

Implementing Lean Construction: Reducing Inflow Variation

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In many circumstances variety is the spice of life. But it is a bitter herb when you are trying to complete a complex and uncertain fast track project. Significant variations occur at every stage in the construction process. Plans change and materials are late. In compressed circumstances, variation becomes more apparent and critical as it exposes the interdependence between activities. Once the work environment is stabilized through modifying the planning system, it becomes possible both to reduce variation in flows and to work behind the shield to improve downstream operations. Suggestions for research and improved practice are offered specifically regarding the management and reduction of flow variation.

Understanding and Responding to Variation:

Variation in delivery is a fact. Responding to variation is a major aspect of Lean Production Theory (LPT). Buffers between operations are an important tool because they allow two activities to proceed independently. Variations in output from upstream operations does not limit the performance of the downstream operation. Buffers can serve at least three functions in relation to shielding work by providing a workable backlog;

1. To compensate for differing average rates of supply and use between the two activities.
2. To compensate for uncertainty in the actual rates of supply and use.
3. To allow differing work sequences by supplier and using activity.

As valuable as buffers are, they are expensive, hard to size, and hardly an optimal solution. The costs associated with buffers include storage space, double handling, inventory management, loss prevention, buffer fill time, and idle inventory. Buffers are hard to size because the actual supply and use rates are unknown and they vary. Ohno recognized that buffers are hardly an optimal solution and admonished management to cease reliance on them. As he said, “You must drain the water from the river to see the rocks.”

Oddly, the flow management problem in construction is more difficult because we seldom are allowed to build buffers. Great pressure for immediate production is transmitted to users by the cost/schedule system, the requirement for cash flow, and the early-start mentality of project managers. As a result, planning is inhibited because the actual rates of consumption are unknown because “normal rates” include delays due to waiting for resources. As a consequence, our advice to establish buffers at first appears contradictory. But in order to find the uninhibited use rates we must make it possible to work without interruptions. An example is in order.

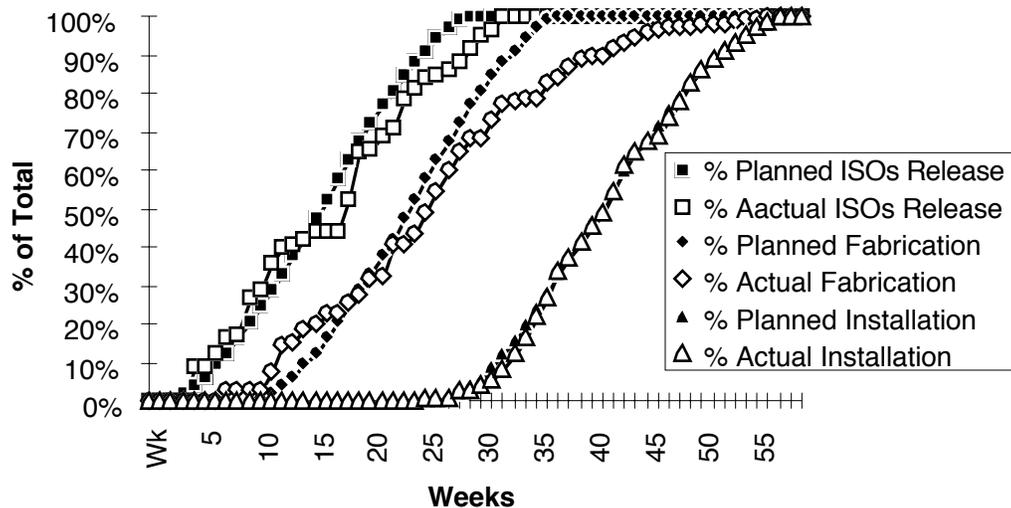


Figure 1: Plan vs Actual Piping Design, Fabrication, and Installation

Figure 1 traces the planned and actual delivery of isometric drawings from the engineer to the fabrication shop, the planned and actual fabrication and delivery of pipe to the site, and the planned and actual installation rates. Each stage except the last shows a high degree of variation from the planned rates of provision.

