

**TOWARD CONSTRUCTION JIT**  
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### 1.0 Introduction

The acronym JIT has been highly visible since the late 1980's, as manufacturing attempted to meet competitive challenges by adopting newly emerging management theories and techniques, referred to by some as Lean Production (1). What is JIT? What is its relevance for the development and implementation of Lean Construction theory and practice (2)?

Manufacturing JIT is a method of pulling work forward from one process to the next "just-in-time"; i.e. when the successor process needs it, ultimately producing throughput. One benefit of manufacturing JIT is reducing work-in-process inventory, and thus working capital. An even greater benefit is reducing production cycle times, since materials spend less time sitting in queues waiting to be processed. However, the greatest benefit of manufacturing JIT is forcing reduction in flow variation, thus contributing to continuous, ongoing improvement. Can this approach be applied to construction? What is "Construction JIT"?

### 2.0 Construction JIT vs Manufacturing JIT

JIT is a technique developed by Taichi Ohno and his fellow workers at Toyota (3). Ohno's fundamental purpose was to change production's directives from estimates of demand to actual demand--a purpose originally rooted in the absence of a mass market and the need to produce small lots of many product varieties.

In assembly line production systems managed by lean production concepts, the directives for production are provided by means of kanban from downstream processes. This system insures that whatever is produced is throughput, i.e. is needed for the production of an order. Kanban works as a near-term adjusting mechanism within a system of production scheduling that strives for firm and stable aggregate output quantities, and provides all suppliers in the extended process progressively more specific production targets as the plan period approaches, resulting ultimately in a firm 2-6 week production schedule. This system provides sufficient flexibility to adjust to actual demand, while assuring that all resources are applied to the production of throughput.

In manufacturing, the need for flexibility comes from a potential difference between forecast and actual demand. Many products are being produced, so it is important to minimize the time required to produce any specific type of product demanded. In construction, there is only one product produced once. And in the case of industrial construction, that product is the facility for producing manufacturing's products. It is consequently important to reduce the time needed to produce the facility, not necessarily the time to produce any component. (NB: This fact often conflicts with the different interests of the various organizations involved in a project.) Further, changes arise from progressive definition of customer wants, so flexibility is needed in order to respond to late-breaking changes.

The application of JIT to construction differs substantially from its application to manufacturing because construction and manufacturing are different types of production, and because of the greater complexity and uncertainty of construction.

The extent and significance of uncertainty in construction has been adequately addressed in earlier papers (4, 5, 6), but a moment's reflection supports the view that construction is complex. The number of parts, relative lack of standardization, and the multiple participants and constraining factors easily make the construction of an automobile factory more difficult than the production of an automobile in that factory. When this complexity is joined with economic pressures to minimize time and cost, that uncertainty results is not surprising. But is construction really a different type of production than manufacturing, or simply a more complex and uncertain version of manufacturing itself?

## 2.1 What kind of production is construction?

Construction is the final component in manufacturing's product development process. Construction is complete before manufacturing's production begins. Consequently, it is misleading to conceive construction as analogous to factory production (although some aspects of construction fit better in that analogy; i.e. fabrication). Construction is best conceived as a product development process, extending from product design through process design to facility (the manufacturing process tool) construction, the end result of which is readiness for manufacturing.

Admittedly, this is a best fit in the case of industrial construction, and becomes less plausible as we move toward the cookie cutter end of the industry spectrum, e.g. manufactured housing. There seems to be a gray zone between manufacturing and construction, where the work looks like construction because final assembly is done where the facility is to be used, but looks like manufacturing because all that remains of the process is to match production output with sales. This gray zone is obviously ripe for industrialization and mechanization, which ultimately pushes it over into the camp of manufacturing. The proper business of construction is completing product and process design. Once that is done, it is but a matter of time before wit and invention capture mere assembly for manufacturing.

Uncertainty is a necessary component in construction conceived as a product development process. The very purpose of the process is to surface and resolve trade-offs between means and ends, all the way from product design through facility construction. The management of projects so conceived is the proper terrain for lean construction concepts and techniques.

So, construction is a different type of production than manufacturing, and has greater uncertainty and flow variation. Is there an application for JIT in construction?

## 2.2 Using JIT to reduce variation and waste: Manufacturing vs Construction

By minimizing inventories between processes, Ohno removed the safety stock that allowed a downstream process to continue working when a feeder process failed. He also required that operators stop the production line when they were unable to fix problems. Consequently, it became necessary to solve problems rather than simply passing bad product down the line. Problems also became highly visible since they could result in line stoppages. Forced confrontation with problems together with analysis to root causes produced a progressively more

streamlined and smoother running production process, with fewer end-of-the-line defects and higher throughput.

