DISPELLING THE COMPLEXITY MYTH: FOUNDING LEAN CONSTRUCTION ON LOCATION-BASED PLANNING

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ABSTRACT

There has been a recent trend toward believing that projects are complex, unpredictable and that control systems of late intervention such as Last Planner are necessary to solve the problem. The complexity assumption is challenged in this paper, and it is shown that the some of the apparent complexity arises from a simple mathematical problem which is easily resolved—and thus better planning becomes not only possible but a better solution.

A complex refurbishment project is used to illustrate the different approaches and to show where apparent complexity arises. It is then shown how under normal planning methods the sites are asked to resolve an intractable problem. They do their best, but they have been let down by the planners.

KEY WORDS

Flowline, Complexity, Chaos, Location-based, Scheduling.

INTRODUCTION

This paper is partly about myths and reality; specifically the complexity myth and project planning reality. "Myth was the favourite and universal method of teaching in archaic times" (Kuhn, cited in Harpur 2004) and myth has been used strongly within the lean construction community to educate the masses toward the evangelical truth of a lean philosophy. "The myth in the hands of a genius gives us a clear picture of the inner import of life itself" (Harpur 2004). Currently there is a myth developing that complexity is an inherent component of construction (and evidence can be seen in the proliferation of complexity papers in the proceedings of this conference).

This is not a criticism. Myth is a powerful teaching tool, and the proponents of lean are attracted to the myth of complexity because it teaches that reactive management is more effective than planned management. The sources of complexity are clients, external factors and site conditions, etc. The effects of complexity are variable schedules or production: perturbations to use the language of complexity. The interpretation of the myth is clear, it exposes the clear truth that command and control management systems fail under real conditions and lean management systems based on pull scheduling are required to accommodate the inevitable consequences of complexity. It is indicated that the nature of complexity is beyond understanding and therefore management. It explains the mysterious and unpredictable site events that disrupt work:

> *"… the mysterious, the ineffable, the workings of the spirit in the human heart or in the cosmos at large cannot be adequately expressed other than by myth, allegory, imagery, parable and metaphor" (Harpur 2004).*

Thus, the myth of complexity is a powerful addition to the arsenal of those preaching lean production methods to the construction management community. It is a reassuring myth as well, as it says "don't worry about your loss of control, it is inevitable. Accept it and manage the reality by adaptive response systems: lean systems based on critical chain schedules with pull scheduling.

Of course there is a double advantage with complexity as a myth. Complexity is a confusing term. On the one hand, it has a meaning which is understood by everyone—it describes things which are complex; and we all understand that

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construction is complex. Thus, it is an attractive concept to the practitioner a powerful teaching tool. On the other hand complexity has an altogether different meaning. In this context it involves a mathematical approach to understanding the world, a world in which exist complex adaptive systems. This is an altogether different interpretation, and is indeed the one that is intended by the teachers. The confusion between the two can be left as a convenient byproduct of the teaching process. The ends justify the means.

There is no doubt that construction projects are complex, that clients are complex and that planning and management of projects is commensurately complex. There can also be no doubt that events occur which disrupt site processes, that these events are unpredictable and that site conditions are verging on chaos. Chaos theory and Complexity are similar bodies of mathematical theory and Chaos may be a more applicable myth to explore and a more appropriate source of understanding for reactive management systems such as lean construction. However, Chaos lacks the positive sense of complexity – it suggests lack of control rather than the process being forgivingly too complex. Thus it is not a suitable myth, as it would present a barrier to learning.

To take the leap and suggest that the construction process is a complex adaptive system requires a lot more than just adopting the myth. Complex adaptive systems require evolutionary processes of learning. They require co-evolution, mutability, self-reproduction, self modification to operating in a system leading to new emergent stable states (Lucas 2003). These are long-term processes in which systems evolve toward stable states of local optima. If we were considering the planning and management of projects in general and indeed the impact of new methodologies such as lean, this argument might have merit. Hopefully, the active discussion of Complexity in the Lean Construction community will move towards studying long term organizational learning as a complex adaptive system. However, when dealing with individual projects, the treatment of a project as a complex adaptive system is self-serving and erroneous. Much more pragmatic mechanisms need to be explored first.

