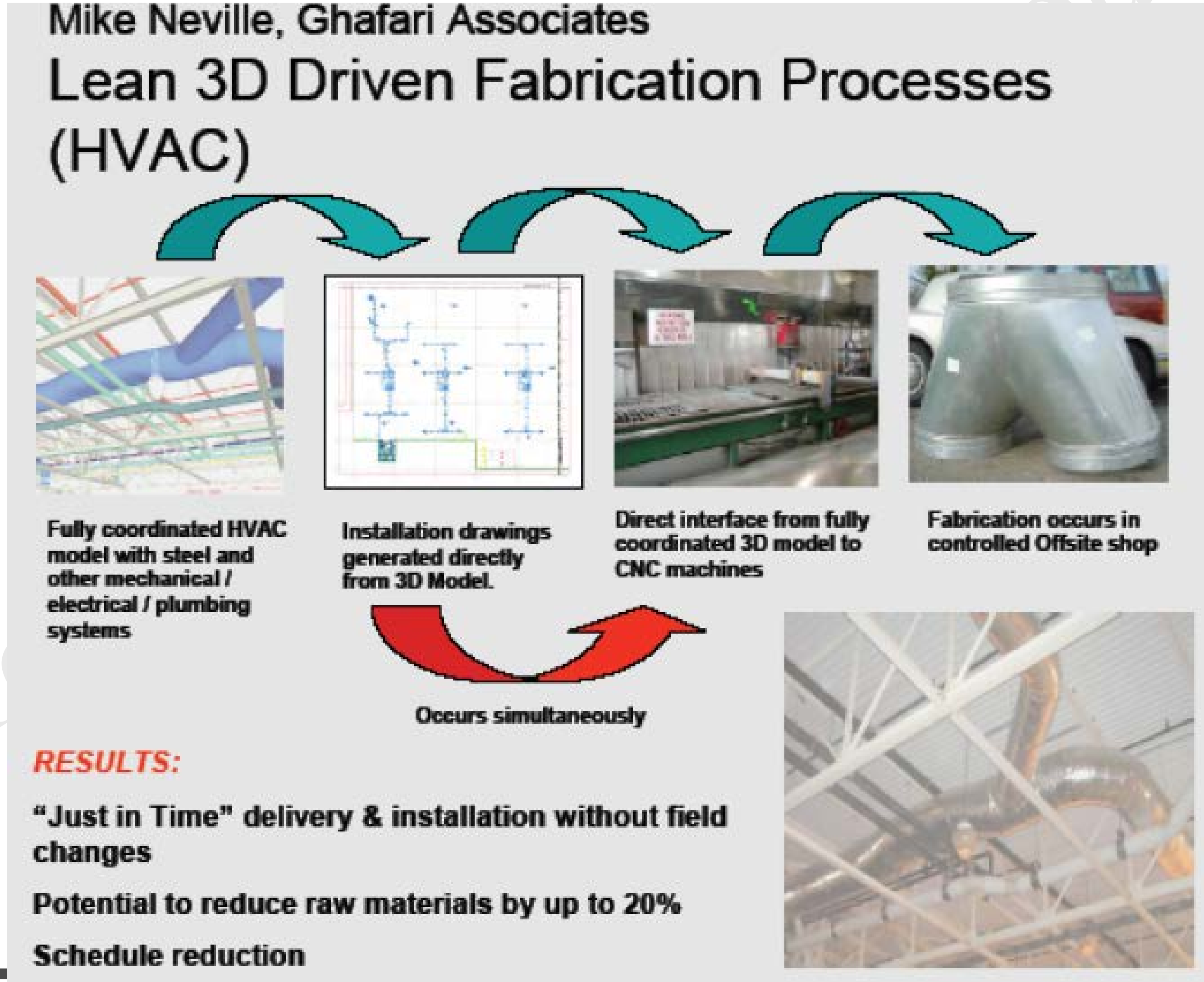
- **Lean design with BIM** was successfully used on the **El Camino Medical Group campus in Mountain View**, California.

- A **250,000 square foot medical office building** was included in the project, as well as a 420,000 square foot parking structure, at a **cost of $94.5 million**.

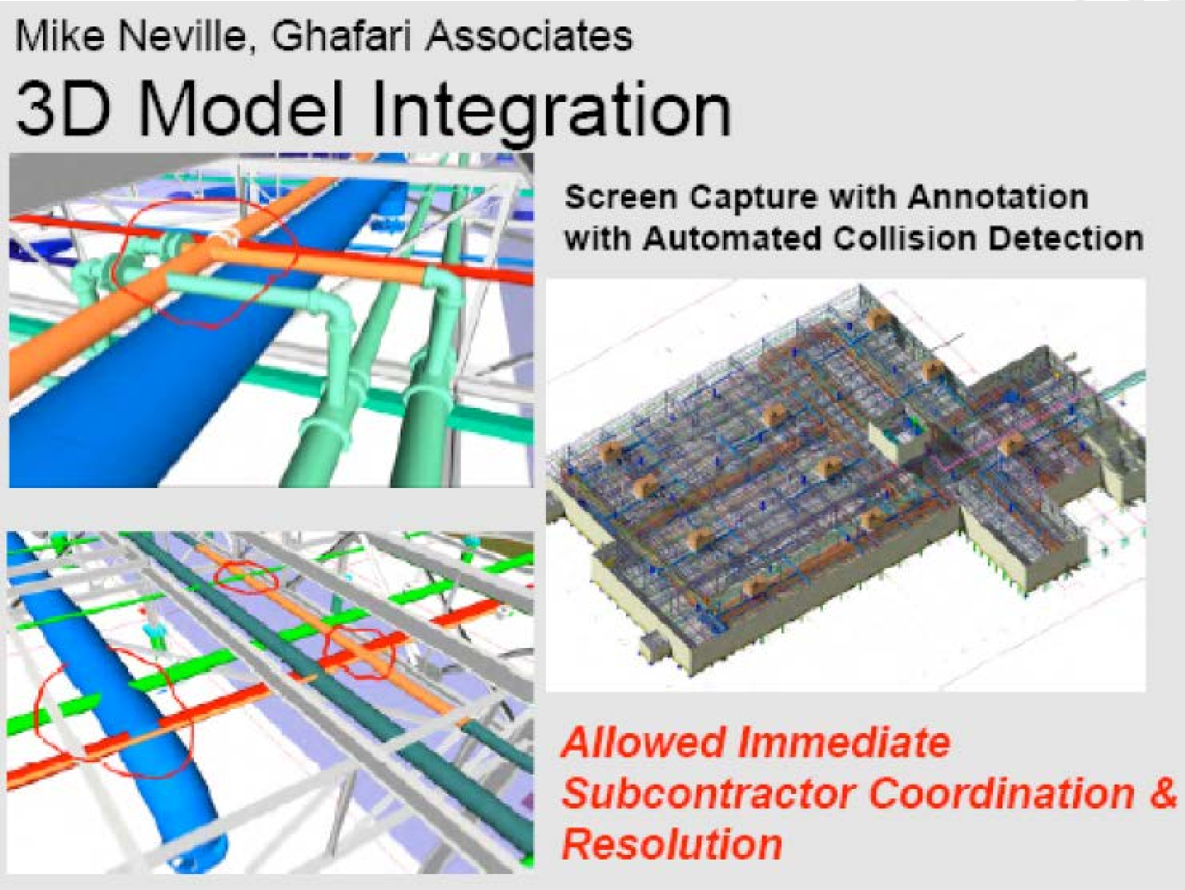
- The project schedule was **highly accelerated for early occupancy**, hence it was necessary to utilize **concurrent engineering approaches** to start construction activity while the **design was still in progress**.

- **The general contractor and a number of mechanical subcontractors** were engaged during the **design phases at approximately the same time** as the architect and the structural engineers.

Building information modeling (BIM) in design phase



Building information modeling (BIM) in design phase



LPDS and the last planner system of production control

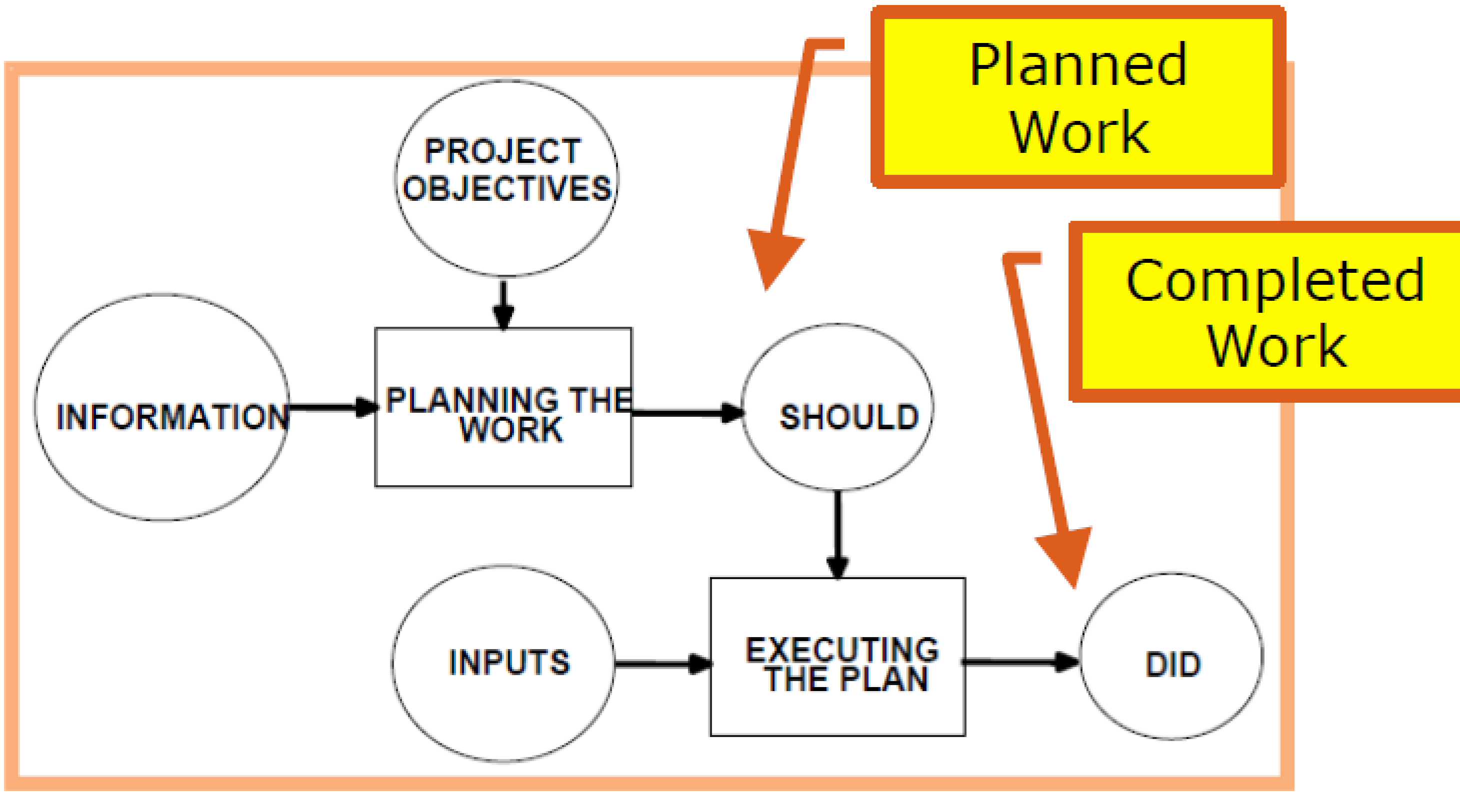
- The **Last Planner® System** of **production control** (LPS) is an important subset of the **LPDS**.

- It is a **collaborative commitment-based planning system** that **integrates** "should/can/will/did" planning with **constraint analysis**, and **work planning** based on reliable promising, and learning.

- It **facilitates continuous improvement** of processes by keeping track of plan reliability as **PPC values**.

- It also tracks the **reasons for non-completion (RNC)**, enabling project teams to adopt **countermeasures** and **continuously improve performance** during the course of a project.

A “push” system



Last planner system in design phase

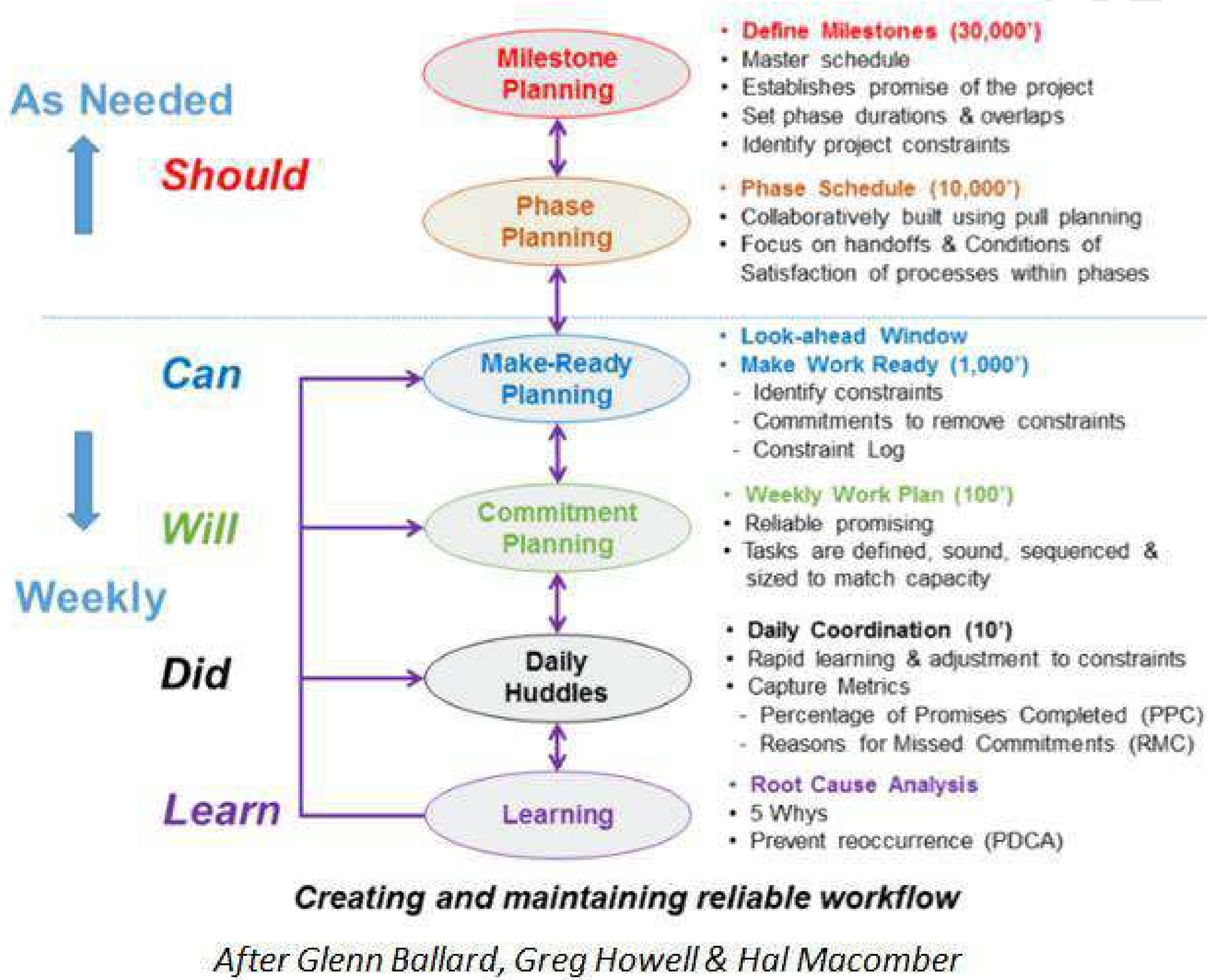
- The **LPS** has been **less frequently** used in **design** than in construction.
  - It involves **downstream project participants** in downstream decisions.

- The **design process** is **iterative**, with **backward loops** to explore alternatives, as **opposed to construction processes** which are **well documented** and **predetermined** by various schedules in the **LPS**.

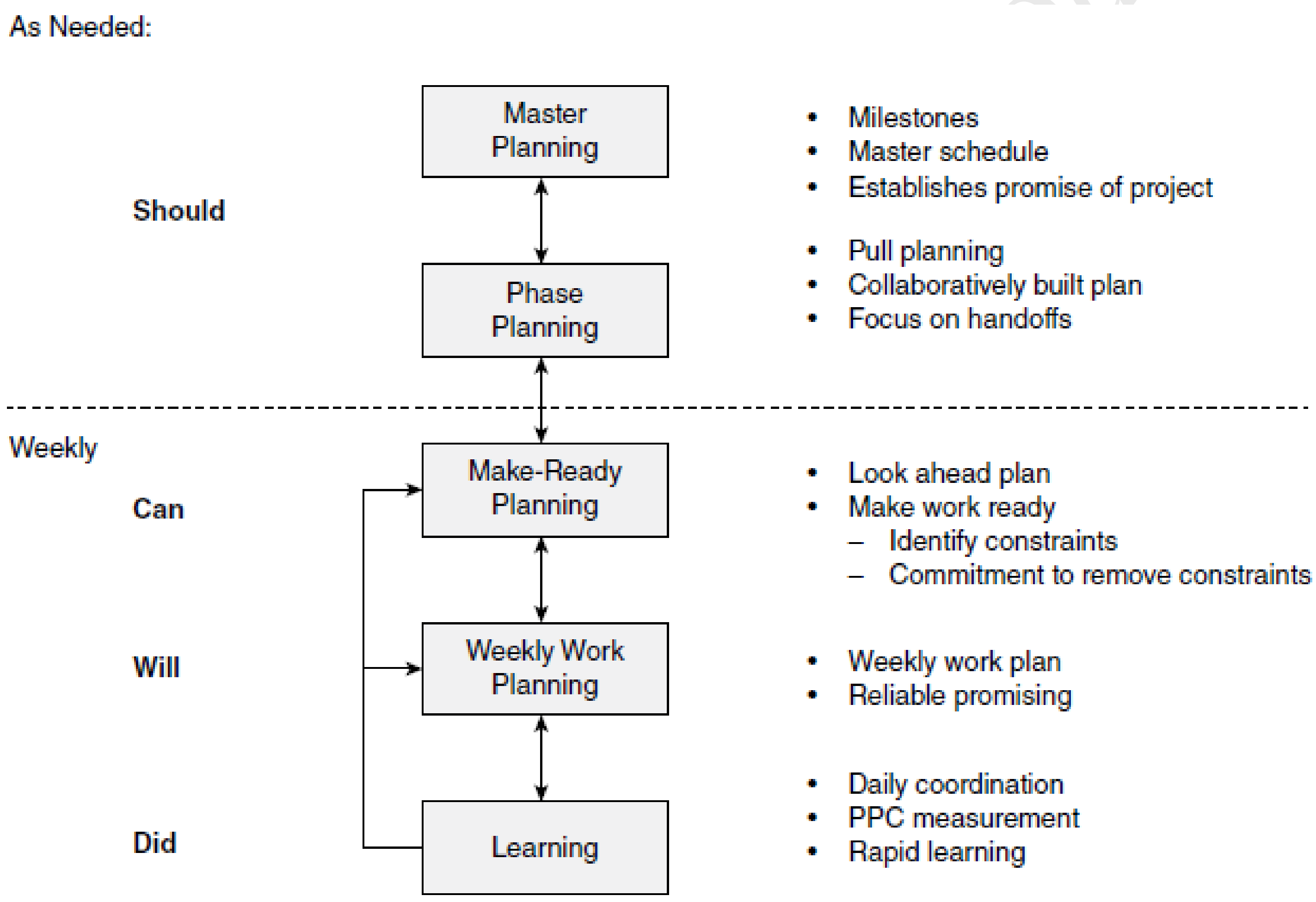
Last planner system – Key terms

- **Work Flow** - the movement of information and materials through networks of interdependent specialists.
- **Release of work** - making work available to the next specialist.
- **Dependence** - waiting on release of work.
- **Variation** (in the workflow) - the range of work completed each day or week.
- **Buffer** - a verb: "to isolate one activity from the next." It takes three forms: time, inventory, and capacity
- **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 specialist, related to productivity.
- **Push** - Advancing work based on a central schedule
- **Pull** - Signaling for components of work to arrive when they will be required.