This project was built under fierce time constraints. Even so, the installation contractor held to their policy of **not** starting installation until 85% of the pipe, structural steel and equipment was on site. They believe, and their balance sheet supports, that they can work extremely efficiently and quickly by waiting for the backlog to develop. Oddly, this company only accepts lump-sum contracts so they will not be forced by the owner into inefficient practices. Their policy is to avoid growth so they only bid on enough work to keep their backlog nearly filled with “high” quality projects. While the strategy works for this contractor, others often proceed with work before a workable backlog exists.

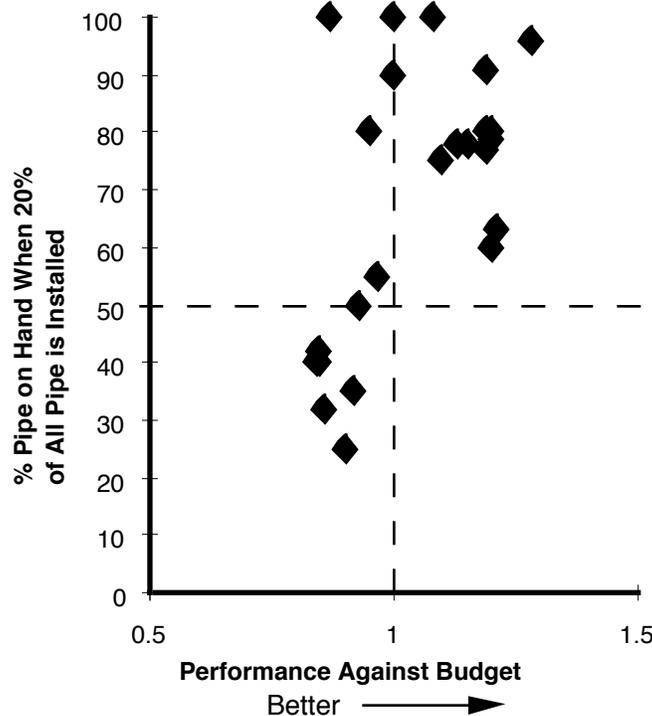


Figure 2: Project Performance vs Buffer Size

Figure 2 shows the relationship on 4 projects between buffers of pipe on hand at the beginning of installation and project performance. Project 2 shows similar performance to project 1 (described in Figure 1 above). Interestingly these projects are almost complete opposites in every other aspect including size, location, union/non union labor, contract form, constructability reviews etc. Despite their differences, management in both cases made explicit decisions to establish buffers and neither gave in to tremendous pressure for partial releases of work or starting before enough work was available so the downstream operation could be expected to run steadily to completion. The value of buffers of resources is understood throughout the construction organization. They occur at all levels in response to variations. We often find middle level

supervisors hoarding materials, tools and equipment in the face of strong pressure to release them to others for use. As a result they have learned clever techniques for hiding resources and will sometimes lie to maintain concealment.

Steel Delivery: Scheduled vs Actual

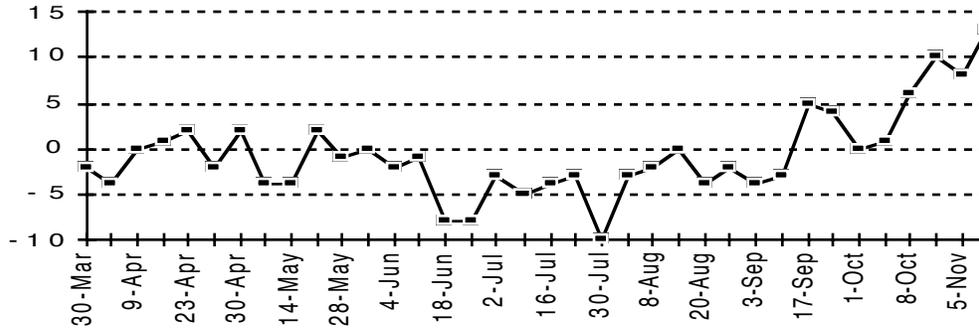


Figure 3: Steel Delivery-Scheduled vs Actual

Figure 3 provides an example of an attempt to provide a buffer which failed because variation had been underestimated. Structural steel was delivered to a jobsite over an eight month period, from April to January. The steel had been divided into delivery sequences to match the contractor's installation schedule. The data points on the chart show in weeks when sequences were delivered relative to their scheduled delivery dates. Points above the line represent early deliveries and points below the line represent late deliveries. The level of variation shown on the chart subverted the contractor's plan to work from a three week backlog of steel-in-hand. The contractor had underestimated the degree of variation and uncertainty in the flow of that resource.

