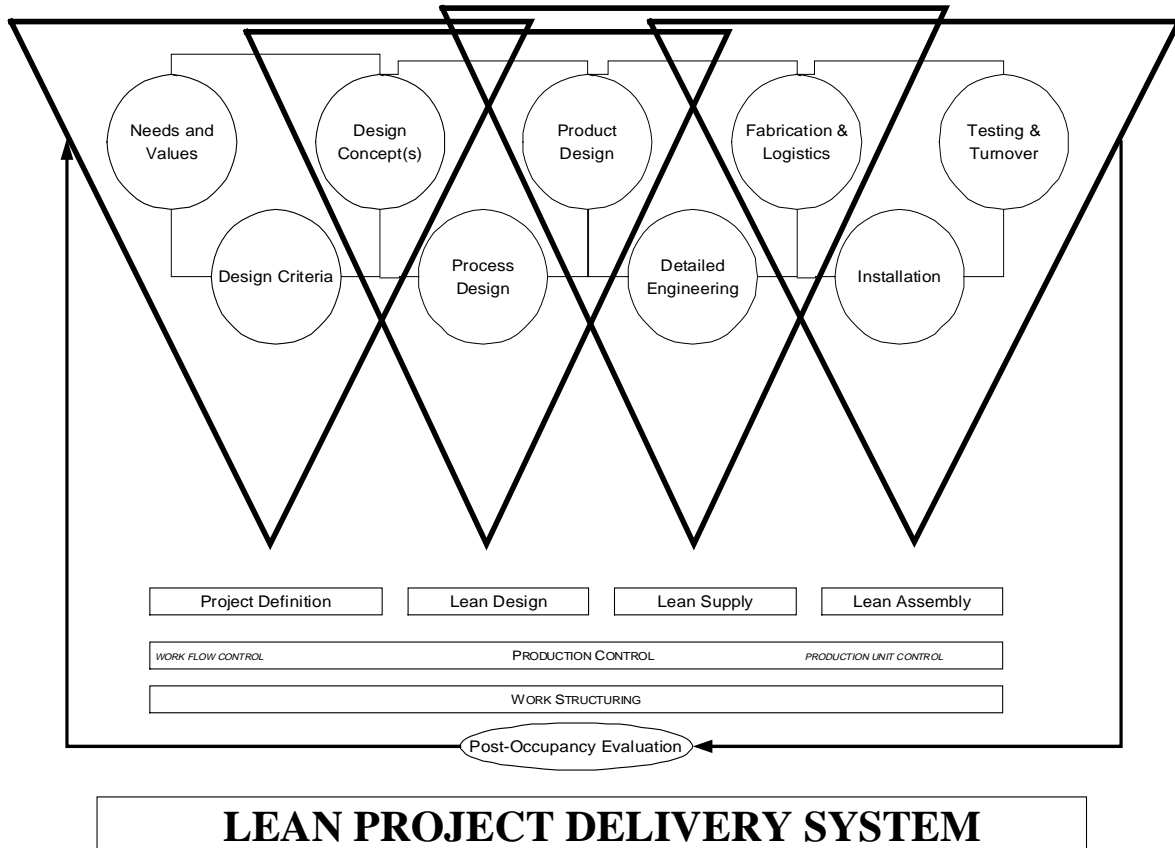


Lean Project Delivery System
LCI White Paper-8¹
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by
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LCI's mission is to develop a new and better way to design and build capital facilities. We call that new way the Lean Project Delivery System (LPDS). Our current LPDS model consists of 13 modules, 9 organized in 4 interconnecting triads or phases extending from project definition to design to supply and assembly, plus 2 production control modules and the work structuring module, both conceived to extend through all project phases, and the post-occupancy evaluation module, which links the end of one project to the beginning of the next.



LEAN PROJECT DELIVERY SYSTEM

¹ R/1. © Lean Construction Institute, 2000. All Rights Reserved. R/0 published 5/1/00. R/1 adds Work Structuring as a separate module.