Last planner system – Schematic



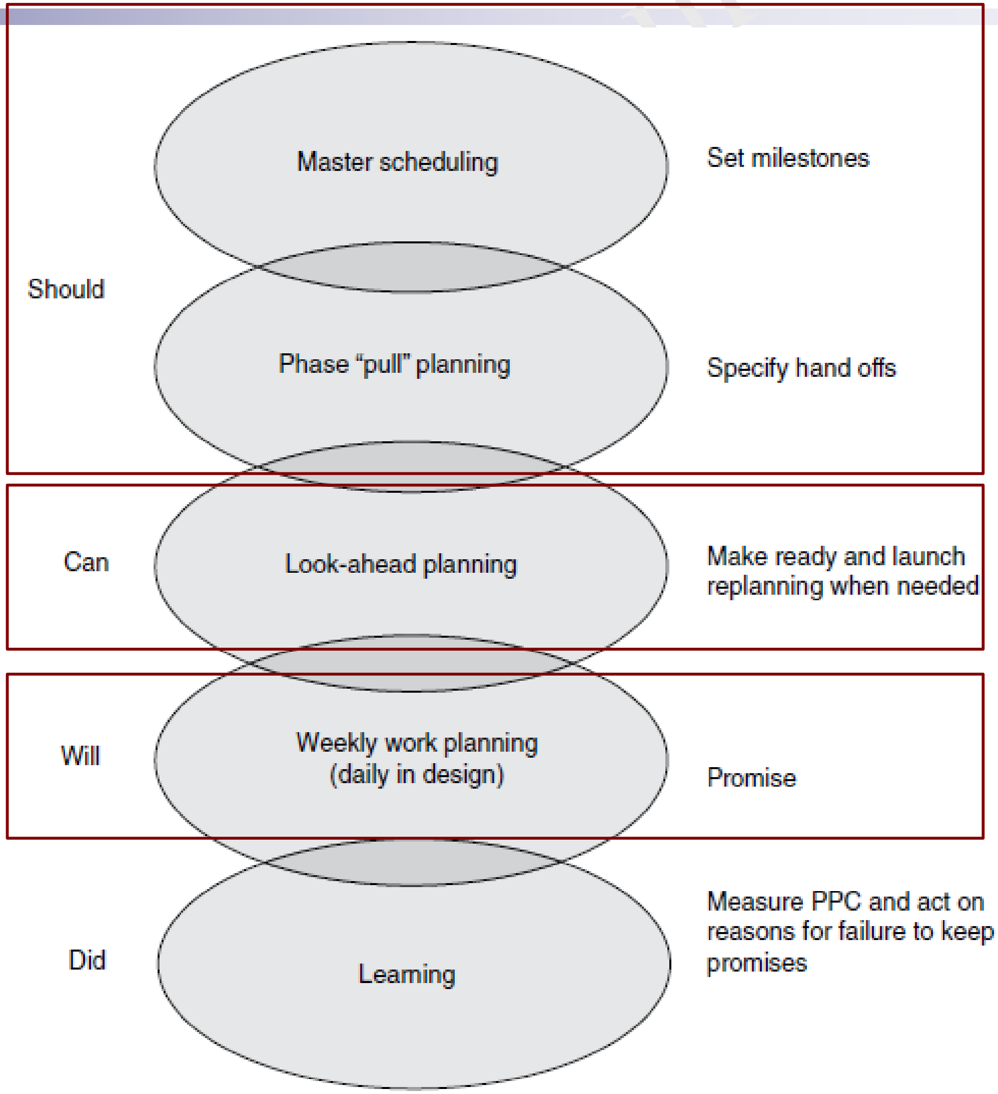
Last planner system – Schematic



Schematic of the Last Planner® System

Last planner system – Interconnected conversations

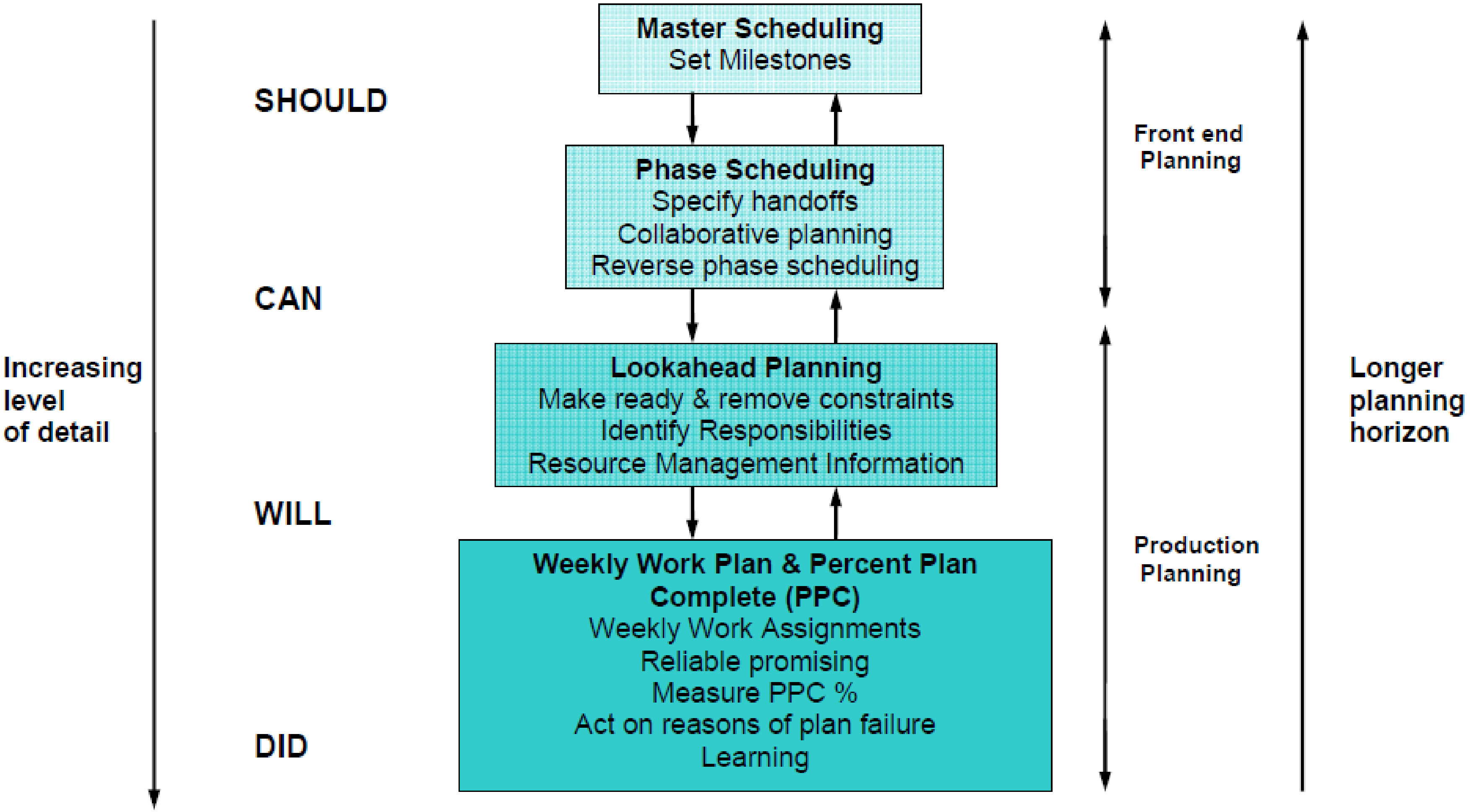
- The **LPS** is based on **three or four** levels of schedules and planning tools.
- Certain projects such as fast-paced **EPC projects** and/or projects involving **engineered-to- order components** may require a **daily work plan:**
  1. The master pull schedule
  2. The look-ahead schedule
  3. The weekly work plan (WWP)
  4. A daily plan (when required)



Interconnected conversations in The Last Planner® System

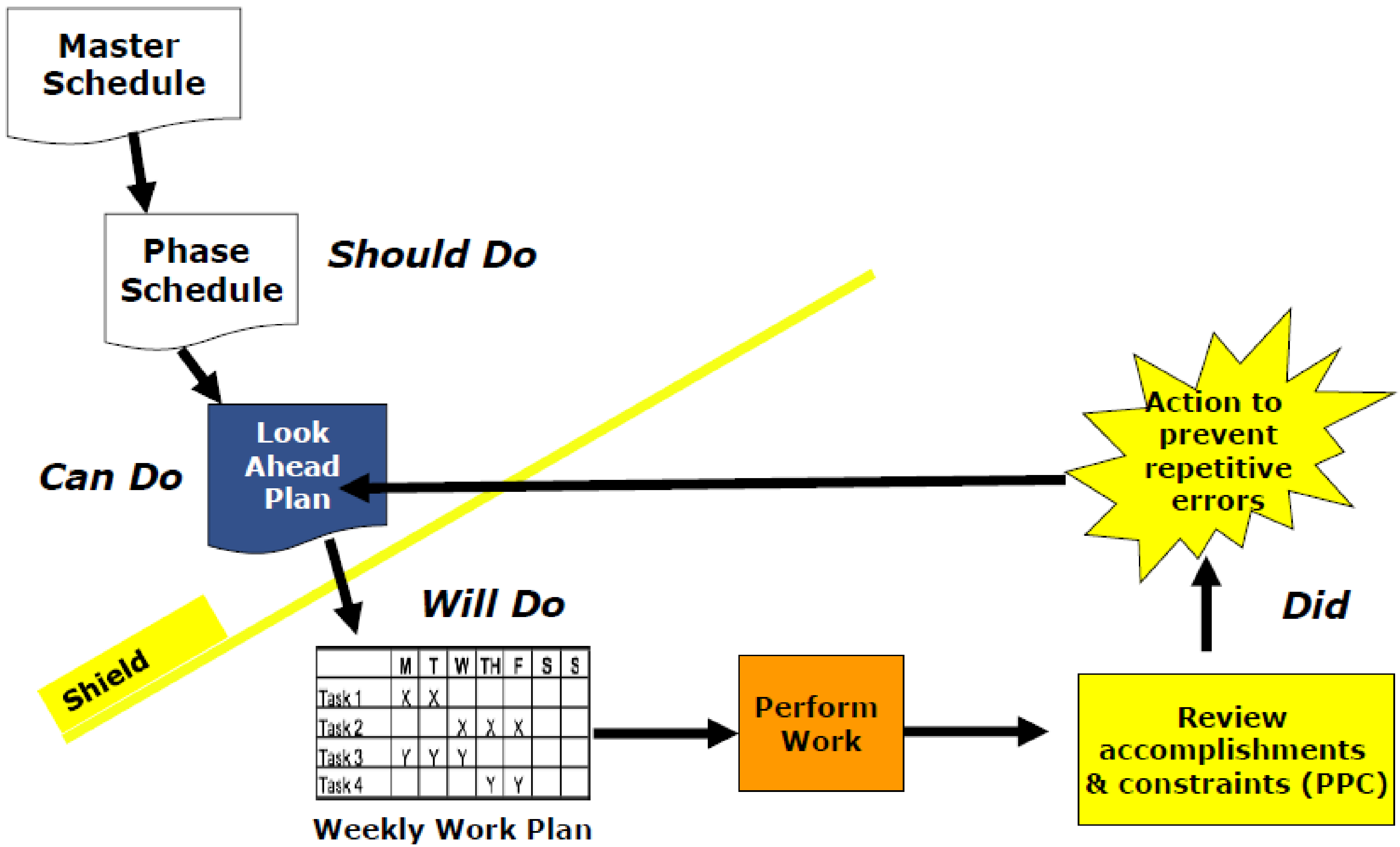
Source: With permission from the Lean Construction Institute. www.leanconstruction.org

Last planner system – Interconnected conversations

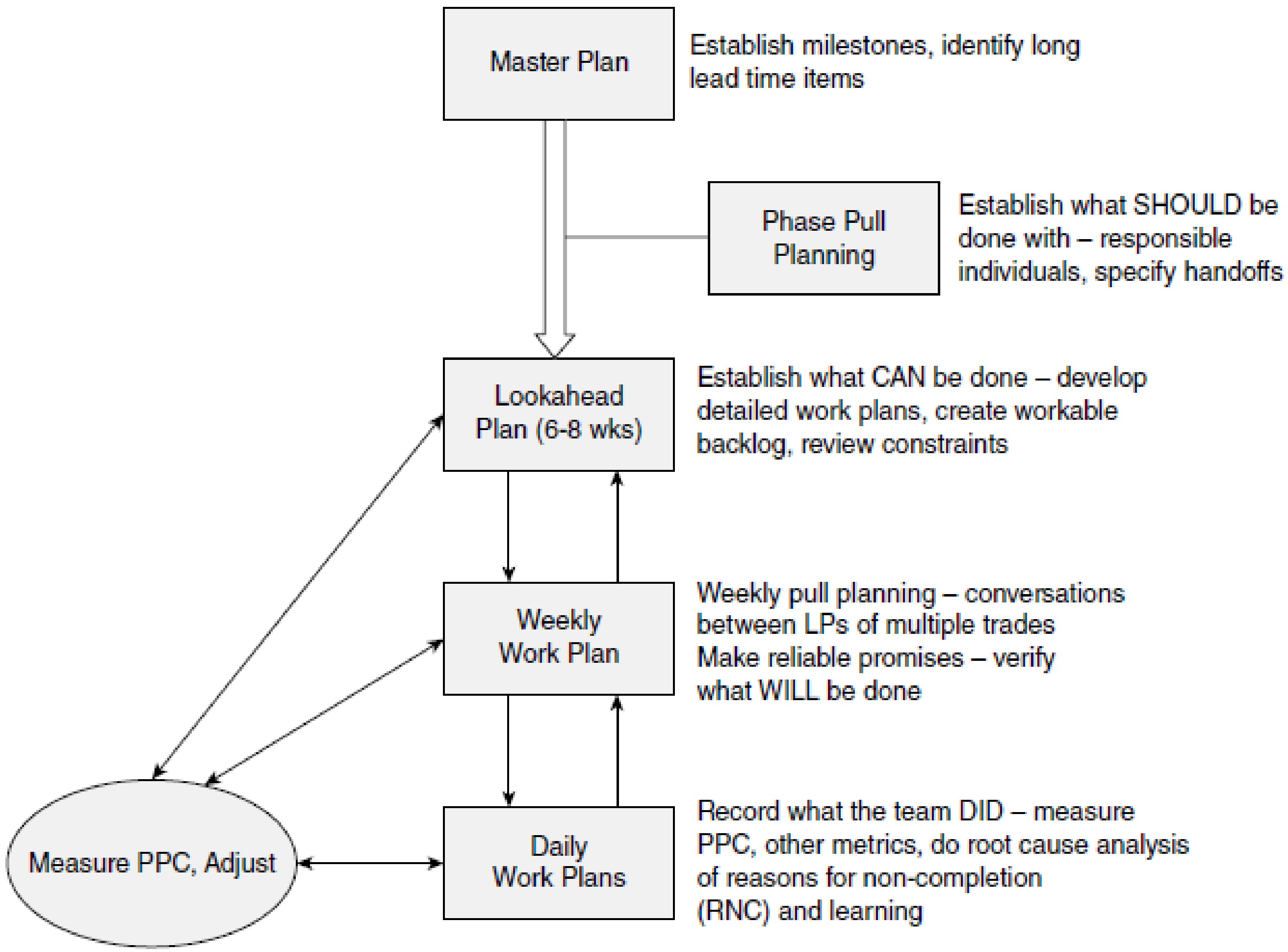


The Last Planner Planning Cycle

Last planner system – Activities and information flows

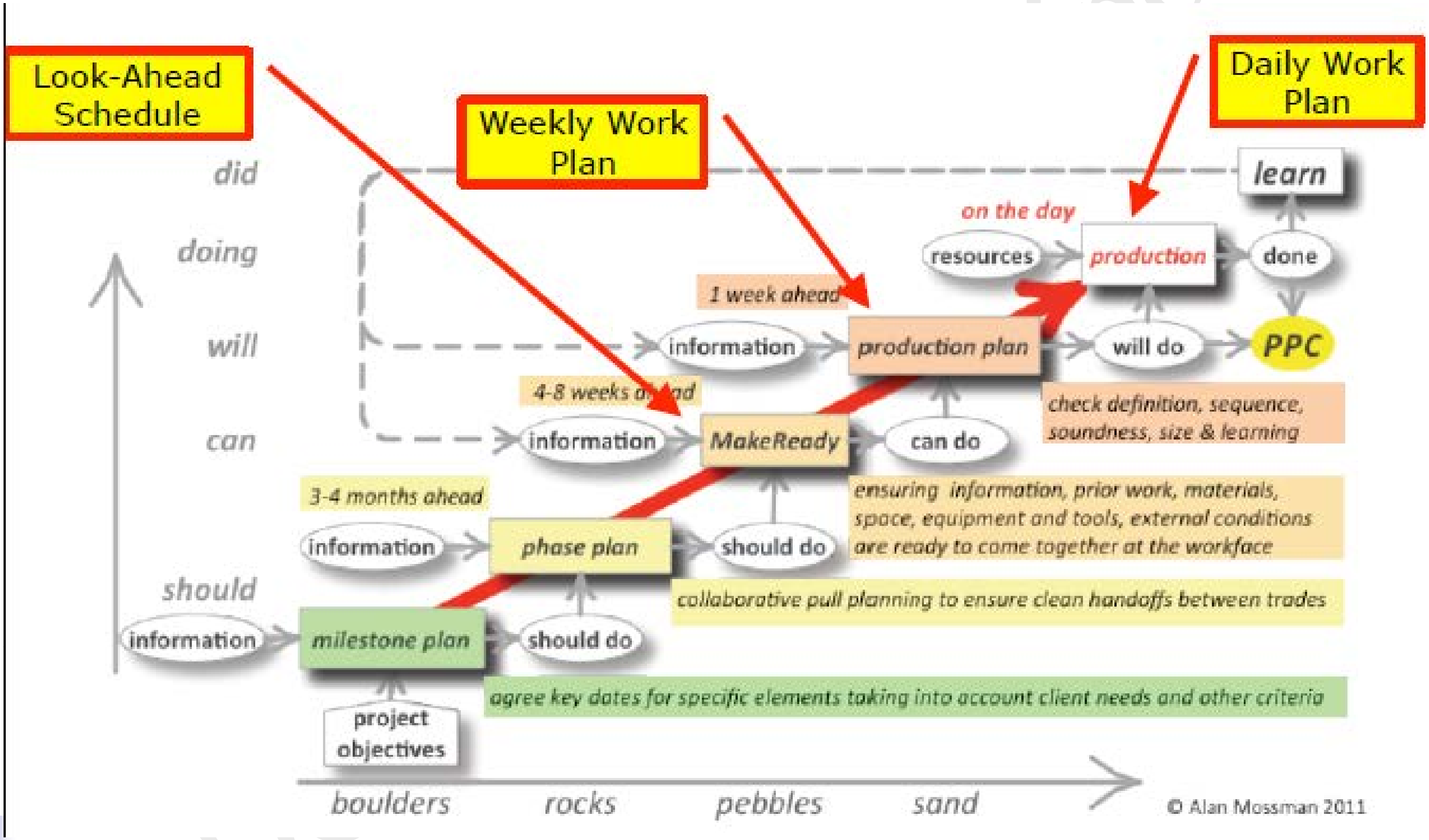


Last planner system – Activities and information flows



Activities and information flows in The Last Planner® System

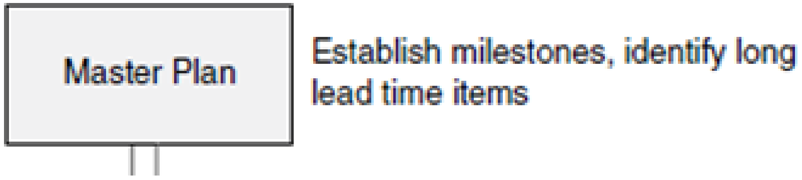
Last planner system – Activities and information flows



Last planner system – Activities and information flows

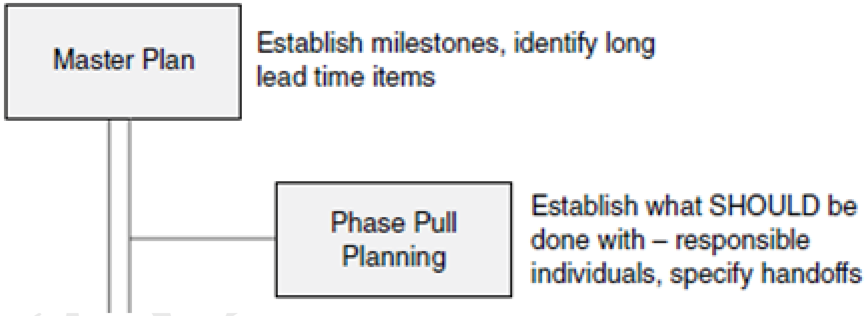
1. **Master Schedule** - Milestones Planning (CPM Schedule) – Identify tasks that Should be done
   - **Sets milestones**, **strategy** & identify **long lead items**
   - Typically **performed** by the **CM** and **project managers** from **each of the companies involved**
   - Incorporates **critical path method logic** to determine **overall project duration**.