How might this work in construction? Construction is schedule-driven. Given a well-structured schedule, if everyone stays on their part of the schedule, the work flows smoothly and maximum performance is achieved. However, as we all know, it is rare that projects perform precisely to their original schedule. Business conditions change, deliveries slip, a design requires correction, etc. If a schedule has sufficient slack in the impacted activities, changes may not impact end dates. When there is little or no slack, players are pressured to make it up in accelerated production. Where in this scenario is the opportunity or impetus for reducing variation and waste? Where are the buffers that conceal variation and waste?

### 3.0 Types of Construction Buffers



**UNBUFFERED FLOW PROCESS**



**BUFFERED FLOW PROCESS**

There are two types of inventories that can serve the function of buffering downstream construction processes from flow variation. The most familiar type is piles of stuff; materials, tools, equipment, manpower, etc. These piles of stuff may originate in decisions to insert certain time intervals between scheduled activities, e.g. between fabrication and installation of pipe spools. Consequently, while they take the form of stuff, they often also represent time added to project duration, so I call these "schedule buffers" (6).

Less familiar are inventories of workable assignments, produced by planning processes that make work ready for downstream production (7). These buffer by enabling a reliable, predictable flow of output from each process. They need not imply the existence of piles of stuff, depending

upon the predictability of flow between supplier and customer processes. I will call these inventories of workable assignments "plan buffers."

### 3.1 Functions of Schedule Buffers

In the construction of process plants (petroleum, chemical, food processing, pulp and paper, etc), projects are frequently fast track; i.e. construction begins before design is completed (8). Late delivery of drawings and materials has led construction contractors to demand earlier delivery, reducing the time available for engineering to complete design, resulting in more delivery problems and demands for even earlier deliveries. This is clearly a vicious circle.

Large schedule buffers between suppliers and construction may shield the contractor from the impact of late deliveries (6), but does nothing to address the root causes of variation. Further, the shielding is expensive, both in time and money. There is a better way.

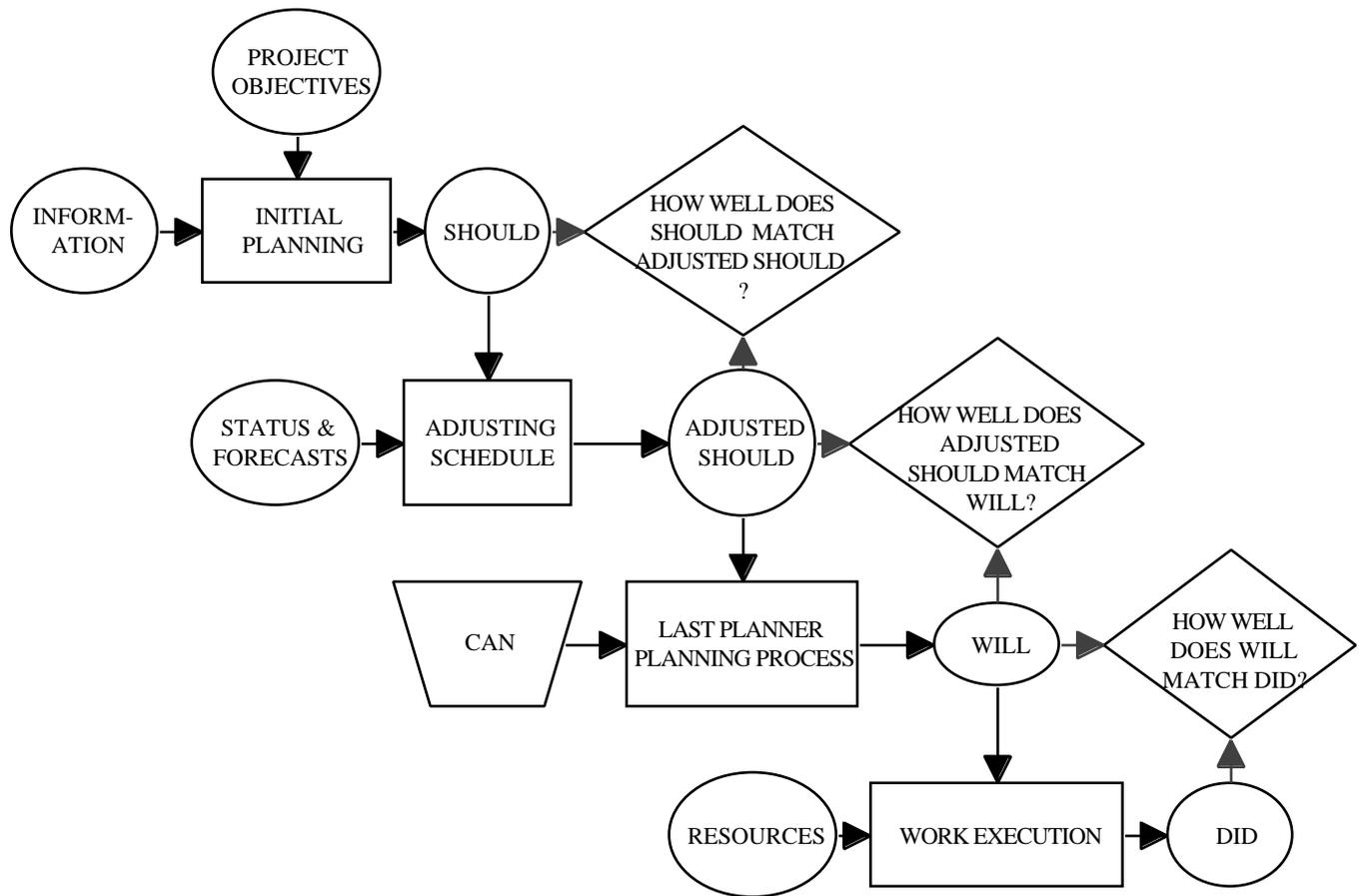
A suggested rule: Place schedule buffers just after processes with variable output. For example, that suggests placing schedule buffers between engineering and fabrication, rather than between fabrication and installation. The fabrication and delivery processes are highly predictable, unless drawings are incorrect or incomplete, or drawings are pulled out of fabrication to be revised. A schedule buffer in front of fabrication would provide more time for engineering to complete its work and do it correctly. It would also provide the fabricator an opportunity to select and bundle work to meet his needs for production efficiency and the contractor's needs for quantities and sequence.