Decisions were taken to reduce labor when the amount of steel on site was evaluated and the degree of unpredictable delivery documented. The owner and contractor then took the logical step and dispatched an engineer to expedite fabrication. They found the hold up was in paint completed steel.

Variation in Plans:

Plans change. The extent of uncertainty was documented in Figures 1 & 2 of the first paper. The current practice is to update the plans to reflect the current status and to reissue the schedule with strong letters urging improved performance. The discussion here is illustrated in Figure 4 and follows the strategy of improving the stability in planning from the bottom up. The first phase is to shield work execution and then to move up to the adjusting mechanism and finally to rethinking initial planning.

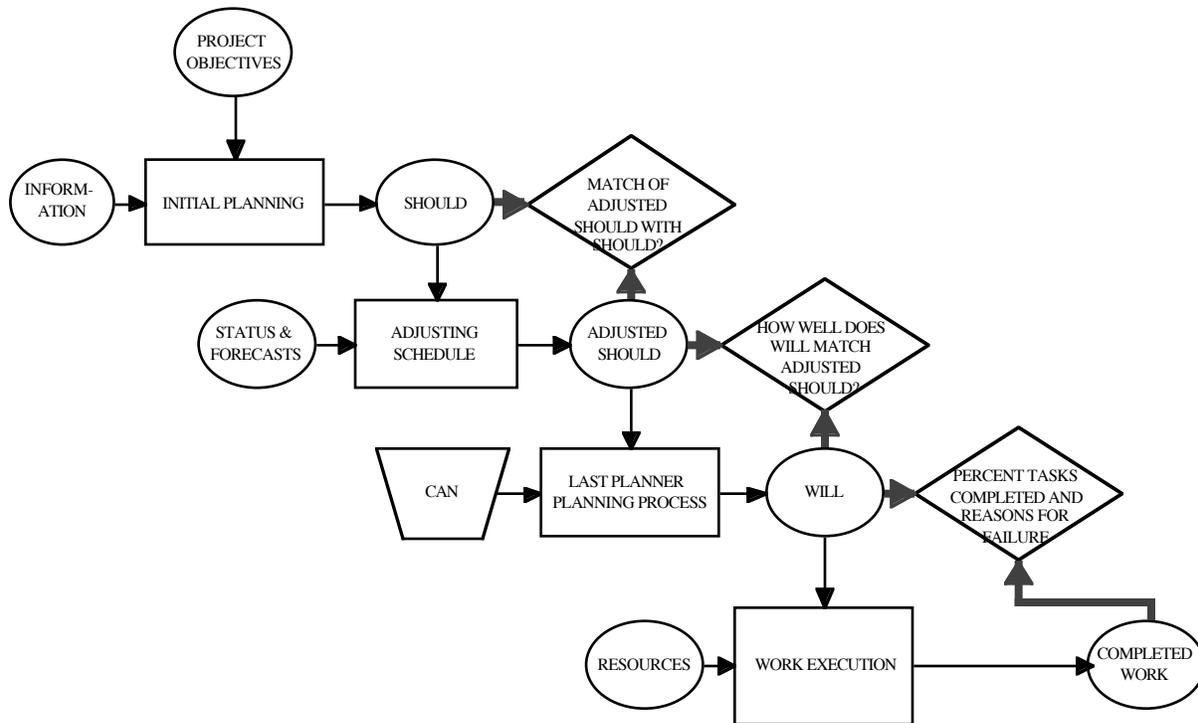


Figure 4: Planning System

Developing workable backlog for the last planner.

Gathering and assuring a backlog of stuff is a complex inventory management problem. The difficulty comes from the unpredictable rates of use and supply of specific resources. In our experience, the resource supply or materials group views their task as one of supplying resources to the crew. As important as this is for doing work, it overlooks the task of providing information to planners on what can be done. It often appears that the material systems in these companies were designed on the premise that everything would work as it should. In fact, even the last planner faces the same task of matching should with can, breaking the operation into pieces, and deciding the appropriate level of detail and update frequency.