This is so called front end planning (SHOULD)



Last planner system – Activities and information flows

2. **Phase Schedule** - Pull Planning - Identify tasks that Should be done
   - **Specify major tasks** needed to achieve milestones (**usually 3-4 months ahead**)
   - **Specify handoffs**; Identify operational control
   - Typically **performed** by the **foremen** from **each of the companies involved** in that phase of work

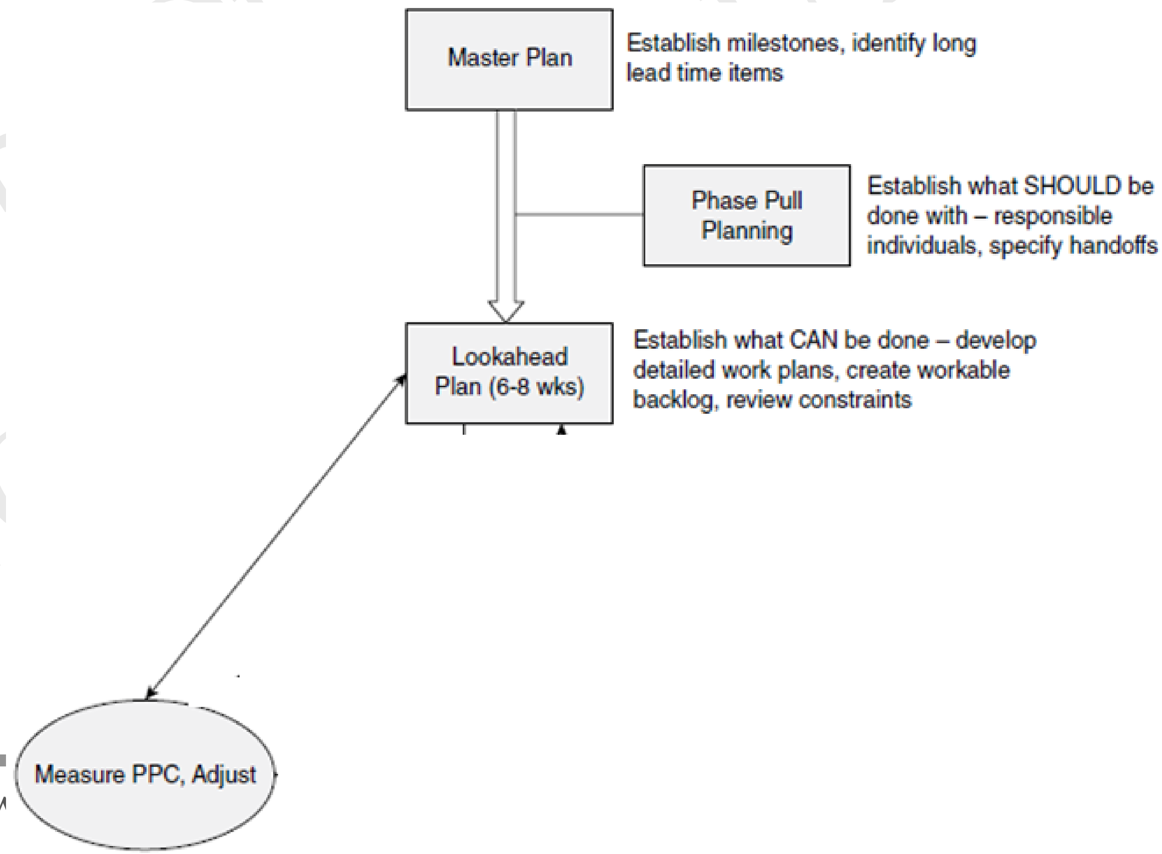


This is so called front end planning (SHOULD)

Last planner system – Activities and information flows

3. **Look-Ahead Schedule** - Make Work Ready Planning - Identify tasks that Can be done
   - ❖ **Begins** with **detailed activities** on the **phase schedule** into the look-ahead plan.
   - ❖ **Make ready & launch** a list of activities need to be worked over the **4-8 weeks**
   - ❖ Typically **performed** by the **foremen** from each of the companies involved;
   - ❖ **Updated weekly** where **constraints** that threaten reliable workflow are studied
   - ❖ **Re-plan** when needed

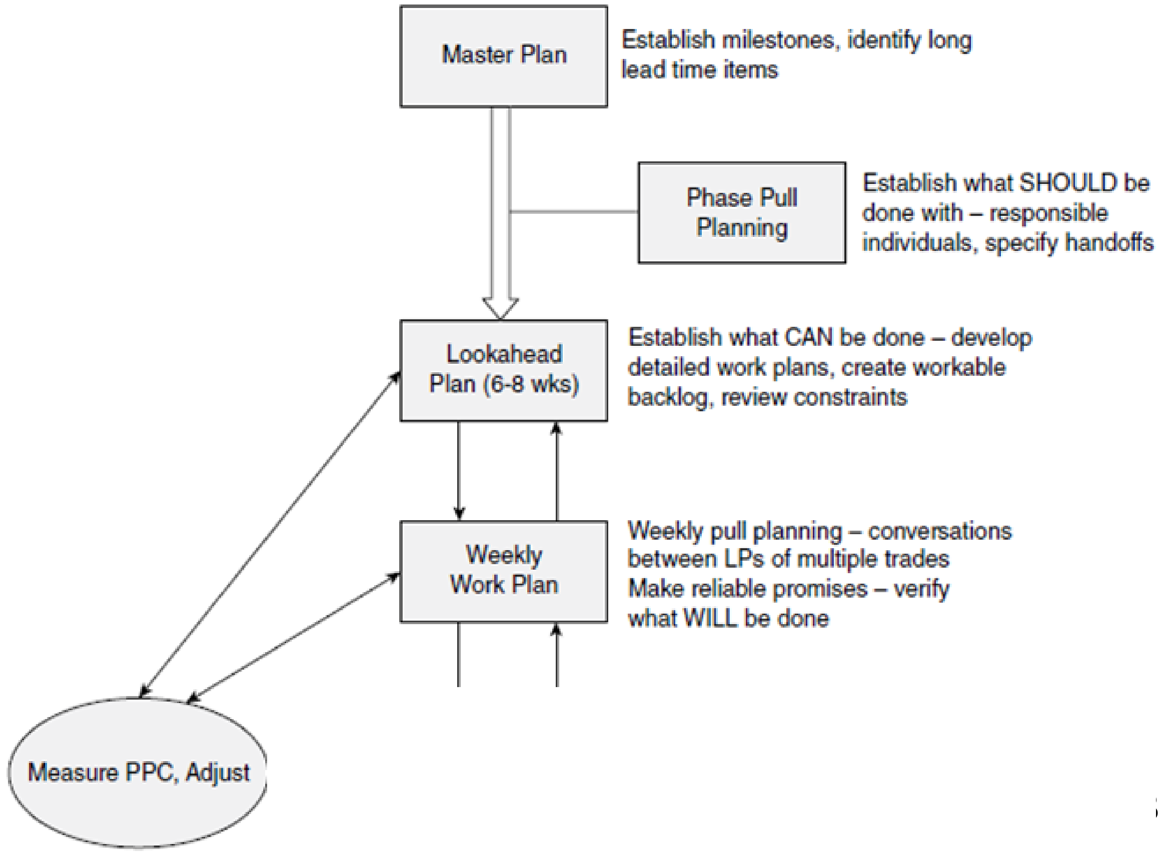
This is so called production planning (CAN)



Last planner system – Activities and information flows

4. **Weekly Work Plan** – Production Planning - Identify tasks that Will be done
   - **Most detailed** plan in the system if **daily not exists**.
   - **Plan reliability** promoted by making only **quality assignments** and **reliable promises** so that the **production unit**.
     - ✓ **Promises** by **foremen** to complete specified tasks

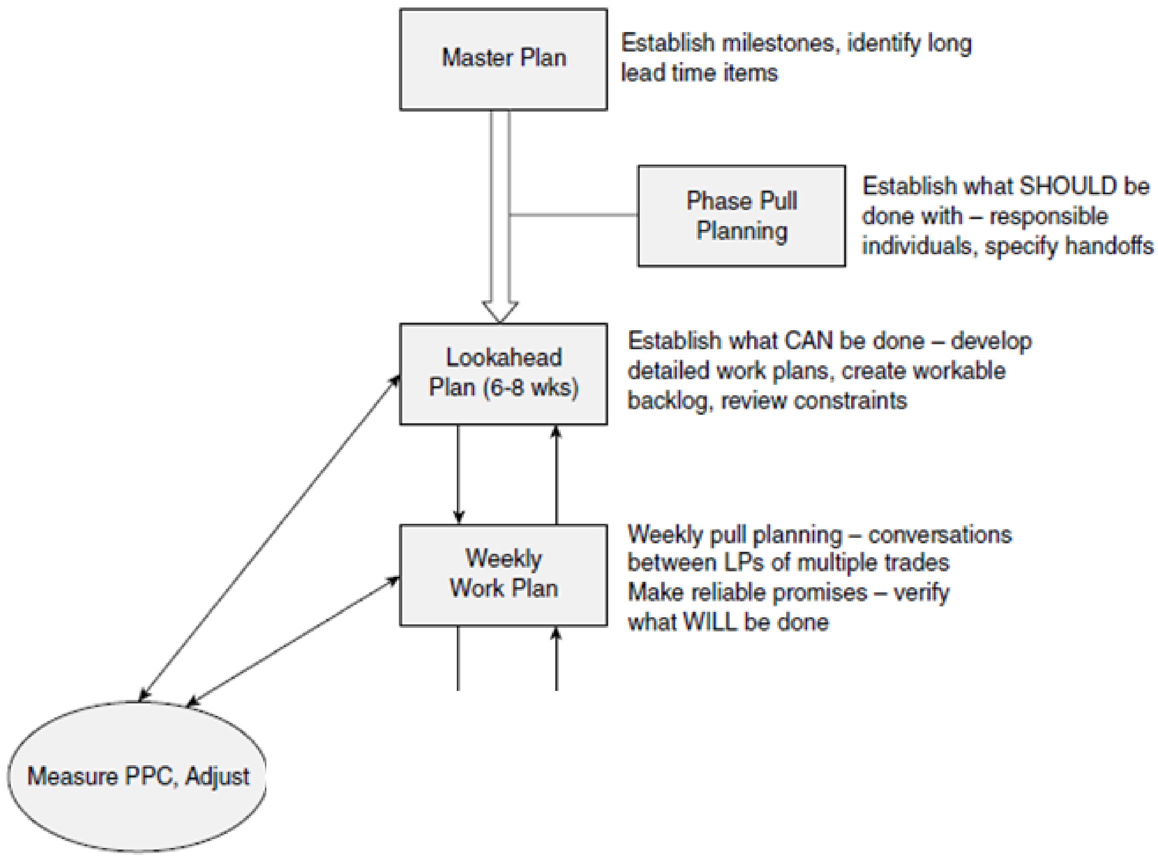
This is so called production planning (WILL)



Last planner system – Activities and information flows

4. **Weekly Work Plan** – Production Planning - Identify tasks that Will be done
   - The work assignment is a **detailed measurable commitment** of completion.
   - At the **end of each week**, assignments are **reviewed for completeness** in order to **measure the reliability** of the planning system.
     - ✓ **Analyzing reasons for plan failures** and **acting on these reasons** is the basis of learning.

This is so called production planning (WILL)

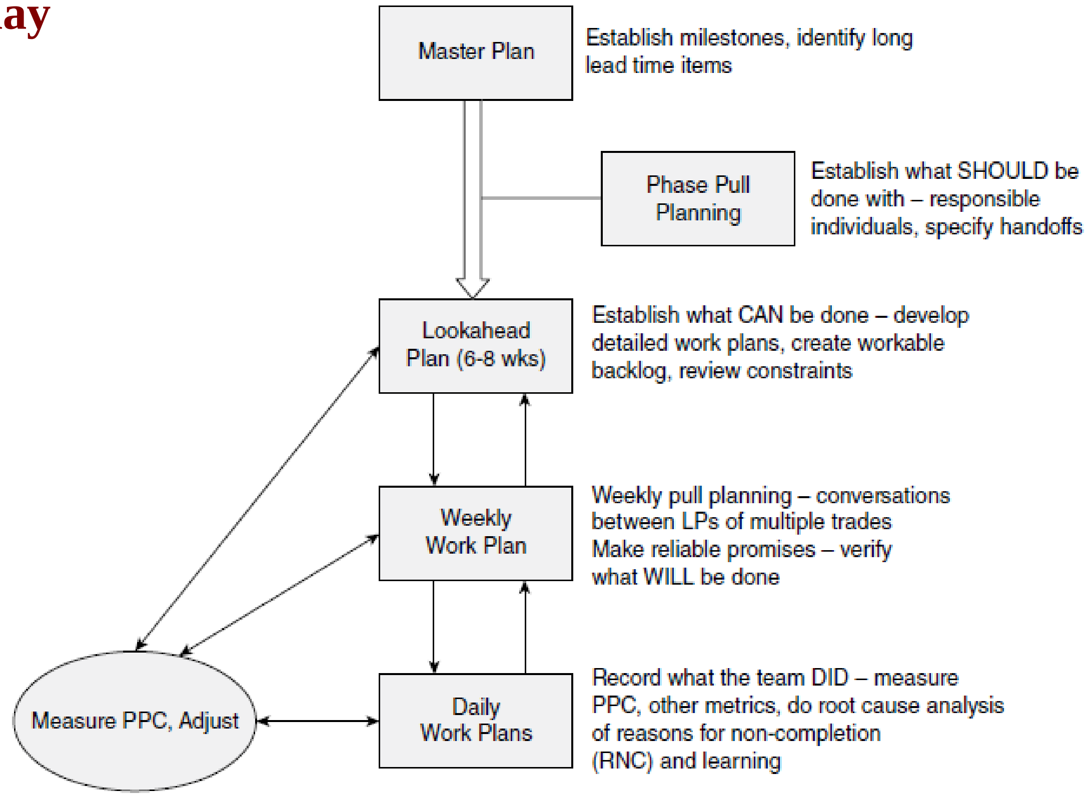


Last planner system – Activities and information flows

5. **Daily Work Plan / Daily Huddle Meetings** – Production Implementation - Identify tasks that Were done

   - **Document** what **was completed yesterday** and
   - **Make adjustments** for **today**

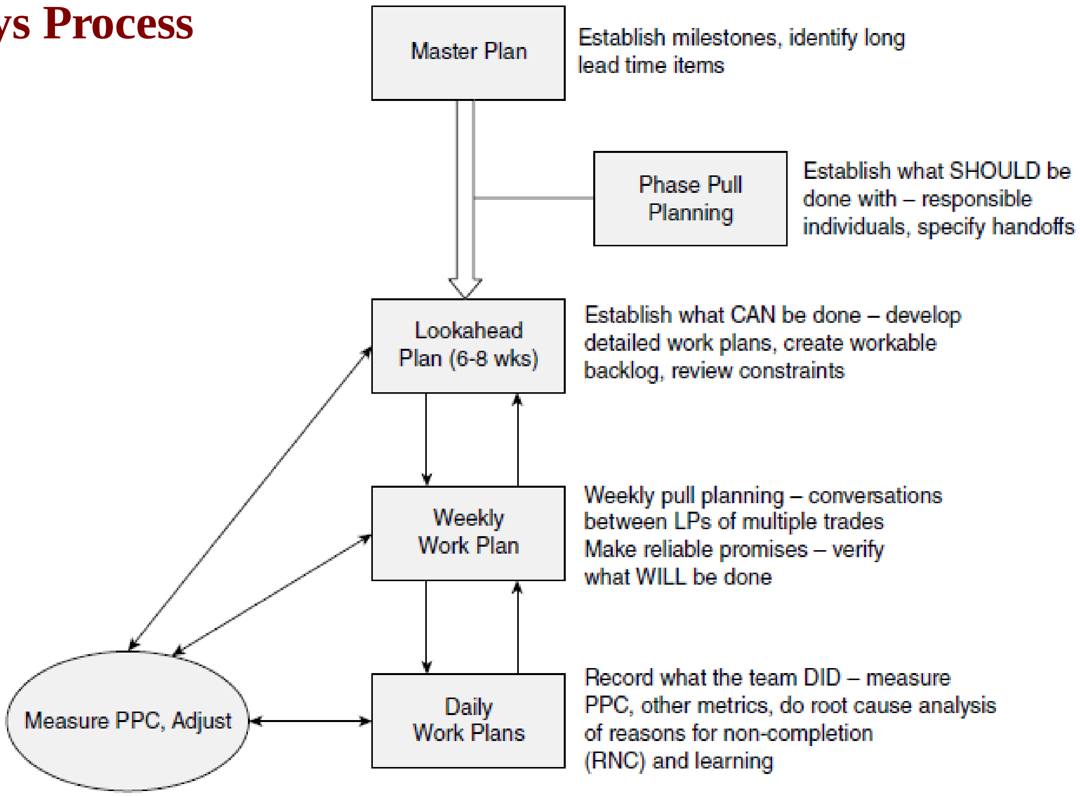
This is so called **production planning** (WILL)



Activities and information flows in The Last Planner® System

Last planner system – Activities and information flows

6. **Learning** - Identify and review tasks that Were done
   - **Measure Percent Plan Complete (PPC)**
   - **Act** on **reasons** for failure to keep promises
   - **Reasons Analysis**: systematic identification of the reasons that tasks were not completed
   - **May need** to use the **5 Whys Process**



Activities and information flows in The Last Planner® System

Last planner system – Activities and information flows

How tasks are broken down into more detail?

PROJECT	is broken into…	MASTER SCHEDULE
MASTER SCHEDULE	is broken into…	PHASES
PHASE SCHEDULE	is broken into…	PROCESSES (LOOK AHEAD)
LOOK-AHEAD SCHEDULE	is broken into…	OPERATIONS (WEEKLY WORK)
WEEKLY WORK PLAN	is broken into…	OPERATIONS (DAILY WORK)

Master schedule

- The **master schedule** represents an **overall view** that identifies **major project phases** and **milestones** for these phases.

- It is produced during **front end planning** and represents the **timing of the various phases** a project goes through.

- This schedule is **broken down mainly** by function, area, or product.

- It covers the **entire project duration** and presents activities at a coarse level with a **long planning horizon.**

- As a product of **work structuring**, the master schedule reflects **important milestones** dictated by project **constraints and objectives**.