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- The Project Definition phase consists of the modules: Needs and Values Determination, Design Criteria, and Conceptual Design.
- Lean Design consists of Conceptual Design, Process Design, and Product Design.
- Lean Supply consists of Product Design, Detailed Engineering, and Fabrication/Logistics.
- Lean Assembly consists of Fabrication/Logistics, Site Installation, and Testing/Turnover.
- Production Control consists of Work Flow Control and Production Unit Control.
- Work Structuring and Post-Occupancy Evaluation are thus far only single modules.

The LPDS will be developed as a philosophy, a set of interdependent functions (the systems level), rules for decision making, procedures for execution of functions, and as implementation aids and tools, including software when appropriate.

The domain for the LPDS is defined by the intersection of projects and production systems. We call this domain *project-based production systems*. Some LPDS modules will be applicable to projects that do not involve the designing and making of artifacts, and possibly also applicable to some types of production systems that are not executed through projects. For example, the production control modules may be applicable to project management generally, and also to all production systems driven primarily by directives rather than by predetermined routings between processing steps or machines. Even so, the LPDS will apply as a whole specifically to temporary production systems such as those used for new product development or capital facilities. Essential features of LPDS include:

- the project is structured and managed as a value generating process
- downstream stakeholders are involved in front end planning and design through cross functional teams
- project control has the job of execution as opposed to reliance on after-the-fact variance detection
- optimization efforts are focused on making work flow reliable as opposed to improving productivity
- pull techniques are used to govern the flow of materials and information through networks of cooperating specialists
- capacity and inventory buffers are used to absorb variability
- feedback loops are incorporated at every level, dedicated to rapid system adjustment; i.e., learning.

Work Structuring

1. "Work Structuring" is a term created by LCI to indicate the development of operation and process design in alignment with product design, the structure of supply chains, the allocation of resources, and design-for-assembly efforts. The purpose of work structuring is to make work flow more reliable and quick while delivering value to the customer.
2. Work structuring is the most fundamental level of process design, answering the questions:
 - In what chunks will work be assigned to specialist production units (PUs)?
 - How will work chunks be sequenced through various PUs?
 - In what chunks will work be released from one PU to the next?

- Where will decoupling buffers be needed and how should they be sized?
- When will the different chunks of work be done?

Work structuring decisions are made in all project phases. For example, decisions regarding supply chain structure may be made in the project definition phase, while seemingly small details like the selection of a specific component in detailed engineering can impact how work flows within the assembly process.

Production Control

1. "Last Planner" is the name for the LCI's system of production control.
2. Production control governs execution of plans and extends throughout a project. "Control" first of all means causing a desired future rather than identifying variances between plan and actual.
3. Production control consists of work flow control and production unit control. Work flow control is accomplished primarily through the lookahead process. Production unit control is accomplished primarily through weekly work planning.
4. Front end planning belongs to the project definition and design phases of projects. One of the products of front end planning is master schedules. Master schedules serve specific purposes; e.g., demonstrating the feasibility of project completion by target end date. Those purposes or functions do not require a high level of detail, which most often is inappropriate because of uncertainty regarding the future.
5. Master schedules are expressed at the level of milestones, typically by phase.
6. Phase schedules are produced by cross functional teams using pull techniques near in time to the scheduled start of the phase.
7. Phase schedules feed into lookahead windows, usually 3 to 12 weeks in duration.
8. Lookahead processes make scheduled tasks ready for assignment. Such tasks are placed in Workable Backlog.
9. Tasks are allowed to maintain their scheduled starts only if the planner is confident they can be made ready in time.
10. Scheduled tasks are made ready by screening for constraints, then by assigning make ready actions to remove those constraints.
11. The lookahead process generates early warning of problems so there is more time to resolve them.
12. Weekly work plans are formed by selection of tasks from Workable Backlog.
13. Every effort is made to make only quality assignments; i.e., those that are well defined, sound, in the proper sequence, and sized to capacity.
14. The percentage of planned assignments completed (PPC) is tracked and reasons for noncompletions are identified and analyzed to root causes. Action is taken on root causes to prevent repetition.