An example of managing workable backlog illustrates the idea and shows that a contractor need not be totally at the mercy of the third party engineer to deliver drawings and materials in accordance with the project schedule.

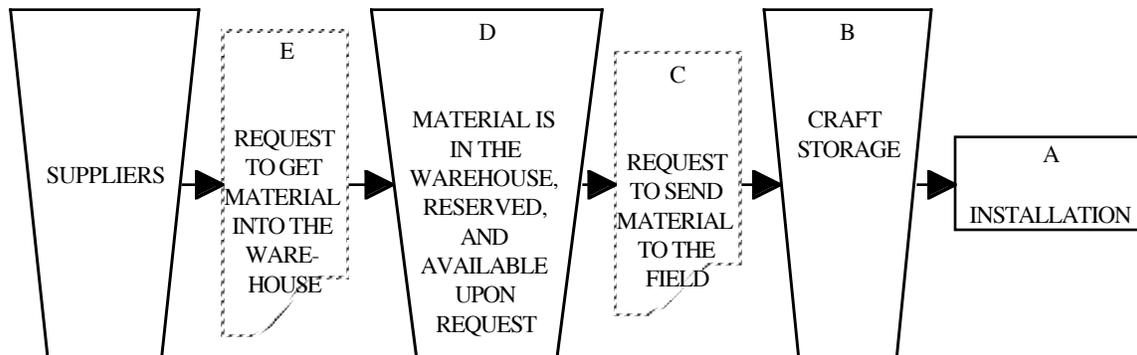


Figure 5: Managing Workable Backlog

A strategy for using resource buffers appropriate to construction-only (but still fast track) projects is illustrated above. The sequence of steps on the flowchart show how the piping craft controlled the flow of materials onto and within the jobsite. Piping supervision had access to computer terminal listings of piping drawings, with the typical progressing milestones displayed: fabrication, erection, connection, trim, punch. From schedules, models and marked up drawings, the supervisors decided what and how much work needed to be done 4 weeks in the future and marked the selected milestones with an "E". The same database was accessible by materials management, who took "E's" as a directive to get the associated materials into the warehouse within two weeks. Materials managers first allocated existing inventory to the priorities, then purchased/expedited missing materials. Once an item was materially sound, the appropriate milestone was marked by materials management with a "D", indicating to piping supervisors that the material required to do that work was in the warehouse, reserved for that use, and ready for issue to the field. The week before they needed to work that material, piping supervisors placed a "C" in the appropriate milestone nodes, thus telling the warehouse to send it to field storage, at which time it was marked a "B". Piping foremen selected work to be done next week from "B's", marking those selected as "A". When a milestone was marked with a letter, the man-hours budgeted for that work were automatically summed for each drawing and for the total items selected, so the planner could know if the right amount of work had been selected.

The consequence of this approach to planning is that people only commit to doing work that can be done. Work is selected for material-soundness, available materials are allocated to plan priorities, and expediting is directed to support plan priorities that are very specific. Secondary benefits include elimination of separate progress reports and material requisitions. Perhaps equally important is the backlog system gives management a significant degree of forward control.