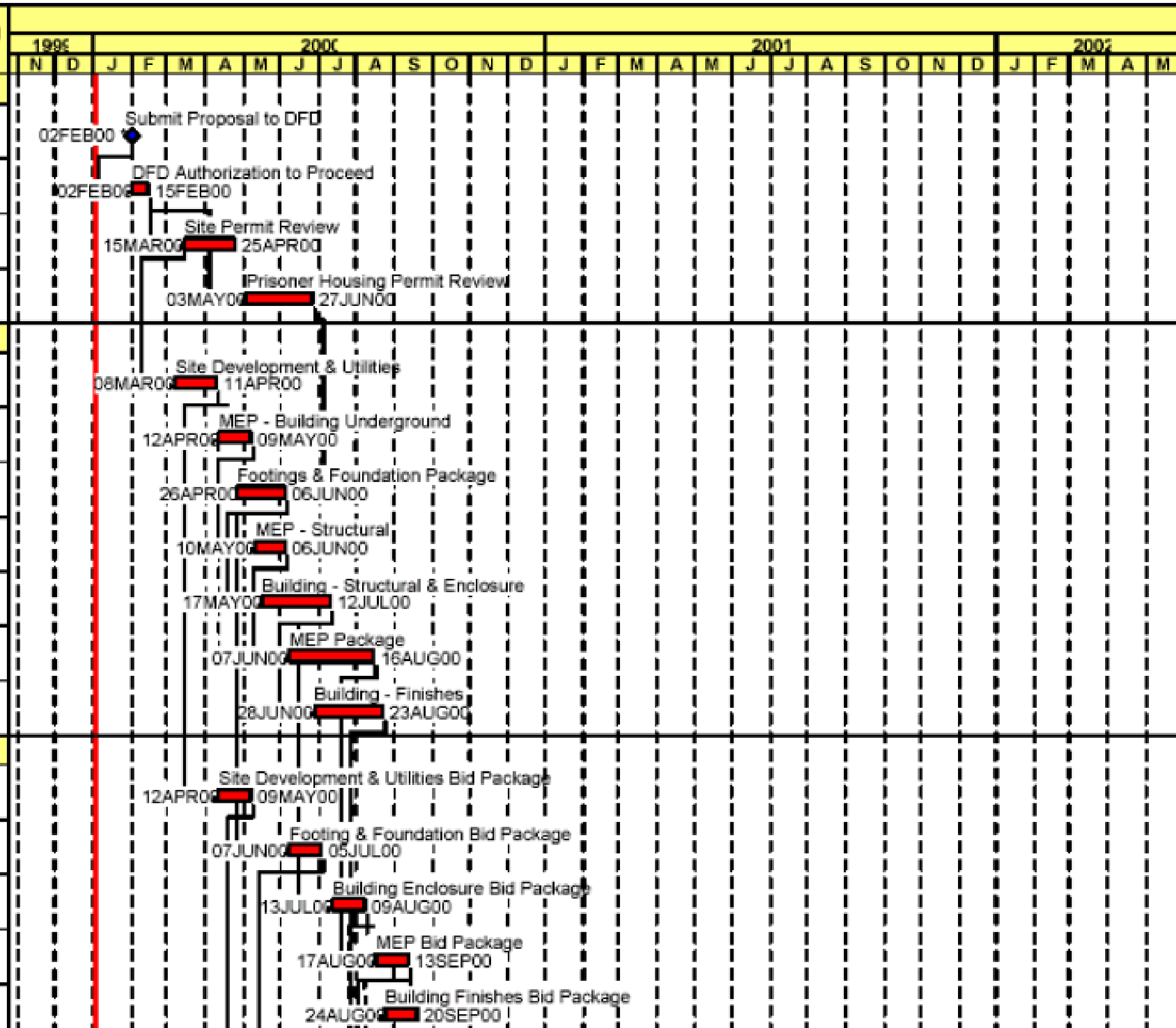
ACEMI

Master schedule

- **In design**, specific milestones would need to be developed for **design deliverables**.
- **Packages of tasks** are transferred **from the milestone schedule** by the **act of "pulling"** in response to the **downstream demand** of other team members.
- It is essential for a team to **collaborate in preparing a milestone** schedule of deliverables.
- In **construction**, **the master schedule** is typically included in the **contractor's bid**.

Master schedule

Act ID	Description	Orig Dur
Approval Process		
1000	Submit Proposal to DFD	0
1010	DFD Authorization to Proceed	10d
1030	Site Permit Review	30d
1050	Prisoner Housing Permit Review	40d
Design Phase		
1080	Site Development & Utilities	25d
1105	MEP - Building Underground	20d
1085	Footings & Foundation Package	30d
1115	MEP - Structural	20d
1090	Building - Structural & Enclosure	40d
1095	MEP Package	50d
1098	Building - Finishes	40d
Bid Packages		
1240	Site Development & Utilities Bid Package	20d
1250	Footing & Foundation Bid Package	20d
1270	Building Enclosure Bid Package	20d
1260	MEP Bid Package	20d
1470	Building Finishes Bid Package	20d



Reverse phase scheduling (pull planning)

- **Reverse Phase Scheduling** or **"Pull Planning"** involves **working backwards** from the **deliverables** of the completed project,

  determining what needs to be done at **each stage** to complete the **preceding activity**.

- In developing a pull **plan for one week**, for example,

  discussion would occur at a **planning board** designed for the purpose with a **separate column for each day** of the week.

Why reverse planning?

Reverse phase scheduling (pull planning)

- A **pull technique** is based on working from a **target completion date backswords**, which **causes tasks** to be **defined and sequenced** so that their **completion releases work**; i.e., **achieves a handoff**.
  - Following that rule **reduces the waste of overproduction**.
    - Working backwards from a target completion date **eliminates work** that has customarily been done **but doesn’t add value**.

Reverse phase scheduling (pull planning)

- In the **case of design**

  it is a **detailed work plan** that

  specifies the **handoffs** between specialists for **each stage of design**,

  indicating what **SHOULD** be done at each phase.

- In **lean construction**, the **reverse phase schedule** is developed through

  conversations with the **primary project team representatives**,

  including their **last planners**, typically with **sticky notes** on a

  display board.

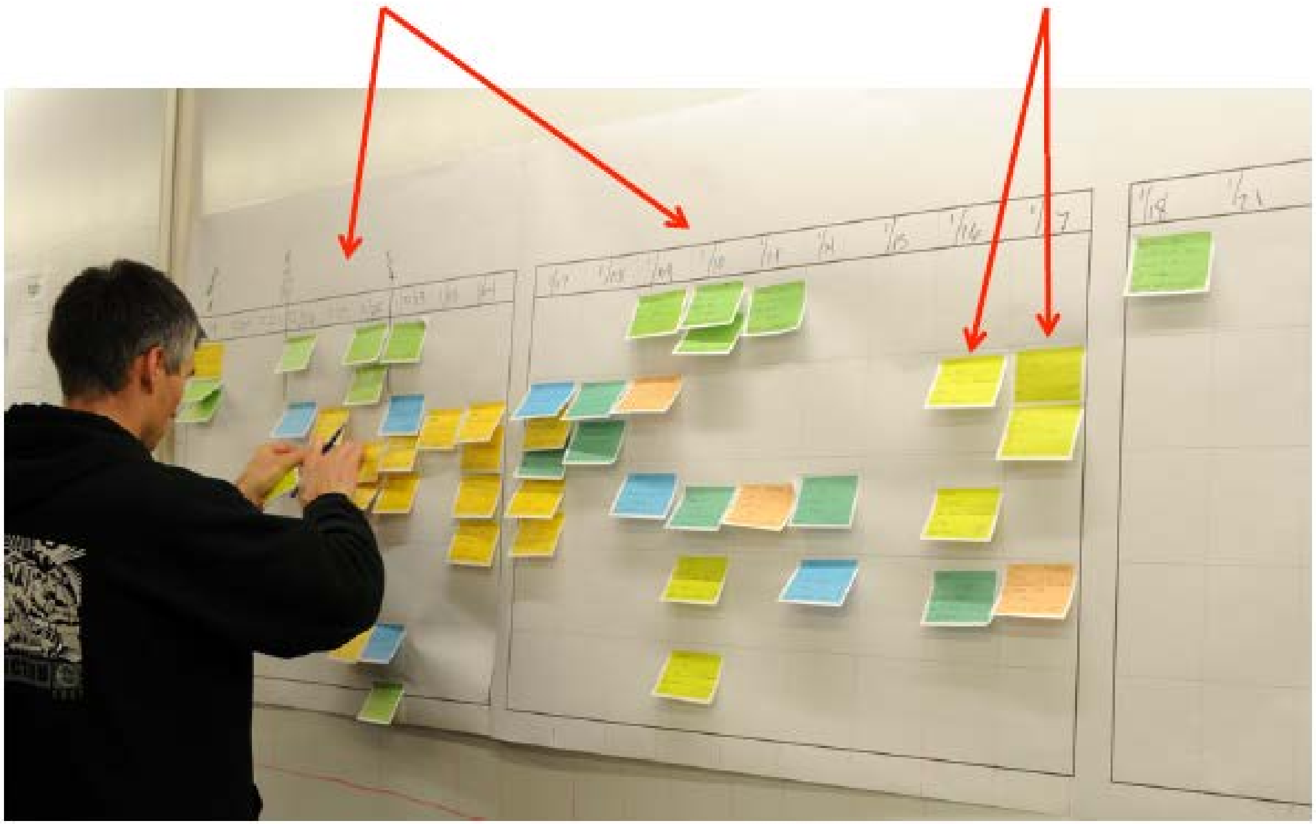
Reverse phase scheduling (pull planning)

Front end planning produces the project **budget** and **schedule**.

It provides a **coordination map** that pushes **completion** and **deliveries** onto a project.

Reverse phase scheduling (pull planning)

What a pull plan looks like?



Reverse phase scheduling (pull planning)

What a pull plan looks like?

Reverse phase scheduling (pull planning)

We will see the steps of how to develop RPS (Pull planning) in Lean Construction

Look-ahead schedule

- The **look-ahead** planning process is the **middle level** in the planning system hierarchy, **following front end planning** which results in the **master schedule** and **phase schedule**.
  - It precedes **commitment planning** which results in the **weekly work plan**

- **Look-ahead** planning
  - ✓ **Details** and **adjust** **budgets and schedules**,
  - ✓ **Pulling** **resources** into play and
  - ✓ **Screening** **activities** for which **resources** are likely **not to be available**.

- **Look-ahead** planning **streamlines the work flow** for the Last Planner.

What time frame does the look-ahead cover?

ACEMI

Look-ahead schedule

- **Master schedule** covers all activities in the **entire project**, from start to finish.
- By **contrast**, the **look-ahead** typically spans **4 to 8 weeks out into the future** because of **uncertainty**
- **How far** out into the future the lookahead spans, is a function of
  - **Nature of the work** to be performed and
  - **Responsiveness** of the **suppliers** to the various activities.
    - ✓ **Some activities** have a **long supplier lead time**, so it takes a long time from the **moment a request for delivery** of an input is made to the **moment of receipt of that delivery**.
      - o **Lead times** must be **identified during front end planning** for each activity in the **master schedule**.

How about activities with a few days lead time?

Look-ahead schedule

- **Quite a few activities** have lead times of only a **few days or weeks**, however.

- **Once ordered**, they can be **delivered** according to a **reliable schedule**
  - Delivery specified, say, **plus or minus a day**
    - **Ordering and obtaining** a reasonable quantity of **standard lumber**, **drywall**, or **commodity concrete** fall into this category.
    - These materials may be **ordered a very long time in advance** of their scheduled use **depending on market pricing**, the need to **reserve plant capacity**, and the **delivery situation**, but **more often than not** they are **procured only a few days** or **weeks ahead** of their use.

Look-ahead schedule

- In the **design phase**,

  look-ahead schedule is derived from the **phase plan**, based on a **time frame of 2 to 4 weeks**, and

  1. It is used for **work flow control**.
  2. It **uses items pulled** from the **master schedule**.

- **In design**, this **time frame may be adjusted** to fit the type of project

- By comparison, the **construction phase** of projects typically uses a **4 to 8 week time frame.**

Look-ahead schedule

SAMPLE

Tasks | Responsible Party | Weeks | Constraints | Explanations | Completions

Six Week Lookahead / Constraints Analysis

Start	Rpt	Activity	Responsible Party	Contract / C.O.'s	Safety	Space Planning	Budgeting	Engineering	Submittals	RFI's	Materials	Labor	Equipment	Prereq Work	Space	Week of 10-23-00 Comments / Other
1		Build mock-up of room 11	Build								x					Millwork & mirror
1	✓	Microscope vibration study	[illegible]													CD's will be issued prior to this info; Isolation system will come as addendum
1		Bid & award bid pack 3	Build													Review with Brad
1		Submit-review-approve roofing shopdrwng	Langer						x							Additional submittals required
1		Release updated construction documents	ARC													Coordinate with Ring & Du
1		Demolition	Build													
1		Pour roof	Build											x		
1		Expe…	RDI	x					x							Stone was ordered 10-13-00
1		Ste l Sho…	[illegible]											x		Klein Dickert will coordinate with Mike D
1		R of deta…	[illegible]											x		
1		hase 3 Millwork Shop Drwngs	[illegible]													
1		Fabricate louvers	[illegible]						x							5-6 week lead time - Ordered 10-13-00
1	✓	Fabricate auto entrance doors	Besam													Shipping 11-3; Besam header to Dickert
1	✓	Fabricate curtainwall	Klein Dickert						x		x					Waiting for framing materials-by October
2		Mock-up review	[illegible]								x			x		Millwork; Mirror
2		Masonry Work	RDI								x					Roger needs to confirm if brick is in
2		Penthouse framing & decking	[illegible]											x		Boldt to confirm placement of AHU's
2		Bid Pack 3 Submittals	TBD	x										x		Award contracts
2		Start work on patient rooms 3847 -49	TBD			x	x									Need to coordinate with Jan Keepers
		Workable Backlog														
		Fabricate AHU's / ACCU	Trane													Shipping: 11-13-00
		Med Gas Equip. Lead-Time	[illegible]													Delivery: 11-6-00

Look-ahead schedule

We will see the steps of how to develop Look-ahead schedule in Lean Construction

ACEMI

Weekly work plan (WWP)

- **Known** as **commitment planning**.
- **Represents** the **most tailed plan** in the system.
- It is done by **designers**, shop floor **supervisors**, construction **foremen**, and numerous others

  who **immediately supervise** those doing the work.
- **Shows interdependence** between the works of various specialist organizations
- **Directly drives** the production **process**.
- **Assignments** are **reviewed** to assess their completeness.
- The so-called **last planner** is the professional who **prepares** the **weekly (or daily) planner schedule.**
- This schedule also includes a **buffer of work** activities based on **future work**.

Weekly work plan (WWP)

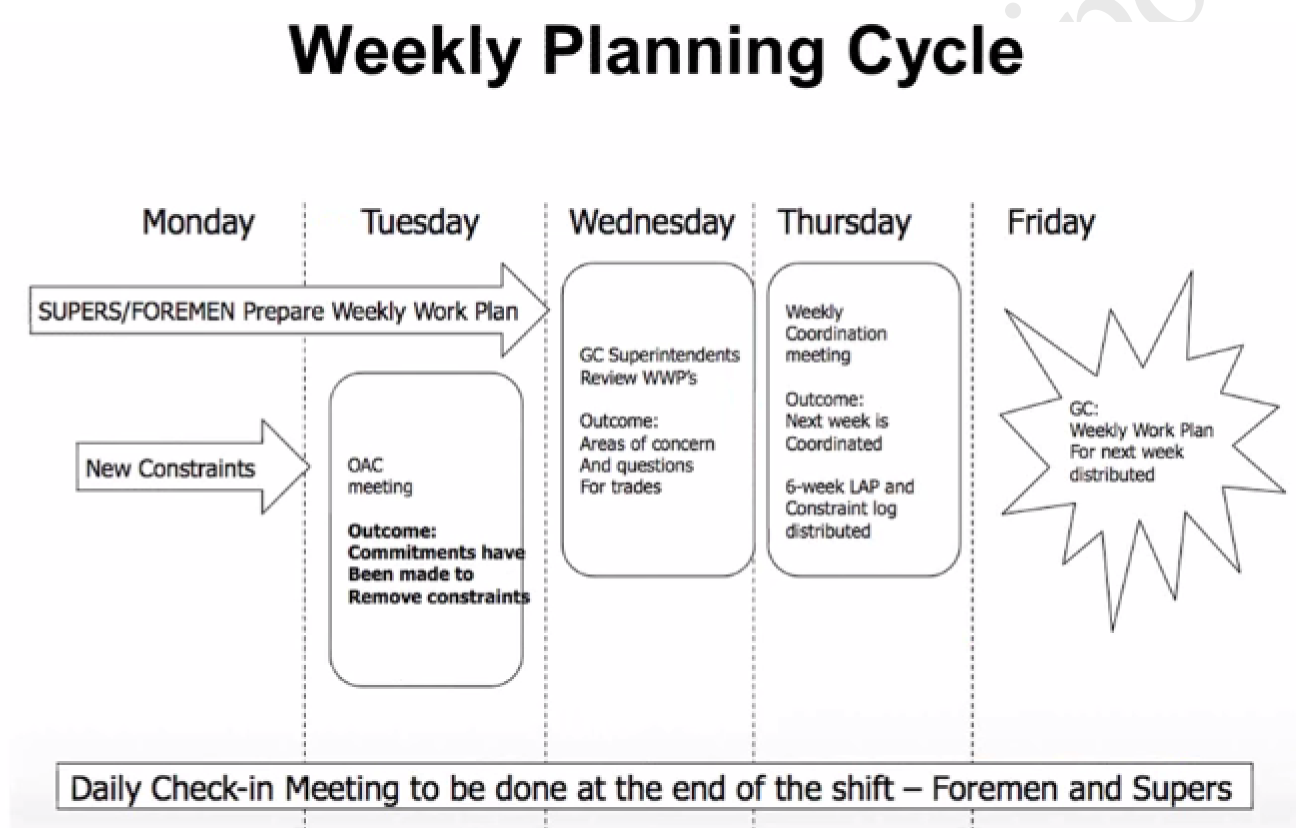
Developing the Weekly Work Plan

- **Each week**, the **Last Planner Team** structures **their Look-Ahead Week 1 and Week 2** as if they were a Weekly Work Plan
  - **Daily tasks** are added to the schedule for **Week 2 and Week 1**
  - **More detail** is added as needed
- In **preparing a weekly work plan**

  starting point would be the **end of that week**.
  - **Working backwards**, the last planners populate the **planning board with stickies.**

The Last Planner Team produces a Weekly Work Plan for "next week" starting from the provisional Weekly Work Plan made the week prior.

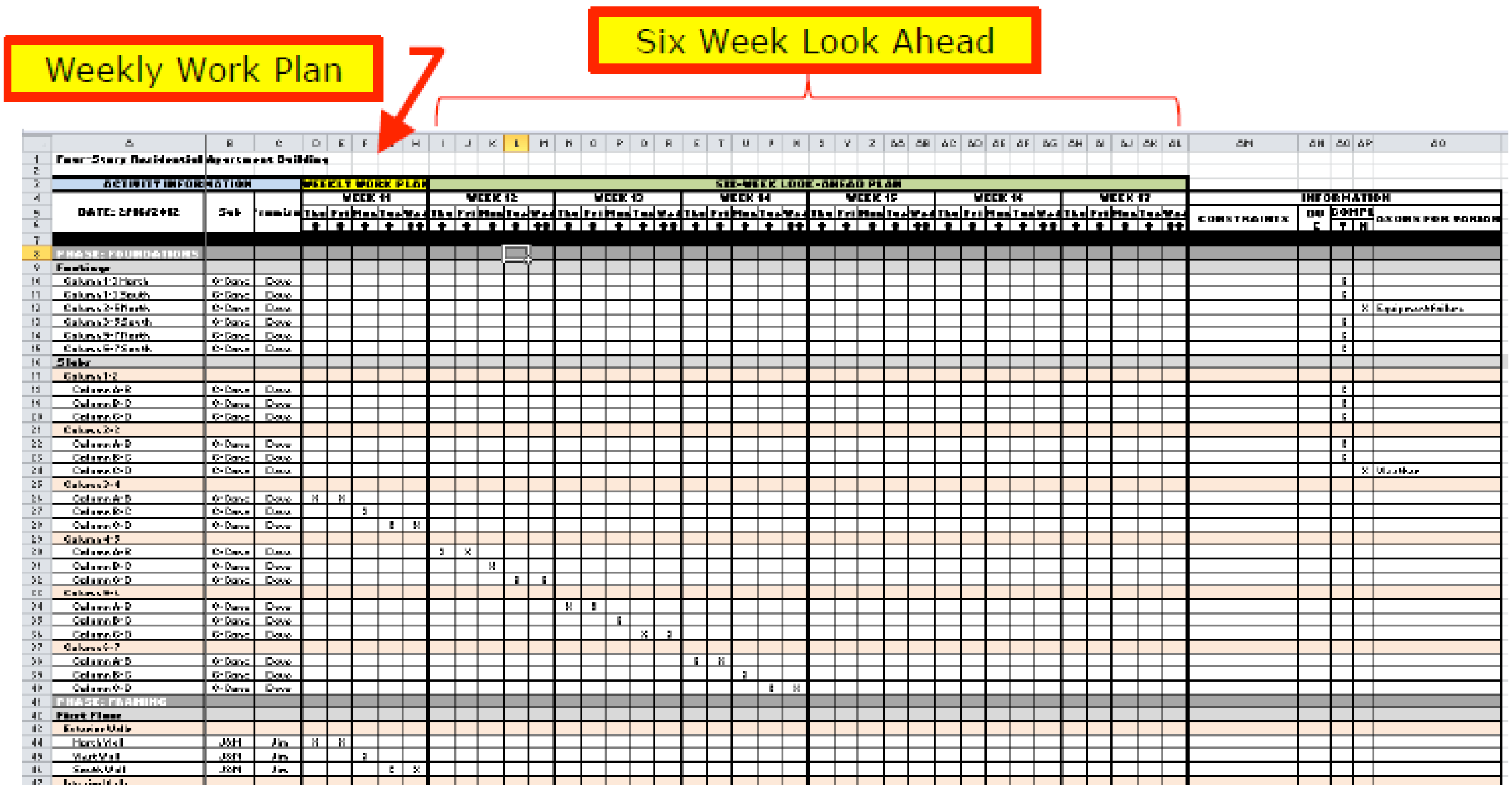
Weekly work plan (WWP)



Weekly work plan (WWP)

Developing the Weekly Work Plan

- The Look-Ahead Plan and Weekly Work Plan (WWP) are reviewed and developed concurrently



Weekly work plan (WWP)

Developing the Weekly Work Plan

- The WWP essentially starts "next week" -- the foremen commit to completing specific tasks next week

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Four-Story Residential Apartment Building												
2													
3	ACTIVITY INFORMATION			WEEKLY WORK PLAN									
4	DATE: 2/16/2012	Sub	Promisor	WEEK 11					WEEK 12				
5				Thu	Fri	Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed
6				2/16	2/17	2/20	2/21	2/22	2/16	2/17	2/20	2/21	2/22
7													
8	PHASE: FOUNDATIONS												
9	Footings												
10	Column 1-3 North	C-Conc	Dave										
11	Column 1-3 South	C-Conc	Dave										
12	Column 3-5 North	C-Conc	Dave										
13	Column 3-5 South	C-Conc	Dave										
14	Column 5-7 North	C-Conc	Dave										
15	Column 5-7 South	C-Conc	Dave										
16	Slabs												
17	Column 1-2												
18	Column A-B	C-Conc	Dave										
19	Column B-C	C-Conc	Dave										
20	Column C-D	C-Conc	Dave										
21	Column 2-3												
22	Column A-B	C-Conc	Dave										
23	Column B-C	C-Conc	Dave										
24	Column C-D	C-Conc	Dave										
25	Column 3-4												
26	Column A-B	C-Conc	Dave	X	X								
27	Column B-C	C-Conc	Dave			X							
28	Column C-D	C-Conc	Dave				X	X					

Weekly work plan (WWP)

- **Weekly meetings** are used to evaluate the **team's performance** during the **preceding week (i.e., what the team DID)**.
- **Root cause analysis** is carried out to determine
  1. **Reasons** for **underperformance**,
  2. **Knowledge gained** is used to improve the process used in **assigning work in subsequent weeks.**

Weekly work plan (WWP)

- The **weekly accomplishment** is measured as **percent planned, complete (PPC)**.