Project Definition

1. The project definition phase will be managed by the *project manager* responsible to the client for the entire project, including both designing and building.

2. The project manager may use traditional sources as inputs, such as architectural programming, but such inputs will be integrated with others, including post-occupancy evaluations.
3. Costing and project duration estimating will be integrated with the production of the project definition, rather than being done after the definition is produced.
4. When appropriate³, a target cost will be established for the facility to be designed. Otherwise, the client will make a decision regarding cost within the definition process.
5. Design criteria for both product and process will be produced.
6. Multiple conceptual designs will be generated and evaluated. When appropriate, more than one will be carried into the Lean Design phase.
7. Conceptual designs will be generated and evaluated in a dialectic with Needs Determination and Design Criteria development.
8. The project definition process will include an explicit information collection and documentation process.
9. Needs will be translated into design criteria using techniques derivative from Quality Function Deployment.
10. Collaborative production and decision making will include clients and stakeholders; e.g., design and construction specialists; suppliers of materials, equipment, and services; facility operators, maintainers, and users; representatives of financiers, insurers, regulators, and inspectors.
11. Work structuring will be applied in the project definition phase in the production of rough cut strategies and plans for project execution, linked to product architecture options, in advance of the more detailed integration of product and process design to be accomplished in subsequent phases.
12. Production control will be applied in the project definition phase once a plan for the phase has been developed. The first plan may be no more than fitting the steps of the project definition process within the available start and completion dates.
13. Project Definition transitions to Lean Design when there is alignment between:
 - ❑ customer needs and stakeholder demands
 - ❑ design criteria for product and process
 - ❑ conceptual design(s)

Lean Design

1. The Lean Design phase develops the conceptual design from Project Definition into Product and Process Design, consistent with the design criteria produced in Project Definition.

³ Target costs are appropriate when the facility is analogous to a product to be sold. Such is the case for clients whose business case is based on a return-on-investment strategy; e.g., commercial building developers. Target costs may be inappropriate for institutional facilities and other situations where the amount of funding is driven more by desired prestige or style, and where funding is often somewhat elastic. Example: Rice U. won't build a Fondren Library unless they can get a facility that meets their desires for a certain impact or statement. If they need more money, they will go back to their alumni and other donors. Should they be unable to get the money, and if they aren't forced by capacity, structural, or code considerations to build a new library, they won't built one at all.

2. Product and process design decisions are made with a view to customer needs as well as to design criteria. Should an opportunity emerge for increasing customer value by expanding customer needs, and if there is sufficient time and money, the project definition process will be reengaged to align needs, criteria, and design concepts.
3. Product and process design decisions are made simultaneously rather than first producing a design for the product, then trying to produce a satisfactory design for the process of designing and making that product.
4. The first process designed is the design process itself. That is done by the design team using team planning techniques (stickies on the wall), employing the Activity Definition Model (ADM). See *LCI White Paper-7: Phase Scheduling*.
5. One set of criteria/objectives for product design will be simplifying site installation to final assembly and testing.
6. Set Based Design (aka Set Based Concurrent Engineering) as practised in Toyota's product development will be developed into principles for process design.
7. The Design Structure Matrix will be used to resequence design tasks in order to reduce needless iteration.
8. Every effort will be made to maximize customer value in the making of trade-offs between needs and objectives.
9. A single conceptual design will normally be selected before the end of this phase because the last responsible moment for making that decision will have usually passed.
10. Design decisions will be deferred until the last responsible moment if doing so offers an opportunity to increase customer value.
11. Production control is applied to the Lean Design phase using standard Last Planner procedures and techniques. An MS Access-based software developed by James Choo and Iris Tommelein will be tested and refined on member projects.
12. IT tools to be tested in the Lean Design phase include:
 - 3D modeling, shared geometry
 - Collaborative design software, web-based
13. Specialty contractors will either serve as designers or will participate in the design process, assisting with selection of equipment and components and with process design.
14. Where specialty contractors do not perform the design, designers will produce only those deliverables needed for permitting and needed by specialty contractors or other suppliers for detailing. Example: the mechanical engineer will produce only single lines of HVAC duct.
15. We will explore how best to use 3D modeling consistently with a set-based approach, recognizing that current models are not well suited to expressing ranges of values or alternative geometries. 3D/4D may be best used in the design phase as a simulation tool for exploring and evaluating alternatives, whereas it may provide the shared geometry needed to minimize interferences and conflicts in the detailed engineering module.
16. We will explore tools and techniques for process modeling.
17. Operations design is strictly speaking that part of process design that deals with 'making'; i.e., fabrication, assembly and testing. We hope to learn how to design operations to facilitate flow. Operations design is completed in First Run Studies during the Assembly phase.
18. The Lean Design phase transitions into Lean Supply when the product and process design have been developed from the design concept consistently with design criteria, which are themselves adequate expressions of customer needs and stakeholder demands. This