Another suggested rule: Size schedule buffers to the degree of uncertainty and variation to be managed. Research (6) has shown that schedule buffers are sized without regard to the toughness of projects; i.e. their level of uncertainty. This amounts to wasting time and money accumulating piles of stuff not all of which is needed.

### 3.2 Functions of Plan Buffers

Schedule buffers do not replace plan buffers. Plan buffers are necessary even when schedule buffers are in place because having a pile of pipe does not provide a piping crew with workable assignments. Pipe spools must match with valves, controls, hangers, gaskets, bolts, welders, lifting equipment, etc, etc. Structures for supporting the pipe must be in place. Preferably, the spools that can be installed are those that should come next in an optimum constructability sequence. Assembling physical components, reserving shared resources, determining optimum sequencing, and sizing assignments to absorb the

productive capacity of the crew is best done prior to making assignments and committing to what work will be done in the plan period, usually one week.



Plan buffers, sometimes called backlogs of workable assignments (7), are the outputs of make ready processes. They determine what CAN be done as distinct from what SHOULD be done. Obviously, commitment to what WILL be done next week can only come from CAN, regardless of the pressure for production and the need to make up schedule slippages. The common practice of pressuring for production regardless of CAN is rooted in a theory of construction project management that disregards capability and management of flows in favor of schedule push and management of contracts (5).

By monitoring the match of DID with WILL using the measurement of PPC, the percentage of planned activities completed, and acting on the root causes of non-completions, we can learn how to produce better plans and how to do what we plan to do. The implications for work flow, project durations and productivity are enormous.

Think of the complete construction process, from engineering through installation and start-up, as a complex of work processes, with

work flowing from one to the next. When a downstream process attempts to plan its work and determine the resources it will need, it may have shielded itself from unreliable inflow using piles of stuff or schedule spacing. However, it only needs those piles of stuff if supplier processes cannot reliably do what they say they are going to do. If supplier processes consistently achieve PPCs near 100%, customer processes can plan their work and match resources to it. Reduction of schedule buffers and better matching of resources to work flow both contribute to reduction of project time and cost.

### 3.3 Plan-Pull vs Schedule-Push

Make Ready processes produce inventories of workable assignments by 'pulling' forward resources needed to do that work that will best contribute to throughput at each point in time. Resources were procured and distributed in accordance with schedules; i.e. the work was driven by schedule-push. Now the driving mechanism becomes plan-pull.

Plan-pull can include reference to successor readiness. For example, the decision to install this structure or that may be determined by the predicted delivery of equipment and piping for each of those structures. Generally, SHOULD is continuously tested against CAN, and WILL is selected from the best of the available alternatives. While plan-pull mechanisms are common, industry thinking has not recognized their role and importance.