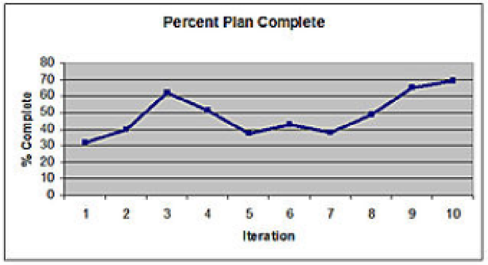
- The **PPC** is based on **100% completion within a given week**;

  tasks are considered to be **either complete or not complete** –

  - There is **no partial credit**.

$$PPC = \frac{\text{number of planned activities completed}}{\text{number of planned activities}}$$

E.g. 10 features planned, 8 features delivered PPC = 8/10 = 80%



- The **last planner** also determines **physical**, specific work assignments for the **next day**.
- **Work selection rules** shield production from **upstream uncertainty** and variation.

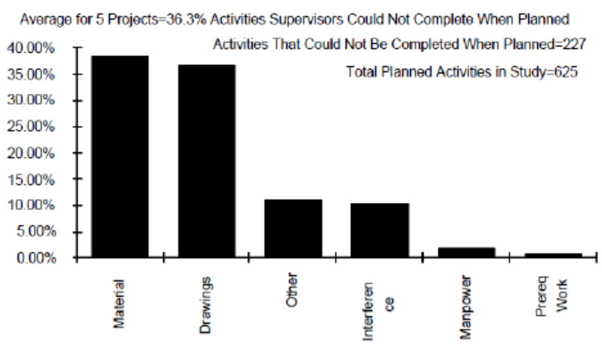
Weekly work plan (WWP)

Weekly work plan (WWP)

We will see the steps of how to develop WWP in Lean Construction

These items were talked before and will be talked more in detail later

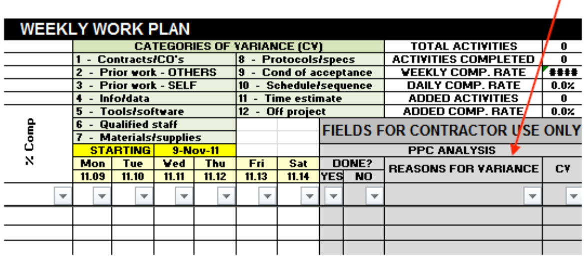
- ❑ Performance measurement and metrics
- ❑ Reasons analysis
- ❑ Commitments and reliable promises



Potential Reasons that work is not completed:

1. Lacked the skill or know-how for completing the promise
2. Prerequisite work of others was incomplete
3. My prerequisite work was incomplete
4. Poor estimate of capacity
5. Capacity reallocated to other work
6. Some aspect of wherewithal was missing (tools, equipment, materials, etc)
7. Misunderstanding of the conditions of satisfaction or acceptance criteria
8. Misunderstanding of the promise date
9. External factor (weather, sickness, loss of power, etc.)
10. Failure to revoke or re-promise

How Reasons are documented

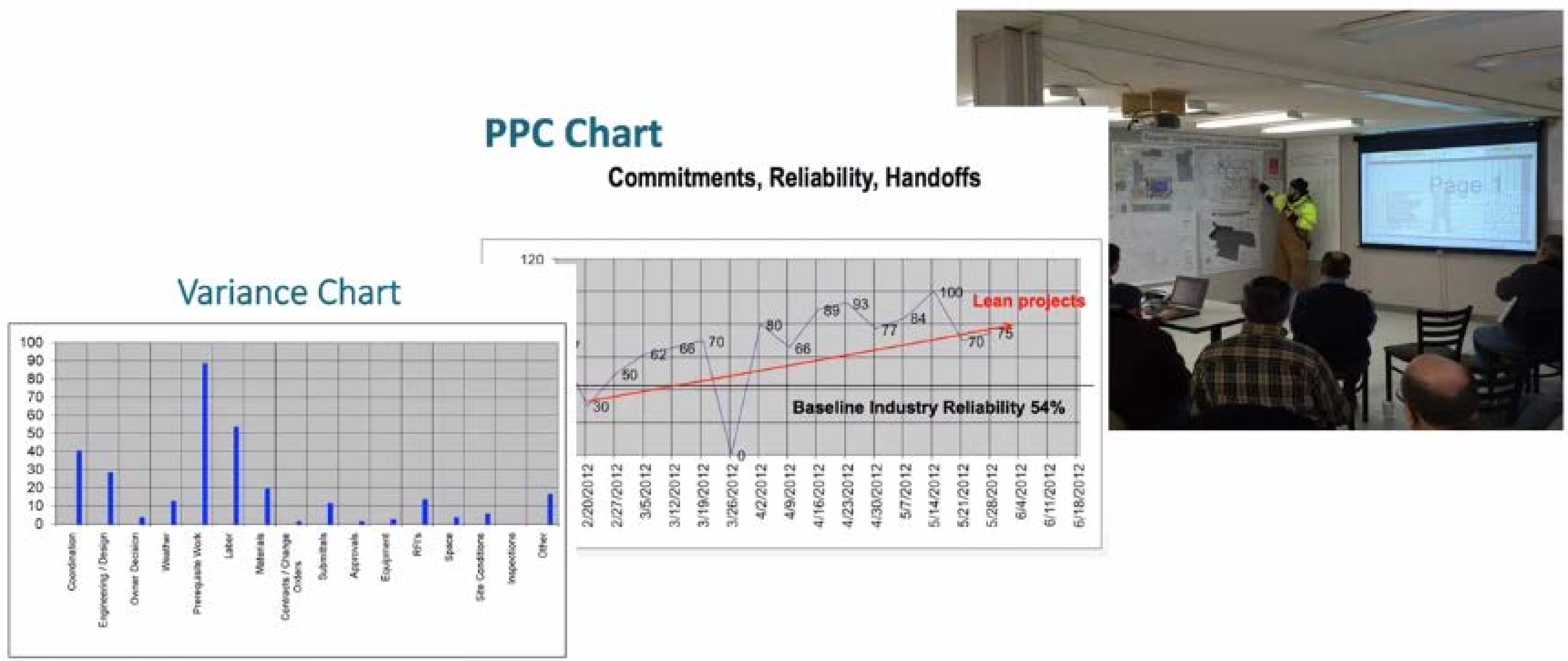


Five Elements of a Reliable Promise

1	The **conditions of satisfaction** are clear to both performer and customer.
2	The performer (promissor) is assessed as **competent** to perform or has access to that competence and other wherewithal (materials, tools, instructions, etc)
3	The performer has estimated the time to perform the action for completing the promise and has allocated (blocked) that **capacity** on the schedule (calendar)
4	The performer is **sincere** in making the promise. In the moment the promise is made, the performer is not having a private, unspoken conversation which contradicts fulfillment
5	Regardless of what the future holds, the performer will **make good on the promise** - particularly if the promise cannot be performed, taking responsibility for whatever consequences may ensue

Learning

These items were talked before and will be talked more in detail later

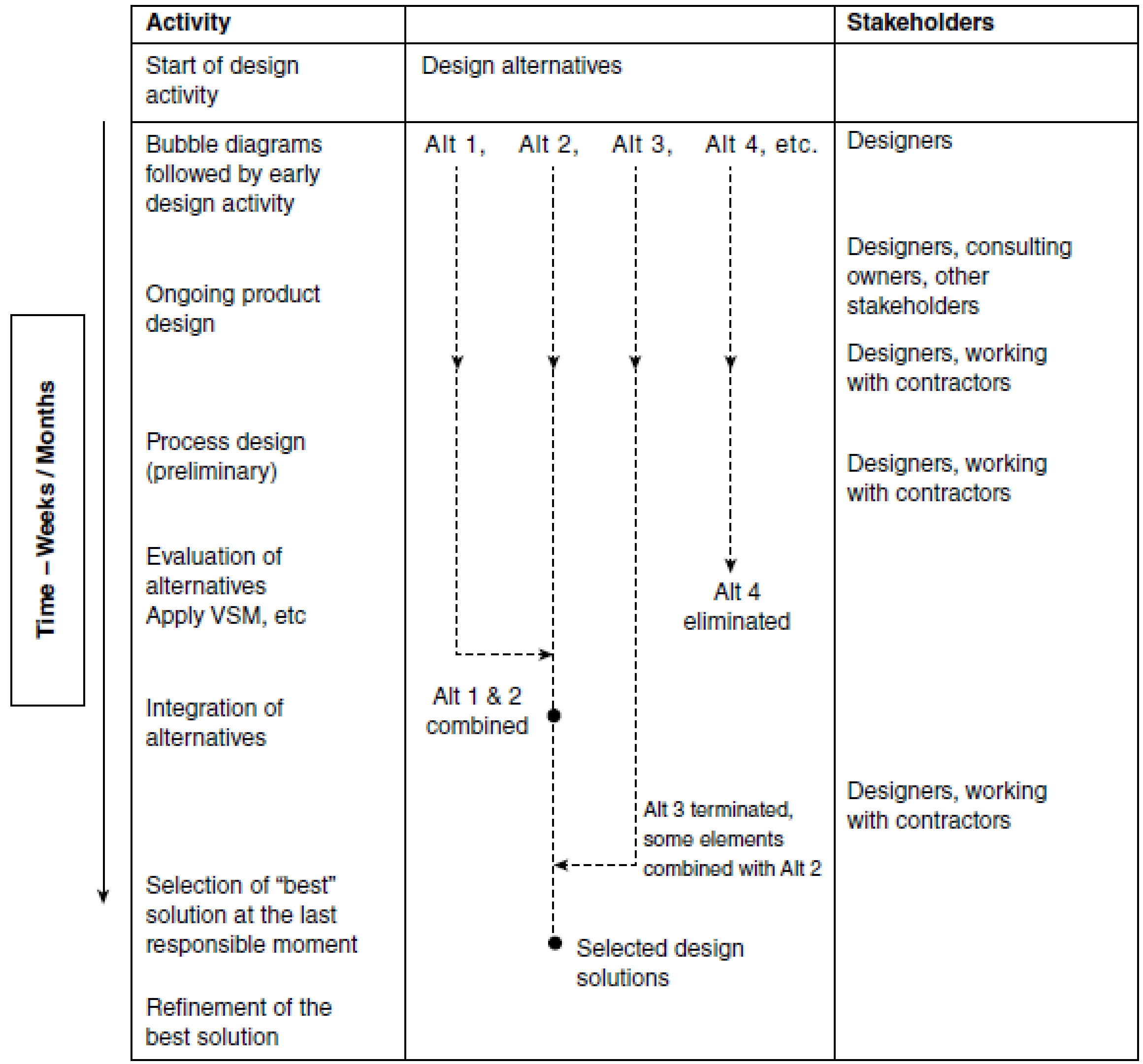


Set-based design

- **Set-based design** is an approach that **defers design decisions** to **"last responsible moment"** to allow for the **evaluation of alternatives** that **improve constructability**.
  - **Toyota** has used this technique to **design new models** in a much shorter time than the industry standard.

Set-based design

- **Set-based design** begins in the **project definition** phase when designers begin to prepare **conceptual designs** to meet the owner’s project requirements.
- **Set-based design** involves developing **a set of design alternatives in parallel** with each other until a point **where a final choice** has to be made.



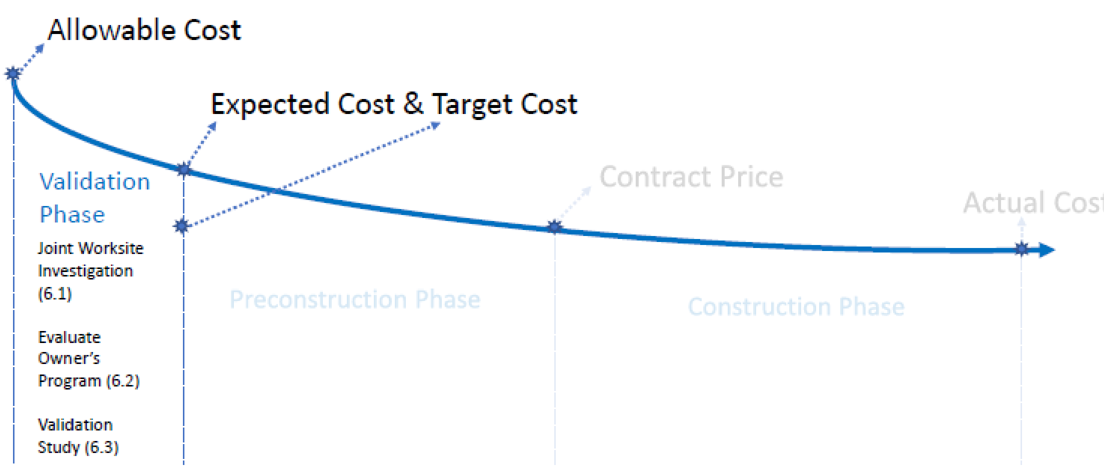
Designing for lean operations

- **Lean operations** and **target value design (TVD)**:
- **TVD** involves **designing to a specific estimate** **rather than** **reducing a design** to meet a stated budget.
  - ✓ Target value design (TVD) involves **designing to a specific estimate** **instead of** ________**estimating based on a detailed design**.
  - ✓ It supports **lean by avoiding the wastes** incurred in scaling back a completed design.

Target-value design (TVD) – Types of costs

Glenn Ballard refers to four components of TVD: *Market Cost*, *Allowable Cost*, *Expected Cost*, and *Target Cost*. They are defined as follows:

> *Market Cost* is a benchmark cost; it consists of the cost per square foot that would be expected for comparable construction projects. *Allowable Cost* represents the maximum cost that must not be exceeded; if the project team cannot design to allowable cost, the project must be cancelled because it would, by definition, become financially unfeasible. *Expected cost* is the estimated cost of the project in its current state during the TVD process; the expected cost is continually recalculated with each new iteration of design. *Target Cost* is the stretch goal for the project, meaning it is usually set below Allowable Cost.
> *(Ballard 2009a; Rybkowski 2009)*



Target-value design (TVD) – General procedure

- **TVD** applies **Target Costing** to building construction and **seeks to address the problem** that affects many projects
  - **Corrective action** may include a **misuse of value engineering** to
    - Radically **cut the scope** of a project, or
    - **Suppress certain features** that are **desirable but unaffordable**.

- **Working in their respective offices** they are subject to **"project creep"** and "project growth"; with **little cross-functional collaboration**,

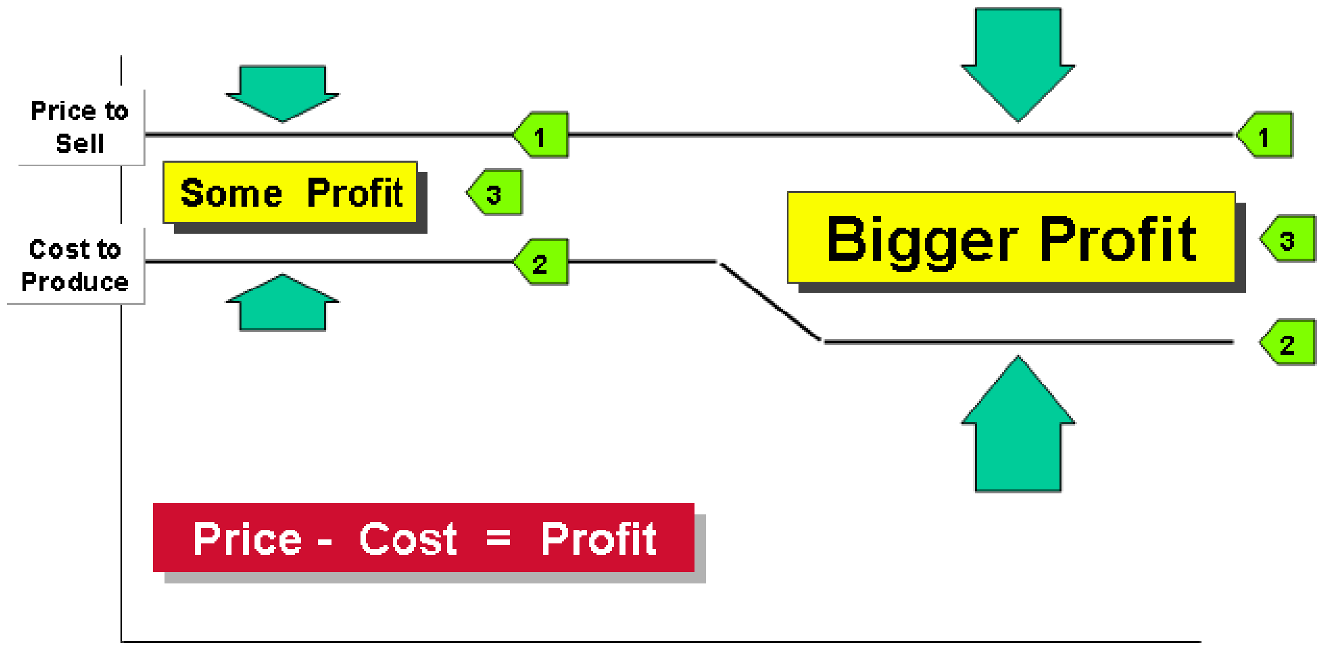
  project designs often become **overpriced**, **un-constructable**, and **behind schedule.**

Target-value design (TVD) – Foundational practices

- Target value design (TVD)
  1. **Set target cost** – typically lower than the budget that assumed current best practice (**expected cost**)
  2. **Form target value design teams** by system and allocate the **target cost** to each team
  3. **Provide cost and performance standards** for the core building elements

Target-value design (TVD) – Foundational practices

- Target costing



What is the role of Target Costing?
Value management or Flow management or both!

Target costing is not the same as GMP. The latter is the sum of all the bids plus contingency. The former is a different view all together.