So, to turn now to the reality, if it is not a complex system, what is it that is attractive about the myth? What is at work here is the failure of planning mechanisms and the apparent inability of plans to represent the reality of on-site construction. This leads to the inevitability of chaotic behavior on site. And the appearance of adaptation in site behavior, the semblance of a self-organising, adaptive system: complexity.

This failure is a mathematical problem, rather than one arising out of perturbation in a dynamic system. That is not to say that disturbance events do not occur. But that the majority of planning failure arises from mathematical errors in the planning system or a failure to plan.

THE PLANNING SYSTEM

Just as complexity is a body of theory that applies mathematics to describe real world phenomena, construction has its own mathematics to simulate the construction process. The most common form is Critical Path Management (CPM) and its variants (refer Kenley 2004 for a discussion of the background to scheduling systems). CPM is an activity-based planning technique, which focuses on managing varying activities within a project. Activity-based planning also includes a less common, but more suitable for lean construction, planning method, Critical Chain, which works well with pull scheduling as there is less emphasis on prior definition of activities.

In recent years, an older form of scheduling has been adopted and applied to construction. Variously known as 'Construction planning technique', 'Vertical Production Method', 'Time-Location Matrix model', 'Time Space Scheduling method', 'Disturbance scheduling' and 'Horizontal and vertical logic scheduling for multistory projects', 'Flow-Line', 'Time versus distance diagrams', 'Linear balance charts', 'Velocity diagrams' and 'Linear scheduling', 'Horizontal and vertical scheduling' and 'Multiple repetitive construction process' Kenley (2004). Flowline (preferred term) is in reality a location-based planning technique, which recognizes that construction projects involve activities which repeat in varying quantities in multiple locations.

CPM is based on the assumption that activities are discrete events. This is the dominant planning philosophy, only recently being challenged. This conforms with Bertelsen and Koskela (2004), who argue that construction makes one-of-a-kind products and on the site, by cooperation within a multi-skilled ad-hoc team. They define a general definition of the nature of construction from a production point of view as:

> *Construction is complex production of a one-of-a-kind product undertaken mainly at the delivery point by cooperation within a multi-skilled ad-hoc team (Bertelsen and Koskela 2004).*

This is a definition which is comfortable to the average construction professional and researcher and fits well an activity-based management strategy. It is used (as Bertelson and Koskela's work

highlights) as a central platform for developing a lean methodology.

Unfortunately the definition is wrong. And this error is at the root of the mathematical errors in the planning system and, it is argued here, the reason why lean construction remains marginal.

Activity-based planning is not an appropriate planning system for lean production. Location-based systems should be the natural lean planning system. The current reliance solely on pull-scheduling (within a Critical Chain framework) and the emphasis on complexity, is a strategy to solve the mathematical problem which this misapprehension causes.

A better definition of construction from a production point of view would be:

> *Construction is the production of a complex, one-of-a-kind product undertaken mainly at the delivery point by a series of repeating but variable activities in multiple locations within a multi-skilled ad-hoc team.*

This differentiation is critical. The stubborn refusal to deal with the consequence of repeating but variable activities in multiple locations is that on-site processes become chaotic and appear complex. For the lean construction community to step up to the next level of performance, they must grasp the significance of location-based planning and use it as the underlying planning system upon which to found their methodology.