### 4.0 A Strategy for Construction JIT

The JIT ideal is elimination of physical buffers (materials or time) between production processes, and the achievement of one piece flow (6) within processes, i.e. batch sizes of one. Ohno was able to virtually eliminate such in-process inventories because production scheduling provided sufficiently stable coordination of flows.

Construction scheduling does not provide such stabilization. Consequently, it is not appropriate to simply eliminate physical buffers without first attacking the causes of variation and uncertainty. Even though manufacturing and construction share the same ultimate objective of reducing variation and waste, their strategies for achieving that objective must be different.

I propose as a strategy for construction JIT: 1-Better location and sizing of schedule buffers, 2-Immediate implementation of plan buffers and make ready processes in front of production processes, and 3-Progressive replacement of schedule buffers by plan buffers.

## 4.1 Better Location and Sizing of Schedule Buffers

#1 will require developing better assessments of project uncertainty and determining the quantitative relationship between buffers and the uncertainty they are intended to buffer. It will also require experimentation with relocating schedule buffers, to test the principle of locating buffers just behind processes that are the source of flow variation.

## 4.2 Place Plan Buffers and Make Ready Processes Ahead of Each Production Process

#2, the Last Planner (LP) initiative, has been described in some detail in previous papers (7). Although it has been experimentally tested in both the United States and South America (Venezuela), it may be helpful to consider it as a research hypothesis.

Hypothesis: Production can be shielded from upstream uncertainty through planning.

**Benefits of the Research**: The Last Planner method of detailed production planning shields production from upstream uncertainty thus improving productivity, revealing sources of uncertainty and variation, releasing resources for further improving performance "behind the shield," and providing a highly predictable near-term work flow to downstream processes.

**Methodology**:

- Solicit engineering and construction projects from industry.
- Evaluate the crew/squad level planning systems of each
- Help participants conform their systems to the Last Planner Model.
- Develop measurements of comparative productivity
  - Before and after LP
  - Between LP and non-LP
- Collect measurement data; i.e. percent planned assignments completed, planned productivity, and actual productivity.
- Analyze measurement data and test hypothesis

**Characteristics of the Last Planner Method**:

- Written weekly work plans for each front line supervisor and work group.
- Assignments drawn from a backlog of workable assignments created by screening for constraints and by acquiring necessary resources.
- Assignments expressed at the level of detail necessary for sci
- Weekly work plans sized to target productivity.
- Front line supervisors participate in the selection and sizing of assignments, provide reasons why planned work was not
- Craft superintendents/Discipline supervisors see that others act on reasons beyond the reach of the craft or discipline.

#### 4.3 Progressively Replace Schedule Buffers with Plan Buffers

That leaves #3, the long term goal of replacing schedule buffers with plan buffers. How will the construction industry achieve that level of predictability of work flow that will eliminate the need for piles of stuff or time between production processes?

Hypothesis: Work flow variation can be reduced.

Benefits of the Research: 1) Project duration can be reduced by reducing the buffers between EPC functions, and buffer sizes can be reduced if work flow variation can be reduced. 2) If work flow can be made more predictable, labor and other resources can be better matched to work flow, thus improving productivity.

Methodology:

Phase I: Identify and analyze examples of successful efforts (tools and techniques) to increase the predictability of work flow.

Phase II: Test tools and techniques in experiments sponsored by industry members.

Examples of Tools and Techniques:

-Developing more accurate assessments of project uncertainty.

-Adjusting schedules using work packages and milestone station, until limits of predictability are met. Act on constraints to push back limits. screen

- Buying information to extend the accuracy and range of forecast
- Producing more advance warning of changes in
- Integrating supplier and customer schedules at the item (e.g. i

## 5.0 Conclusion

Construction JIT will be advanced by implementing demonstrated techniques and industry research to test theories and develop new tools and techniques. Research topics have been proposed that constitute a strategy for implementing Construction JIT.

Construction and manufacturing are different types of production, nonetheless a form of JIT is applicable to construction, in which physical buffers may ultimately be replaced by better managing uncertainty and eliminating the causes of flow variation. As the implementation of plan buffers propagates certainty throughout projects, productivity will improve from better matching labor to work flow, and project durations will shorten as physical buffers shrink with the flow variation they are designed to absorb.

A new way of conceiving the tasks and tools of construction project management has been proposed. Instead of relying simply on schedule-push, managers are advised to systematically employ plan-pull as a means of adjusting to uncertainty and insuring that resources are employed to maximum advantage at each point in time. Instead of concentrating management attention and effort on managing contracts and enforcing obligations, managers are advised to manage the flow of work across production processes and the various specialty organizations brought into a project to execute those processes.

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