alignment will be explicitly examined and agreed by the design/build team and the client before transition.

Lean Supply

1. The Lean Supply phase consists of detailed engineering of the product design produced in Lean Design, then fabrication or purchasing of components and materials, and the logistics management of deliveries and inventories.
2. All decisions regarding the engineering, production, or delivery of materials and components are made with an eye to maximizing customer value.
3. 3D modeling will be used for detailed engineering.
4. Where possible, fabrication will be driven directly from the 3D model.
5. Collaborative design tools will be used to integrate design inputs developed on different platforms into a single model.
6. Process design will have addressed buffer type, location, and sizing. That will be further detailed and then controlled in this phase, in which the 'iterative' relationship among the modules within the phase are more like continuous adjustment than like the generative conversation characteristic of design proper.
7. We will apply lean manufacturing techniques to fabrication shops.
8. It is in this phase that the project, which is a temporary production system, is physically linked to the supply chains that exist independently of the project. Mapping those supply chains is a central research task. Once chains are understood, they may be reconfigured, and both costs and lead times reduced.
9. An objective of process design is to minimize inventories, right sizing them to the flow variability that cannot be eliminated. Where time is of the essence, capacity buffers will be substituted for inventory buffers.
10. This phase transitions into Lean Assembly once site deliveries begin. Site deliveries may be initiated within a fast tracking strategy that decouples facility systems or components so that assembly of one component can begin while detailed engineering of subsequent components is still underway. We will test the hypothesis that a lean version of design-then-build can deliver projects faster than fast tracking. Even so, in no case will all fabrication and procurement of components be completed prior to initiating site installation.

Lean Assembly

1. Lean Assembly begins with the first delivery of tools, labor, materials or components to the site and ends when the keys are turned over to the client.
2. A key issue is coordination of deliveries to ensure soundness of assignments while sizing buffers to residual variability.
3. An objective is to approximate one-touch material handling ideals.
4. We will develop the technique of in-process inspection both in shops and at sites.
5. We will first do descriptive research of testing/turnover processes, looking at 'zero punch list' initiatives and at system integration issues. We expect to find considerable waste and value loss.
6. We will encourage incorporation of First Run Studies into assembly lookahead processes, measure their benefits, and link feedback to project definition, design, and supply.

7. We will develop and test the hypothesis that the front line supervisor's role will change from giving orders to coaching and managing improvement.
8. We will learn how to structure and manage intimately connected operations as continuous flow processes.
9. We will promote multiskilling in shops and site installation. Multiskilling is probably best initiated within the context of continuous flow processes, as a means for fine balancing. From there, it could be extended to the objective of minimizing total site head count.