Target-value design (TVD) – Foundational practices

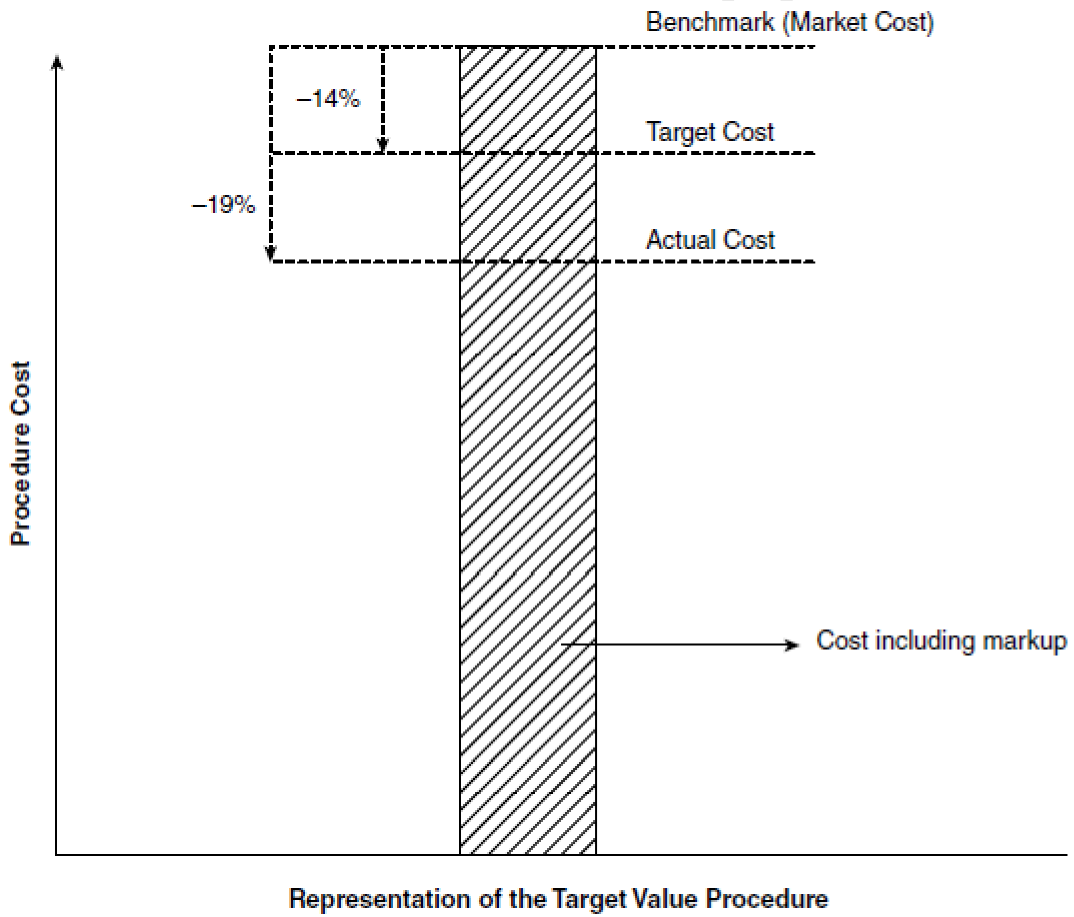
- Requires a **fundamental shift in thinking** from “expected costs” to “target costs”
- Strives to **reduce the waste and rework** in the design/estimate/redesign cycle
- Cries out for an **integrated product/process/cost** model.

Target-value design (TVD) – Practical procedure

- Target value design (TVD)
  1. **Conduct design activities** in **Big Room** (*Obeya* in Japanese)
  2. **Create a multi-disciplined team** that consists of designers-architectural, structural, MEP, estimator, contractors, facilitator, and etc.
  3. **Determine the market cost** for the facility using available benchmarks such as cost per square foot, etc.
  4. **Work closely** with the client to establish the **allowable cost**; it represents the maximum cost that must not be exceeded.
  5. Once the **target cost** is established, **use it to work with a detailed estimate**
  6. **Apply concurrent design principles** to design both the **product** and the **process** that will produce it.
  7. **Working** in **small**, **diverse** groups is best.
  8. **Collaboratively plan** and **re-plan** the project
  9. **Lead** the design effort for **learning** and **innovation**.
  10. **Learn** by carrying out **conversations** on the results of each **design cycle**.

Target-value design (TVD) – Practical procedure

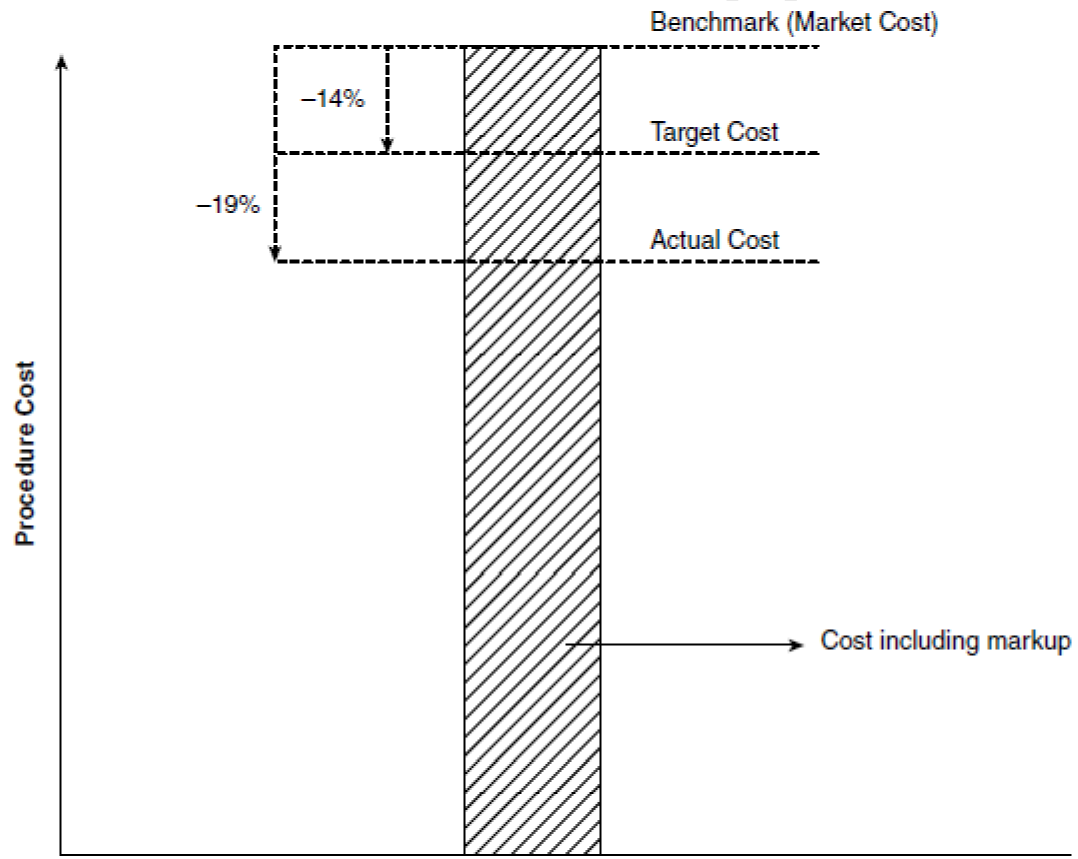
- For this process to work the **construction staff** must include members who can:
  *estimate from **preliminary drawings** instead of contract drawings and specifications.*
- **Designers** need to be **receptive to critical reviews** of their designs with regard to both **pricing** and **constructability**.



In this example the target cost was set at 14% below the market or benchmark cost (not to scale). The actual cost was 19% below market

Target-value design (TVD) – Practical procedure

- The **owner (or representatives)** must be **accessible** and be **equipped** to provide **feedback** on **balancing:**
  1. Project costs
  2. Building features.
- This may involve **value engineering** compromises of **life-cycle costs** versus form, function, and time.



Representation of the Target Value Procedure

In this example the target cost was set at 14% below the market or benchmark cost (not to scale). The actual cost was 19% below market

Target-value design (TVD) – Value engineering

- Using **value engineering** as a **target costing tool**
  - **Systematic** and **interdisciplinary**
  - **Examination** of a project and project components in terms of **function** and **worth**.
  - **Structured** methodology
  - **Encourages** analysis and creativity
  - **Develops** sets of solutions
  - **Develops** highest value solution based on functionality and cost

Target-value design (TVD) – Value engineering

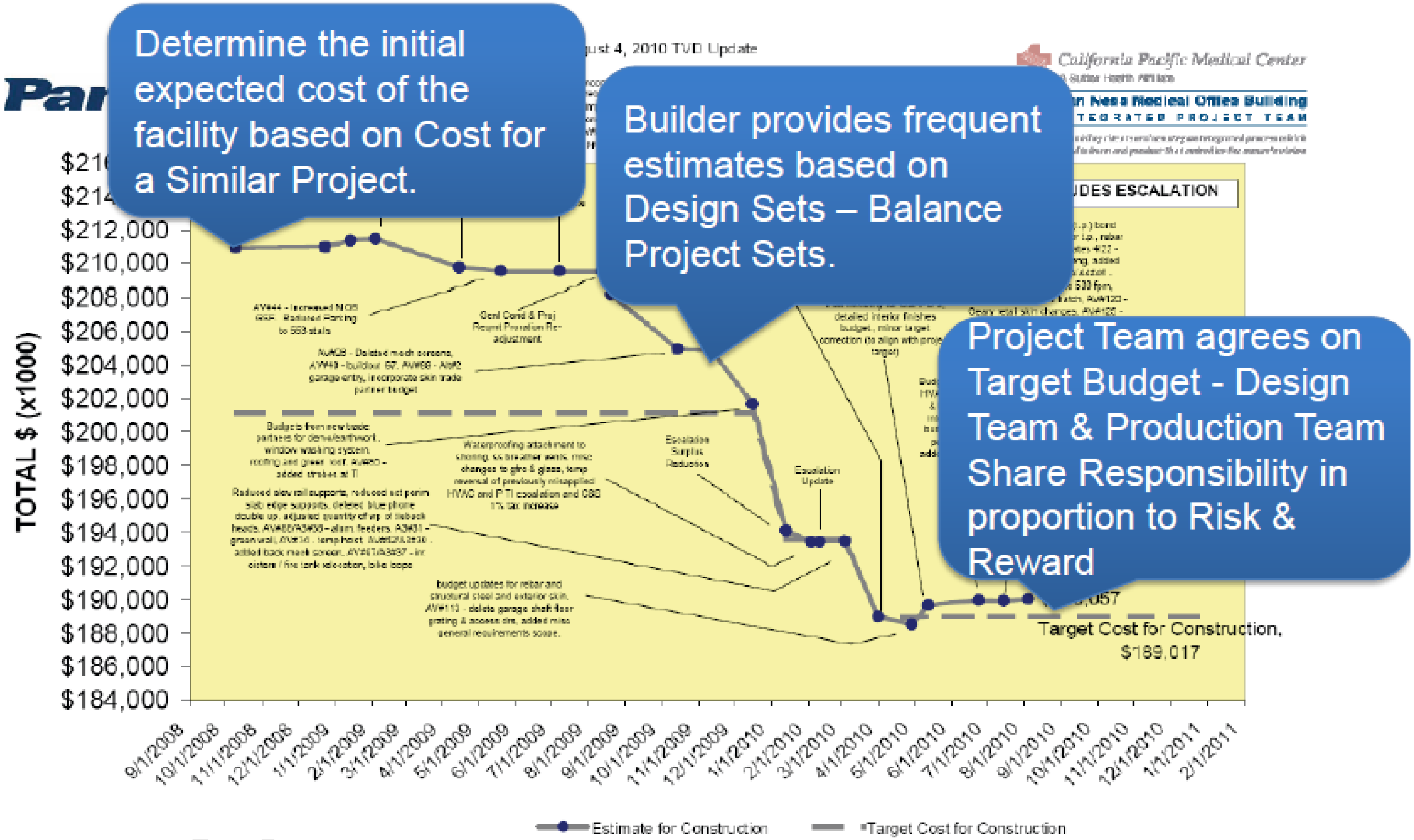
- Value engineering (5 basic steps)
  1. **What is it?** The first question **focuses** on the **analysis**.
     - When associated with target costing the analysis is on
       - ✓ **Major functions or systems** of a project
       - ✓ **Components and subcomponents** of a project
  2. **What does it do?** The second question **defines function**.
     - **Function analysis** is at the heart of value engineering and is required for determining value.
       - ✓ An important product of function analysis is the **improvement in understanding of scope** that occurs among the study team members.

Target-value design (TVD) – Value engineering

- Value engineering (5 basic steps)

3. **What does it cost?** The third question deals with the **cost of functions**.
   - The purpose is to identify those **functions where value is low compared to cost.**
     - These items are **prime** for value engineering.
4. **What else will do the job?** The fourth question requires **creativity and innovation** to advance sets of **alternative solutions**.
5. **What does it cost?** The fifth question is **similar to the third but focuses** on the **highest value solution** in terms of function and cost.
   - Cost is determined in terms of **initial capital cost** and **life cycle cost**.

Target-value design (TVD) – Examples



Target-value design (TVD) – Examples

- Real time budget reviews

Design structure matric (DSM)

- Also known as the dependency structure matrix, dependency source matrix, and dependency structure method

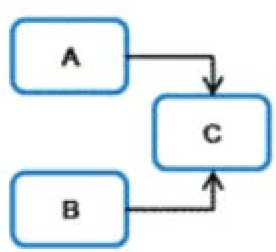
- **General method** for representing and analyzing system models in a variety of **application areas**.

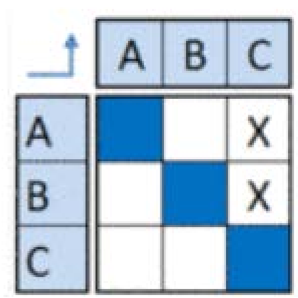
- A **square matrix** that has an **equal number** of rows and columns shows **relationships between elements** in a system.

Design structure matric (DSM)

- For example, consider a system that is composed of **three elements** (or sub-systems): element “A”, element “B”, and element “C”.
- DSM works under the **assumption** that – for the modeling purpose – the **three elements** completely **<u>describe</u>** the system and **<u>characterize</u>** its behavior.
- It is **binary** (i.e. a matrix populated with only **zeros and ones**)
- If there exists an edge from node i to node j, then the value of element ij (row i, column j) **marked with an X**.

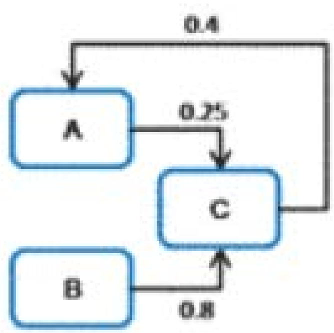
Otherwise, the value of the element is **zero** (or **left empty**).





Design structure matric (DSM)

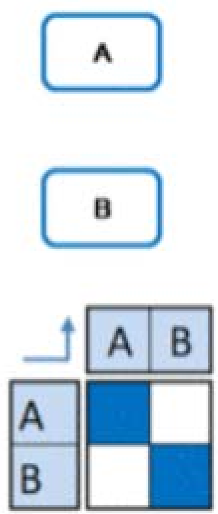
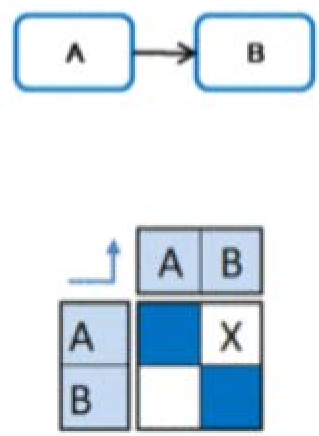
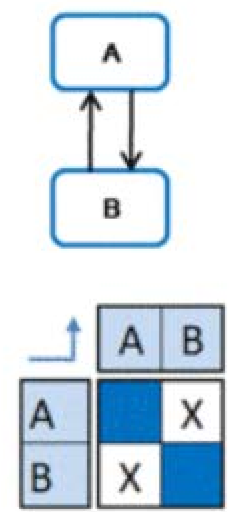
- A matrix can also represent **weighted dependencies**.
- In such a case, a **numerical DSM** is used.
- Equally, an **additional column** can be used to represent the **weight of an element**.



		A	B	C
A	0.1			0.25
B	0.4			0.8
C	0.8	0.4		

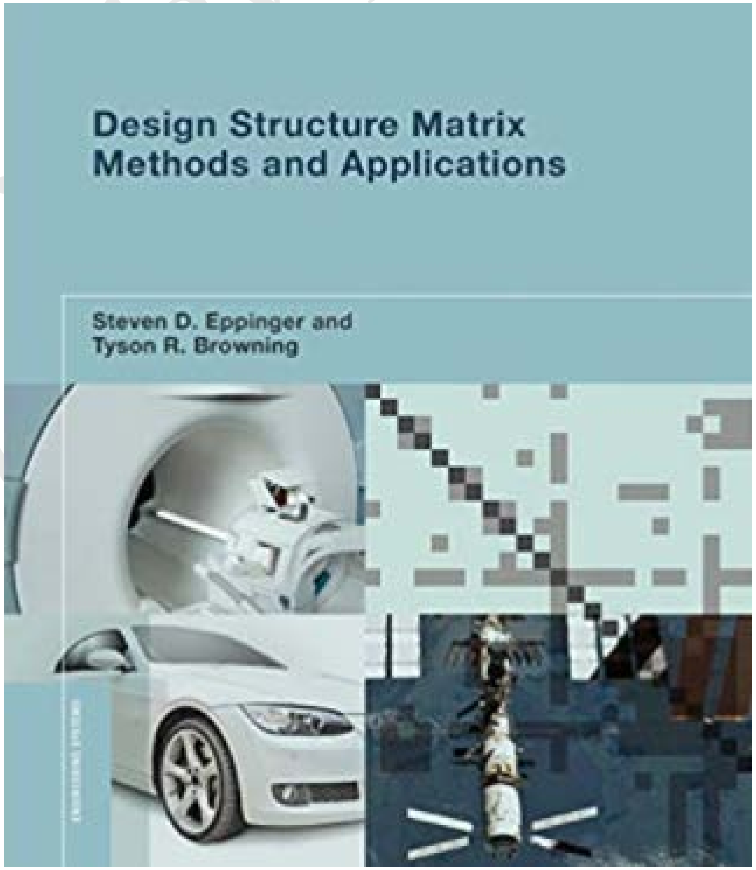
Design structure matric (DSM)

- **Parallel:** tasks or elements do not interact and are independent
- **Sequential:** one task or element influences the behavior or decision of another in a sequential manner.
- **Coupled:** flow of influence or information is intertwined: element A influences B and element B influences A.

Configuration of Relationships	parallel	sequential	coupled
Graph and DSM representation			

Design structure matric (DSM)

- A book, Design Structure Matrix Methods and Applications, provides a comprehensive introduction to DSM.



Lean Design and Construction

ASSIGNMENT 2-2-1:

1. Read the questions below with your team members to discuss the following questions together.
   a) Describe a staff support structure that can be used for managing lean construction projects.
   b) What are the steps in Target Value Design? What are its advantages?
   c) Who is the so-called Last Planner? What value does that individual bring beyond the traditional method of project planning and scheduling?
2. Try to answer the above questions together in one or two pages.
3. Send your paper (in PDF format) to ralavipour@gmail.com

Due on the next week (next week with similar day)

اجرا و مدیریت پروژه به روش اصول ناب
(Lean Project Management)

فصل دوم: بکارگیری مفاهیم و اصول روش ناب در مدیریت پروژه (Lean Project Management)

بخش سوم: استفاده از اصول روش ناب در مرحله ساخت/اجرا (Construction) پروژه

ارائه دهندگان:

سید محمدرضا علوی‌پور

(PhD, PMP, CMIT)

کامبیز کردانی

(M.Sc., PMP)

What we will learn?

- Lean in construction phase of LPDS
  - Concepts
  - Lean supply
  - Lean assembly
  - Lean use
  - Learning loops
  - Production control and work structuring
  - The last planner system in construction
  - LC levels of implementation

Lean in Construction Phase of the LPDS

(Concepts)

Introduction

- The previous section provided an overview of the **lean project delivery system (LPDS)** with an emphasis on the programming and **design phase of projects.**

- It also presented the **Last Planner® System** from the **perspective of design**, in preparation for the **construction phase of projects**.