WORKABLE BACKLOG

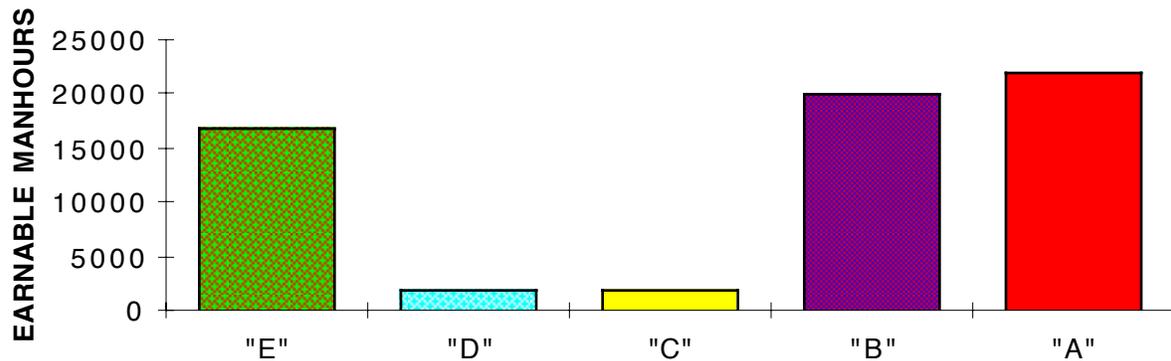


Figure 6: Quantifying Workable Backlog

Figure 6 shows the actual level of backlogs at each station early in the implementation of the planning phase. With this data, it is no longer necessary to wait for cost reports to trickle in after being massaged by middle management to see the problem and begin to take action.

The Adjustment Process:

The Adjusting Process is the next level in the planning system. Current adjustment approaches fail to provide useful plans in part because the primary task of the Planning and Controls group is to prepare forecasts for senior management. Unfortunately, since corporate rules force the planners to put the best face on the situation, these forecasts are seldom prepared using detailed updates on resource availability. Many practitioners will take strong exception to this claim. However most plans rest on a policy of including all future activities as if the resources for all were 100% certain of arriving to support the plan. A review of the current approach to the 90 Day look ahead schedule used by a major contractor makes the point.

The 90 Day Lookahead Schedule is a drop-out from the project schedule, sometimes at a higher level of detail. A scheduled activity may not be deleted from the 90 Day even when the management knows it cannot be done because that appears to reduce the pressure both upstream and downstream to meet contractual commitments and milestones. When they know something cannot be done, the status is communicated informally to craft planners, so they know not to expect on-time delivery.

We suggest the opposite: allow scheduled activities onto the 90 Day **only** if managers are morally certain that it will enter into workable backlog as scheduled. Each week, slide the 90 Day window forward one week and review the status of all scheduled activities that fall within the window. If an activity is questionable, it falls out of the 90 Day, gets flagged for expediting attention, and reappears on the 90 Day when its on-time delivery is assured or the schedule has been adjusted to accommodate a later delivery.

Picture a line running from 0% to 100% probability of on-time delivery. We now adjust the schedule only when probability nears 0%. Instead we should begin adjusting the schedule when probability departs from 100%. Defining risk and agreeing on trigger levels of probability may seem difficult, but in fact must occur if we are to find a way to provide both the earliest warning of impending variation and the information on performance needed to improve the planning system.

Initial Planning

Let us return to Figure 4 to better understand the stages of planning. At the top, consider the obstacles to improving the stability of initial plans. The directives to the initial planning typically include explicit project objectives with an implication that the objectives should remain stable. At this stage, (as in all following stages) control is achieved and variation reduced by careful attention to the stability of inputs. Initial plans are based on the answers to questions like; “How is the market trending? What is happening to the process technology? What is our available cash flow?” Since none of these questions can be answered with absolute certainty and changes in the answers can have dramatic effect on project success, the best advice falls in two categories:

1) Monitoring the basis for the plan; This means carefully identifying key assumptions or premises and assigning the responsibility for monitoring and early detection of changes to specific individuals. This applies the principle of reducing inflow variation at the outset of the project. Significant research is required to better understand how to diagnose the situation in terms of uncertainty, how to break projects into pieces, how to set the level of planning detail, and how to determine the appropriate update frequency. Similar research would be useful at each of the following planning stages. Practitioners are advised to explicitly consider these questions when planning the planning process.

2) Carefully testing the objectives against means for achievement. Objectives are only fixed when the means have been carefully examined. This applies the principle of matching “Should” with “Can” at the outset.

Summary:

Flow variation can be reduced by stabilizing all functions through which work flows from concept to completion. Better understanding uncertainty, suppliers and customers can eliminate the causes and so reduce variation in shared processes. In addition planning systems must be redesigned to include a level for adjusting “SHOULD”, so operations can better match “SHOULD” with “WILL”. The next step in implementation of lean construction is to work behind the shield on improving performance, taking full advantage of the reduction in variation and uncertainty thus far achieved.

Laufer, A., Howell, G., “Construction Planning: Towards a New Paradigm”. PMI Journal, Mar.. 1994