- This section presents **lean in the construction phase** of the LPDS, including **lean supply, lean assembly,** and **use**.

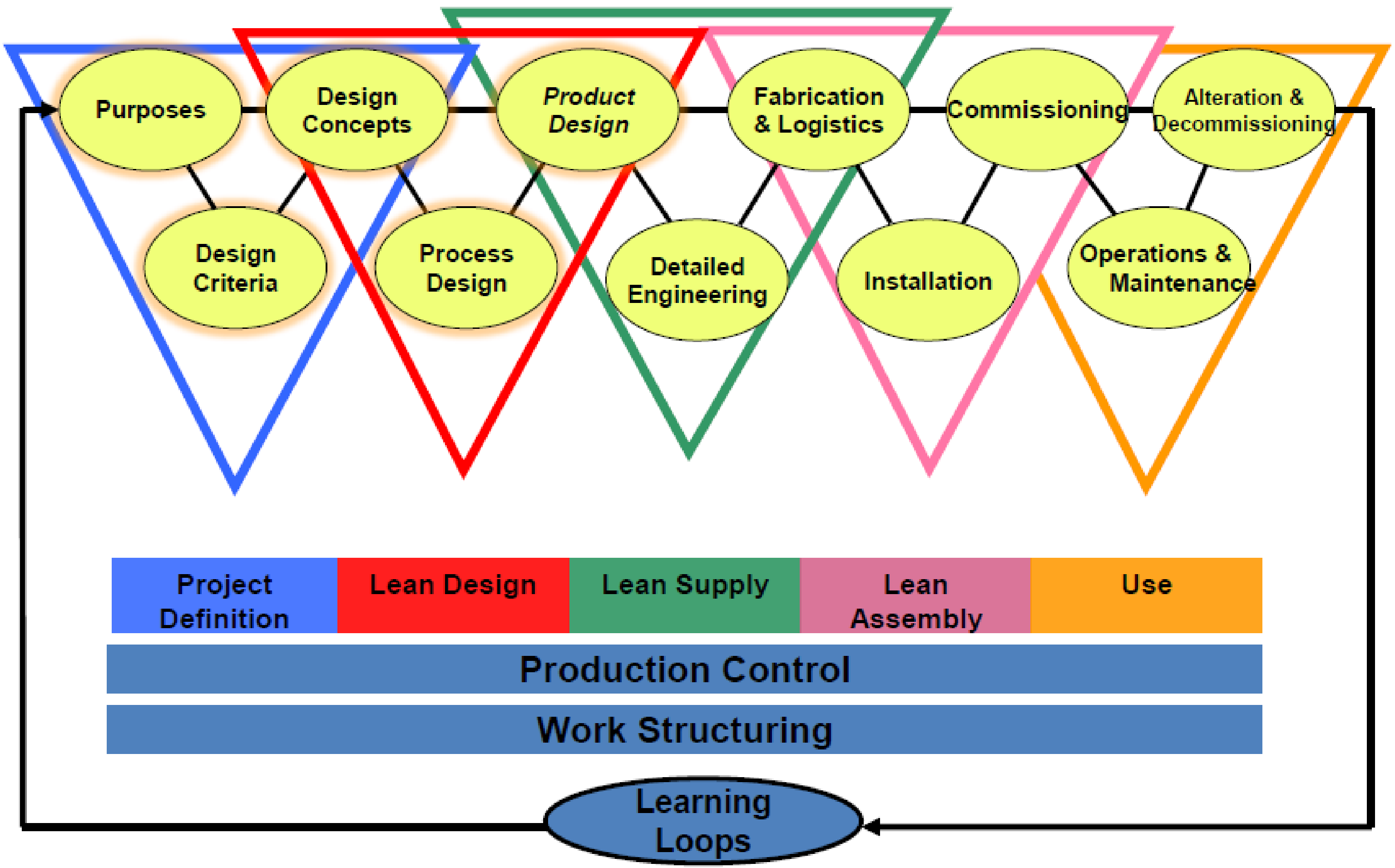
- The **Last Planner® System** is described **extensively** with regard to the **joint activities** of different specialists in the project team.

Lean in Construction Phase of the LPDS

(Lean Supply)

Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



ACEMI

Introduction

- The third triad, **lean supply** requires
    1. Up-front product
    2. Process design

  to define

    1. What is needed
    2. When it should be delivered.

- This is especially important with **engineered to order components** as utilized in EPC projects.

What is the difference between <u>Lean Supply</u> and <u>Traditional Procurement</u>?

Traditional procurement

- **Traditional projects** depend on **procurement specialists or buyers** to ensure that
  1. Materials are **available** for installation;
  2. Materials **operate** as a functional silo that is decoupled from **project workflow**.

What are the flaws in this process?

- Flaws in this process result in
  1. **Material shortages** or **incorrect materials** on site when they are needed that often cause **serious project delays and losses** in construction **quality**.
  2. Alternatively, **material inventories accumulate**, creating
     1. **Unsafe** condition on-site,
     2. Tying up scarce **capital**.

These situations represent examples of construction waste.

Lean supply

- **Lean supply addresses** these problems through three main approaches (Arbulu and Koerckel 2005):
  - **(1) Improving** workflow **reliability** – maintain **constraint identification** and **removal**,
  - **(2) Using web-based project management software** to increase transparency across value streams, and
  - **(3) Linking** production **workflow** with material **supply**.

Lean supply vs. traditional procurement

A comparison between lean supply chains and traditional procurement

	Lean Supply Chains	*Traditional Procurement*
1	Based on systems thinking	Purchasing function not systems based
2	Factored in product and process design	Standard procedure –
3	Tries to match resources with site needs	Seeks lowest price through competitive bidding
4	Seeks overall cost savings via value stream strategy.	Narrow focus on balancing price quantity and quality
5	Early supplier involvement	Late supplier involvement
6	Pulls resources where possible	Pushes resources at the site
7	Material consolidation through centralized logistics centers	Independent warehouses/inventories
8	Multi-project view	Individual contract view
9	Supply channelized to project needs	Project constrained by supply
10	Long term strategy for procurement	Short sighted thinking and control
11	Material supply is synchronized through the LPS.	Material supply decoupled from workflow

Source: Adapted from AGC course Unit 5

Supply chain management and lean construction

- The **main elements** of SCM are
  1. Information flow,
  2. Order fulfillment, and
  3. Product development
     - With
       1. Faster response times,
       2. Less waste,
       3. More effective information flow, and
       4. Smaller amounts of inventory.

The design process can support the supply chain by using standardization to eliminate waste as well.

Implementation of SCM has many challenges!

Challenges of supply chain management in construction

- The **industry trend toward <u>subcontracting</u>** has resulted in
  1. Specialization and fragmentation;
  2. Each subcontractor tends to act in **its own interest** and
  3. Relationships between the various parties often **becomes adversarial**.

- The **sharing of information is critical** for both SCM and lean construction.
  - *A general contractor (GC), for example, should be able to* ***extract a reliable commitment*** *from an air conditioning* ***subcontractor*** *that a chiller has been* ***ordered*** *from a specified supplier.*

How this could happen?

Challenges of supply chain management in construction

- Using an **online information system**, it should be possible for the **GC and the owner's project manager** to verify the **supplier's delivery schedule**, although **pricing information** could be kept **confidential**.

  - *The dimensions and capacities of the chiller could be **verified long before delivery** to **ensure** that it will be delivered and installed in seamless agreement with the **construction schedule**.*

Just in time (JIT) and lean construction

- In **JIT**, production is driven by **customer demand**;
  - That is, the **needs of the next trade downstream** as opposed to “pushing “ to meet schedules.

- This system allows a **JIT approach** to be used, so that
  - *Chiller is **not delivered too far in advance**, when on-site storage requirements may become costly and inconvenient.*
  - ***Late deliveries would be avoided**.*

Unavoidable deviations from the **construction schedule** would be shared with **all stakeholders** and needed **adjustments made**.

Just in time (JIT) and lean construction

- One important function of the supply chain is to ensure the **appropriate timing of material** acquisitions to **avoid excess material inventories.**

- **Materials** fall within **three categories** that must each be **handled differently**:
  1. **Made to stock items (MTS):** These are **commercial items** that are made to meet **market forecasts**.
     - *Examples are consumables such as nails and small tools.*
  2. **Made to order items (MTO):** These are **standard items** such as **rebar** and **concrete** that are **easily produced** to meet project needs.
  3. **Engineered to order (ETO):** Items are **customized to the project**;
     - *They include steel trusses, HVAC ductwork, systems piping for chillers, and plumbing.*

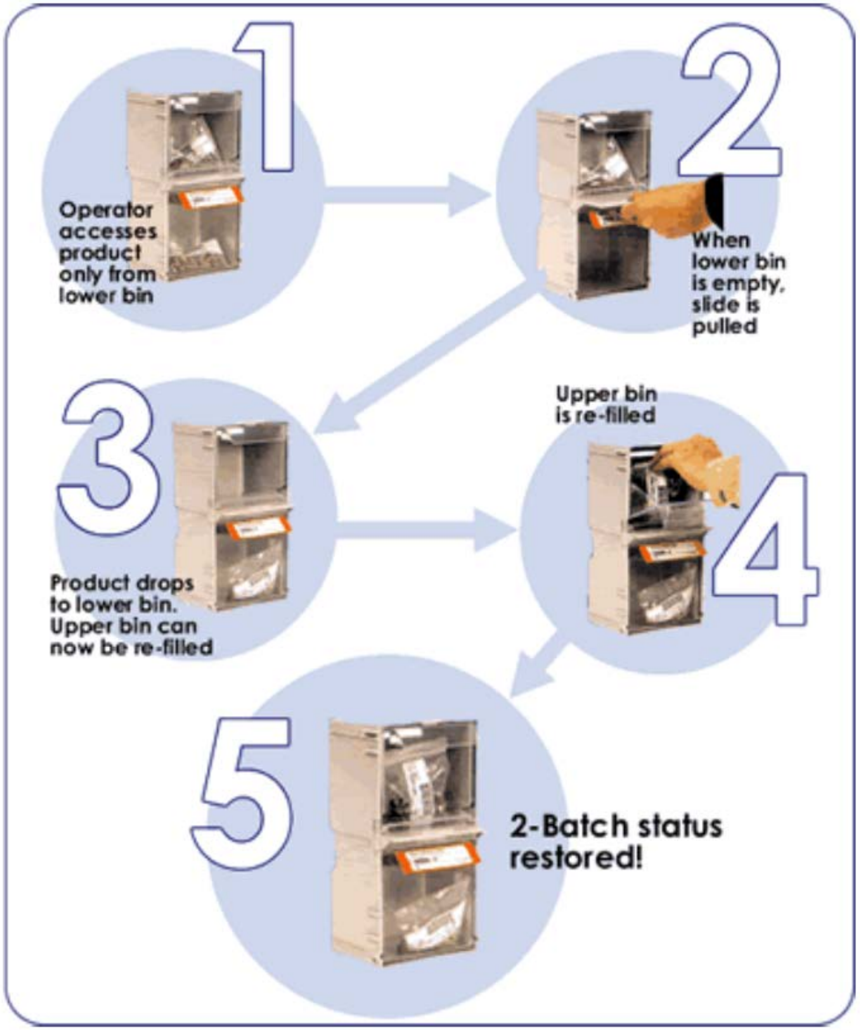
Kanban and lean construction

- **Pull/Kanban** is a system of **delivery instructions** from **downstream to upstream activities** in which the **upstream supplier does not produce until the downstream customer** indicates a need.
  - ✓ It is an **essential part** of the **just-in- time (JIT) process**.
- In its **original form**, Kanban was a **card-based system** that improved process management through **visual control.**
- **Kanban cards maintaining information** on product name, number, due dates, and so on.
- The **kanban** tells the **supplying process** exactly **what it wants** and **how many**.
- The **supplying process** is **not authorized** to make more product **until the kanban advises** it to do so.

ACEMI

Kanban and lean construction

Bin system to show when materials or parts are running low



Kanban and lean construction

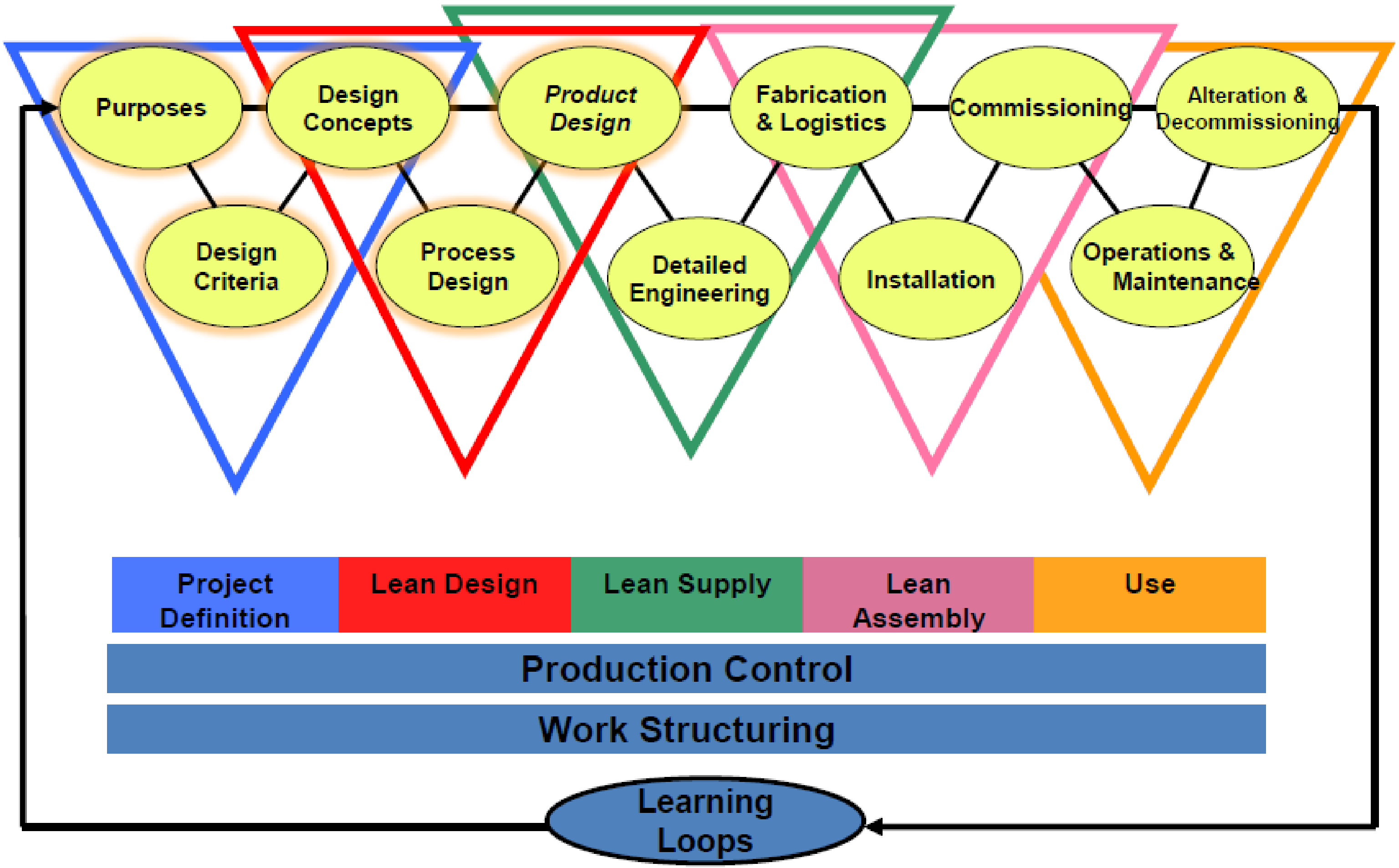
Inventory control

Lean in Construction Phase of the LPDS

(Lean Assembly)

Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



ACEMI

Introduction

- **Lean assembly** is practiced in the **actual construction** of a project.
- **Lean assembly puts** materials, systems, and components in place to create a completed facility.
- The **objective** of lean assembly is to **assemble building elements** in the most efficient manner possible, **both onsite and offsite**.
- It can be **accomplished in a number of ways**, such as through **prefabrication offsite** where the work can be done in **controlled environment** like a **factory**, and then transported to the site.
  - ✓ *Piping systems, for example, can be assembled in sections in a prefabrication facility, tested under high quality standards, then shipped to a site on a just-in- time basis.*

Prefabrication

- **Prefabrication** is a **production technique** that can **enable a contractor** to **operate in a lean manner** by reducing the many **nonvalue-added steps** that are required in field fabrication.
  - Whereas **field work contends** with **uncertain conditions** such as *weather, and limitations in the availability of skilled labor, material, and equipment, shop fabrication benefits from a predictable, controlled environment.*

ACEMI

Commissioning

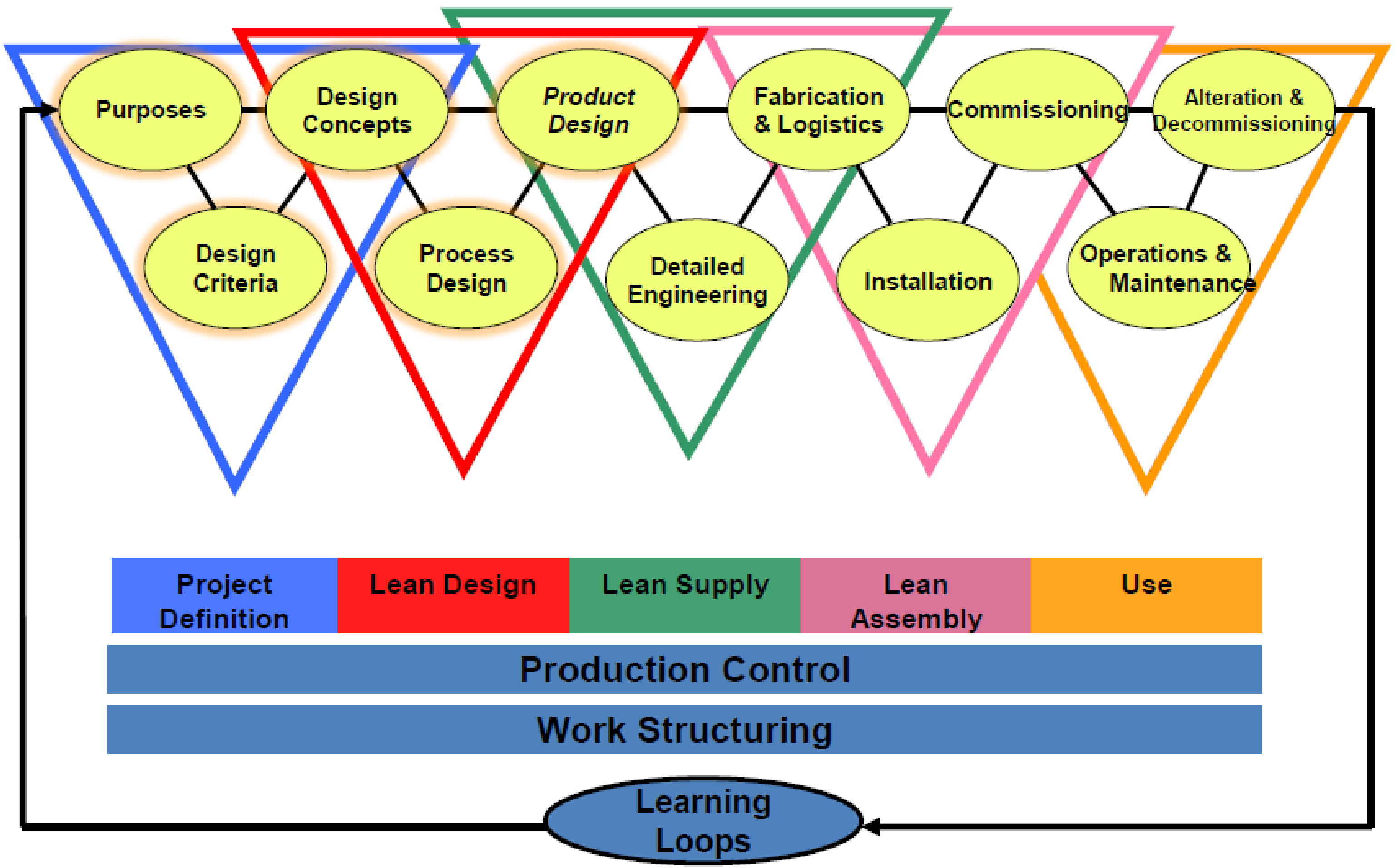
- The **commissioning** process provides **quality assurance** before a facility is **completed and accepted** by the owner by ensuring that **all systems have been installed** as promised in keeping with the **designer's plans and specifications**.
  - ✓ It improves the **probability** that the facility will meet the **owner's project requirements (OPR)** and performs as expected, to provide user satisfaction.

Lean in Construction Phase of the LPDS

(Lean Use)

Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



Lean use

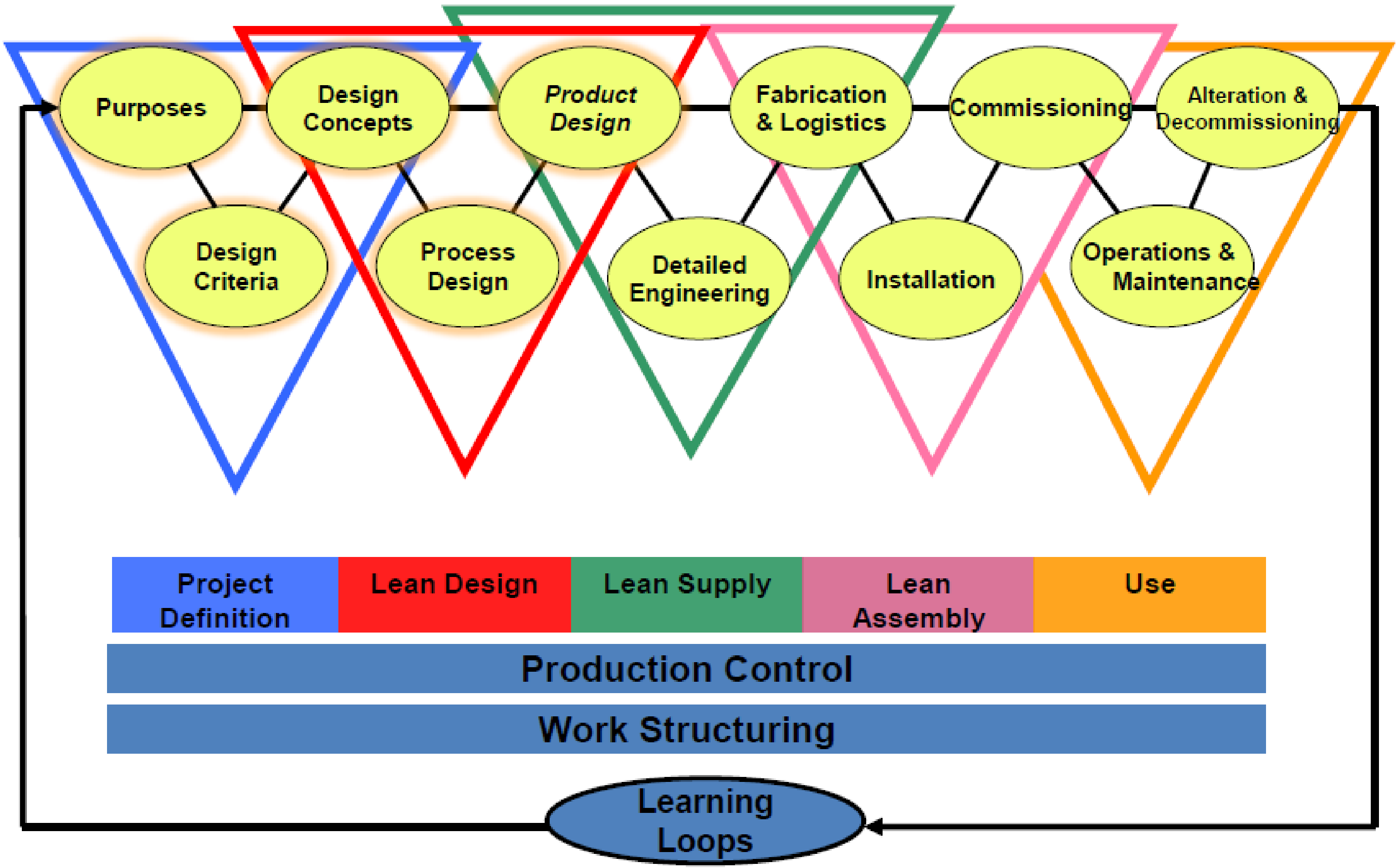
- The “Use” triad of the LPDS
  - Refers to a **completed facility,** and
  - Contains the activities
    - Commissioning,
    - Operations and maintenance, and
    - Alteration and decommissioning.
      - Following **successful commissioning**, the facility should **undergo a protracted operations and maintenance** phase as it is used.
      - **“Alteration and Decommissioning”** refers to a **future activity** when the facility may be repaired, renovated, or taken out of service.

Lean in Construction Phase of the LPDS

(Learning Loops)

Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



Learning loops

- **"Learning loops"** refer to the **application of root cause analysis** to construction activities to

  review PPC values and **commitment reliability**.

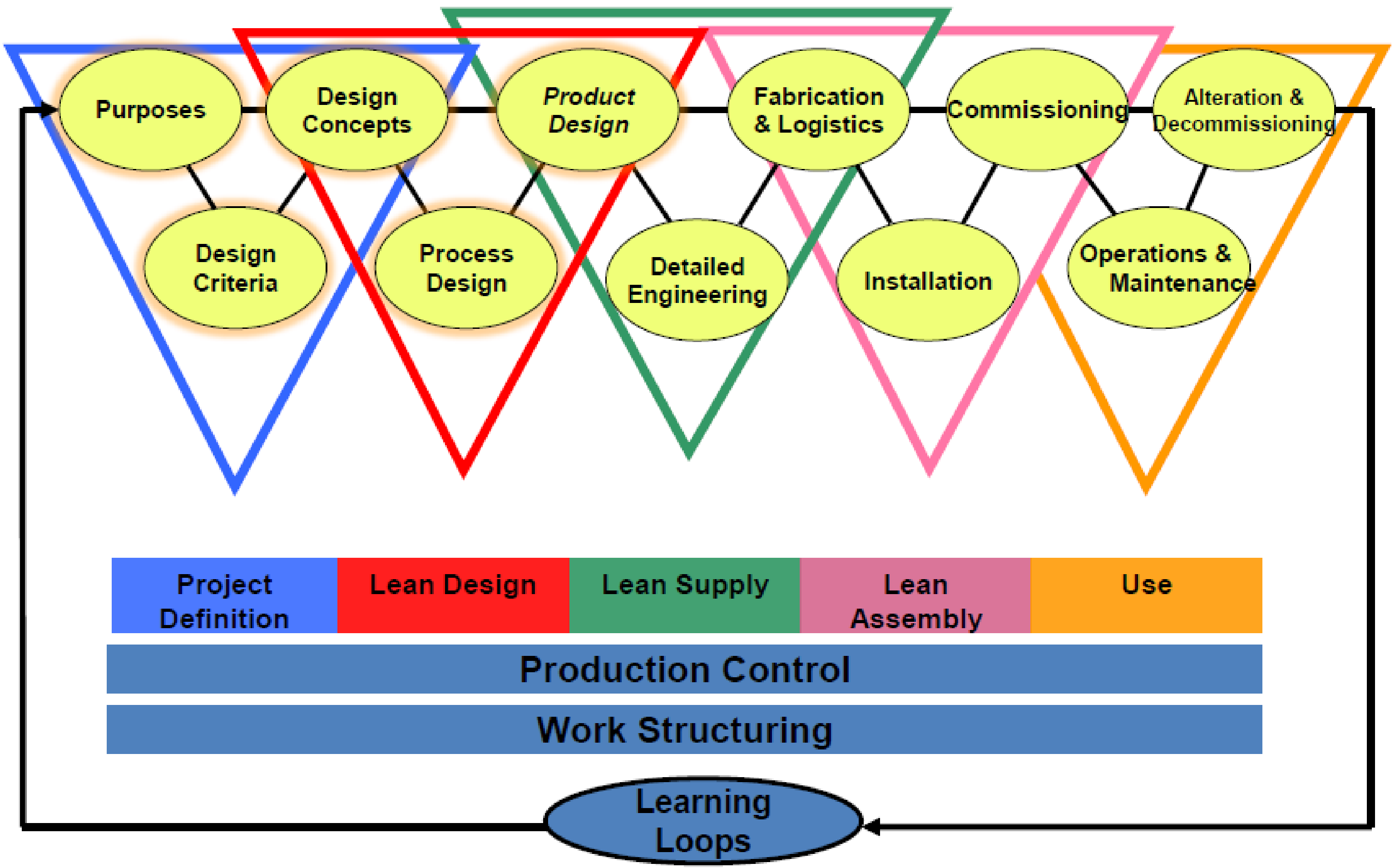
  - ✓ In this review, **project teams** determine the **reasons why the tasks** planned for a particular week may **not have been accomplished**.
  - ✓ **If errors are detected** in this review, the team endeavors **"not to make the same mistake in succeeding weeks".**

Lean in Construction Phase of the LPDS

(Production Control and Work Structuring)

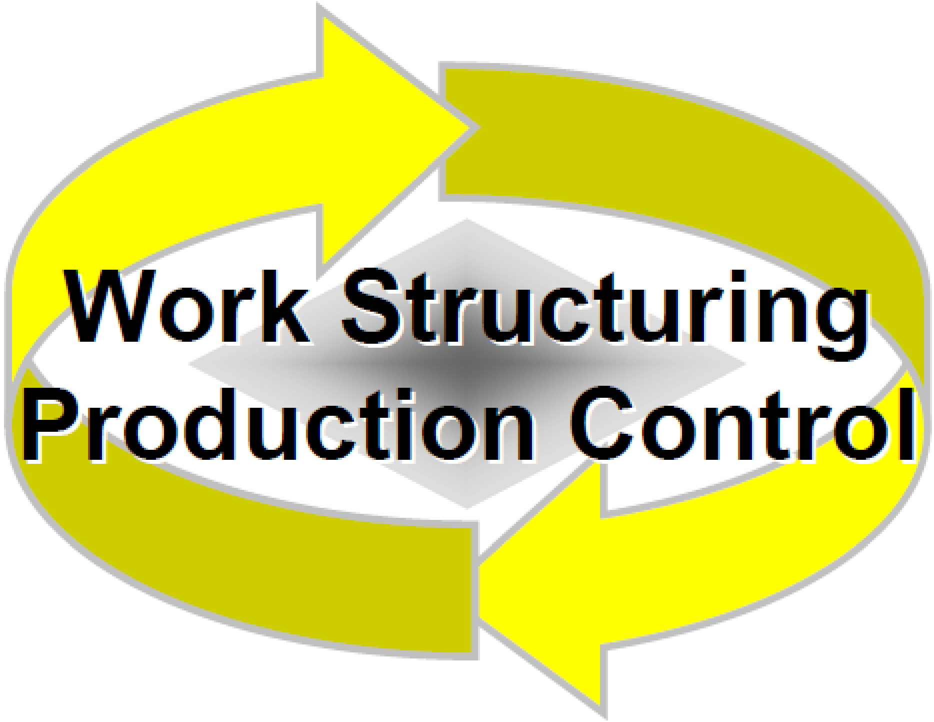
Structure of the lean project delivery system (LPDS)

- Source: Adopted from Ballard and Howell, Building Research and Information, 2003



Introduction

We will first discuss the "heart" of the LPDS: Work Structuring and Production Control



Lean production management

- **Reliable workflow** at these levels achieved using:

LEAN PRODUCTION MANAGEMENT

Production Planning = Lean Work Structuring (LWS)

Production Control = Last Planner System (LPS)

Lean production management

LEAN PROJECT AND PRODUCTION PLANNING

LEAN WORK STRUCTURING (LWS)

Lean work structuring

- **Work structuring and production control** are used **throughout a project** to manage production (Ballard 1999).

- **Work structuring** is a **process of subdividing work** so that pieces are different from one production unit to the next to **promote flow.**

- **Work structuring** develops and aligns the **project's process design** with
  1. Engineering design,
  2. Supply chain capability,
  3. Resource allocation strategies, and
  4. Assembly efforts.

Is it WBS?

Lean work structuring

- **Work structuring** differs from **work breakdown structure** which was traditionally used by planners to **decompose a project into work packages** to create a framework for project planning, scheduling, and controls in the functions it performs.

What questions WS answers?

Lean work structuring

- Work structuring **answers the following questions**:

  (1) In **what units** will work be assigned to groups of workers?

  (2) **How** will work be **sequenced**?

  (3) **How** will work be **released** from one group of workers to the next?

  (4) Will **consecutive groups** of workers execute work in a **continuous flow** process or will their work be **decoupled**?

  (5) Where will **decoupling buffers** be needed and how should they be **sized**?

  (6) **When** will different units of work be **done**?

(Howell et al. 1993 and Tsao et al. 2004).

What are some of the products of work structuring?

Lean work structuring

- **Some of the products** of work structuring are:
  - **Project execution strategies** including global sequencing where sequence of execution is delineated

    building A, then D, then B etc; or build floors of hi-rise in quadrants going counterclockwise starting at the north side
  - Project **organizational** and **contractual** **structure**
  - Configuration of **supply chains**
  - **Detailed** operations **design**

    how to form-rebar-pour basement walls
  - Master schedules
  - Phase schedules

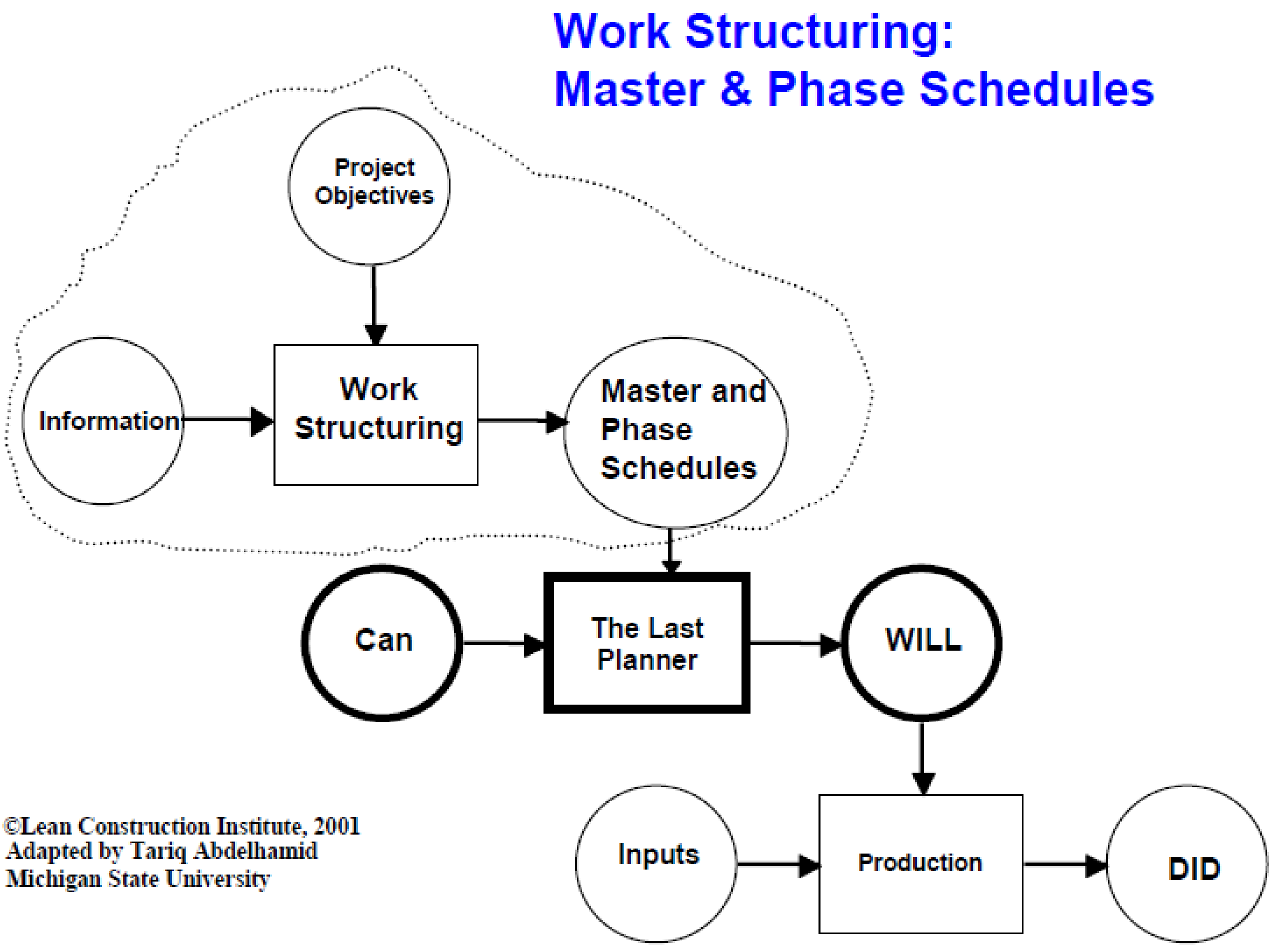
Work structuring and last planner

- In the **Last Planner® System of production control,**

  work structuring culminates in the **form of schedules** that represent **specific project goals.**

  - **Schedules** are created for **each phase of the project**,
    1. **Beginning** at the design phase, and
    2. **Ending** at project completion.

Work structuring and last planner



Lean production control

- **Production control** is represented in the LPDS as a horizontal bar that extends from the **very inception of the project to its conclusion**.
  - It consists of **work flow control** and **production unit control.**

Lean production control and Last planner

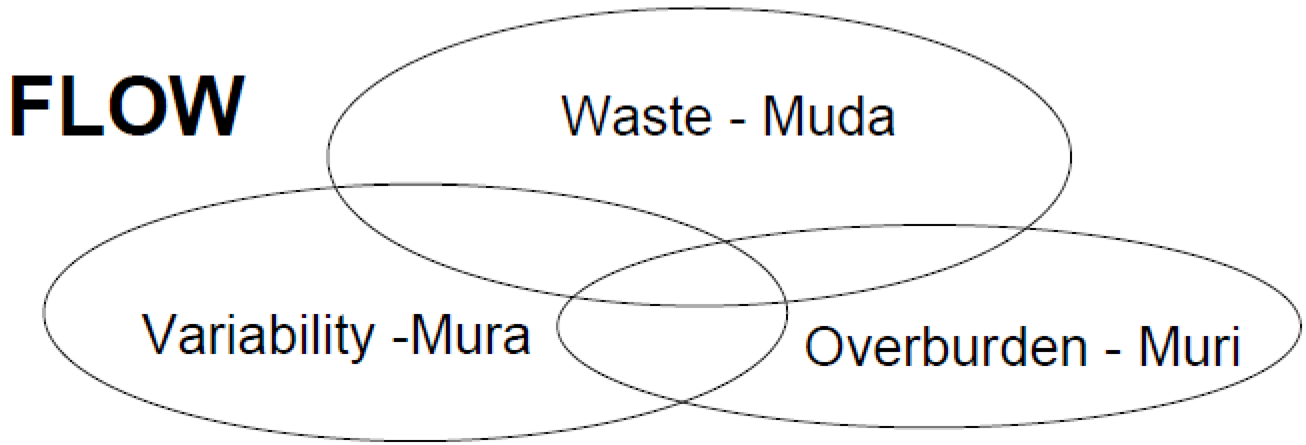
- The **LPS of production control**

sets up and **manages** schedules in order that:

- The **flow** of work is **structured** for the project.
- **Workflow** is **planned** within the **structure** of the work.
- **Work** is **controlled** to accomplish the plan.
- **Weekly measurement** evaluates **accomplishment** and **permits** fine tuning for improvement.

Lean production control

- Improve **workflow reliability** on **your site** by thinking through **production process during product design**.
- Thinking **production (flow)** during **design** and **project planning**



Lean in Construction Phase of the LPDS

(The Last Planner System in Construction)

موسسه مهندسی و مدیریت ساخت علوی پور

تهران، بلوار فردوس شرق، بعد از خیابان حسن آباد، مجتمع آبگینه، طبقه سوم اداری، واحد C42

+۹۸۲۱۴۶۱۰۰۴۵۰

+۹۸۲۱۴۶۱۰۰۴۴۵

www.dralavipour.com

info@dralavipour.com

@Acemi_social

@Alavipour_pm

youtube.com/channel/UC2vltk3T9m1X69hSWUwfp2Q

www.linkedin.com/company/iranacemi

ACEMI