PRODUCTION AND TURBULENCE

Timmerman (1986: 436) advocates that "… many past failures of [environmental] management have been due to the misapplication of various myths, especially myths about nature". He was referring to environmental management and few would challenge that complex adaptive systems apply in the environment, in particular with respect to the response to human interaction (as perturbation). Shipworth and Kenley (1999) described a model using Environmental Impact Fitness Landscapes to model the gross environmental impact of a set of impacts from human sources onto an ecological system. The model was proposed explicitly as a framework capable for handling both linear (i.e. additive) superpositions of the set of individual impacts as well as arbitarily complex degrees of nonlinear (i.e. synergistic/antagonistic) interaction. Each such set of impacts has some cumulative effect on the environment resulting from the individual effects of the impacts and from their interactions with each other and with the environment; i.e. gross impact is some (not necessarily linear) function of the set's member's individual impacts. It follows that variation of the individual impacts, and/or the manner of their interaction, varies the set's gross impact. This represents a picture of a holistic sustained and dynamic system capable of cumulative gross impact. This is not what we observe in construction production, where the picture is more one of plans and errors.

Bertelsen and koskela argue that in general (factory) production:

> *"…all understand production as flow as well as (at least implicitly) transformation. However, they all see the flow as laminar, albeit with small eddies. These are either considered as errors that should be corrected or as unforeseeable events, which should be handled by buffers, to be kept as small as possible. In contrast to this, construction is indeed a true turbulent kind of production and should be managed as such.*

At the heart of the discussion is the concept of truly turbulent production. The question is, is this a true statement, or is it a teaching myth which is in danger of being misapplied?

It is interesting that the lean advocates hold that factory production is laminar, whereas construction production is truly turbulent. The following discussion demonstrates activity-based scheduling as one source of this turbulence and illustrates how laminar flow can be restored using location-based planning.

PLANNING AND LEAN

Factory production is organized and linear. Everyone is familiar with the concept of the production-line and generally it is accepted that, whether lean or not, factory production will follow this form.

Why then is it that construction is organized around discrete activities which are organized in sequence but not location. This results in the equivalent to a factory production system based around individual activities following apparently random (but using a sequential logic) location patterns on the factory floor. Were this to take place in a real factory, lean specialists would be the first to insist on instilling "flow" into the production process as a starting point – and then following with the suite of lean production methods. In contrast, in construction the production is required to follow the non-linear activity-based sequence logic; flow is ignored. The reason is that "that is the way we have always done it". But, more importantly, it is because the lean construction researchers are so intent on complexity as the cause and pull-scheduling as the solution, that they reject proper organization of the production process as reverting to the old ways of command and control.

The correct lean position should be that proper planning should be a requisite starting point. Such planning should be based around flow concepts and, therefore, should be for most projects location-based.

MATHEMATICAL ERRORS IN THE PLANNING SYSTEM

The best way to demonstrate the difference between activity-based and location-based production is to use a simple case. The following describes the organization of fit-out activities for a multi-level office refurbishment in Sydney. In this situation, the contractor had won the project using location-based planning methods (CPM). Following common procedures, a critical chain was derived for each floor, each floor was then front-end linked to provide a cascading sequence of work up the building. For the purposes of the illustration, only selected demolition and refurbishment activities will be followed. Figure one illustrated this (using DYNAProject flowline software) and shows the typical CPM based floor cycle with each floor operating separately. As is normal practice, there is no attempt here to link work crews across floors to achieve work flow.

The durations for each activity are the anticipated durations used to derive the CPM schedule for the tender. In usual fashion, there has been no attempt to align production rates.

Figure 2 illustrates the same schedule using flowline methods and with production rates as allowed in the tender. This unrealistic schedule greatly extends the contract duration, as it is based on flow principles but without alignment of production rates. This exposes the extent of the problem being absorbed within the schedule in Figure 1. Figure 2 separates level 5 as clearly demonstrated in Figure 1. This achieves handover of level 5 last, but does not provide late hand-over of Level 5 to the contractor at the start as required for this project.

Flowline requires that production rates are aligned where possible. Failure to align leads to either extension in the contract duration, or to disturbance in work flow, such as discontinuity. Figure 3 illustrates an aligned flowline for the site production (non-sensitive tasks remain non-aligned).

Contrasting Figures 1 and 3 highlights the following:

- In Figure 1, there is intense disruption between activities
- In Figure 2, the overall duration is the same as Figure 1, but the duration for each floor increases the higher up the building.

The intense disruption between activities arises because once a trade commences on a floor, there

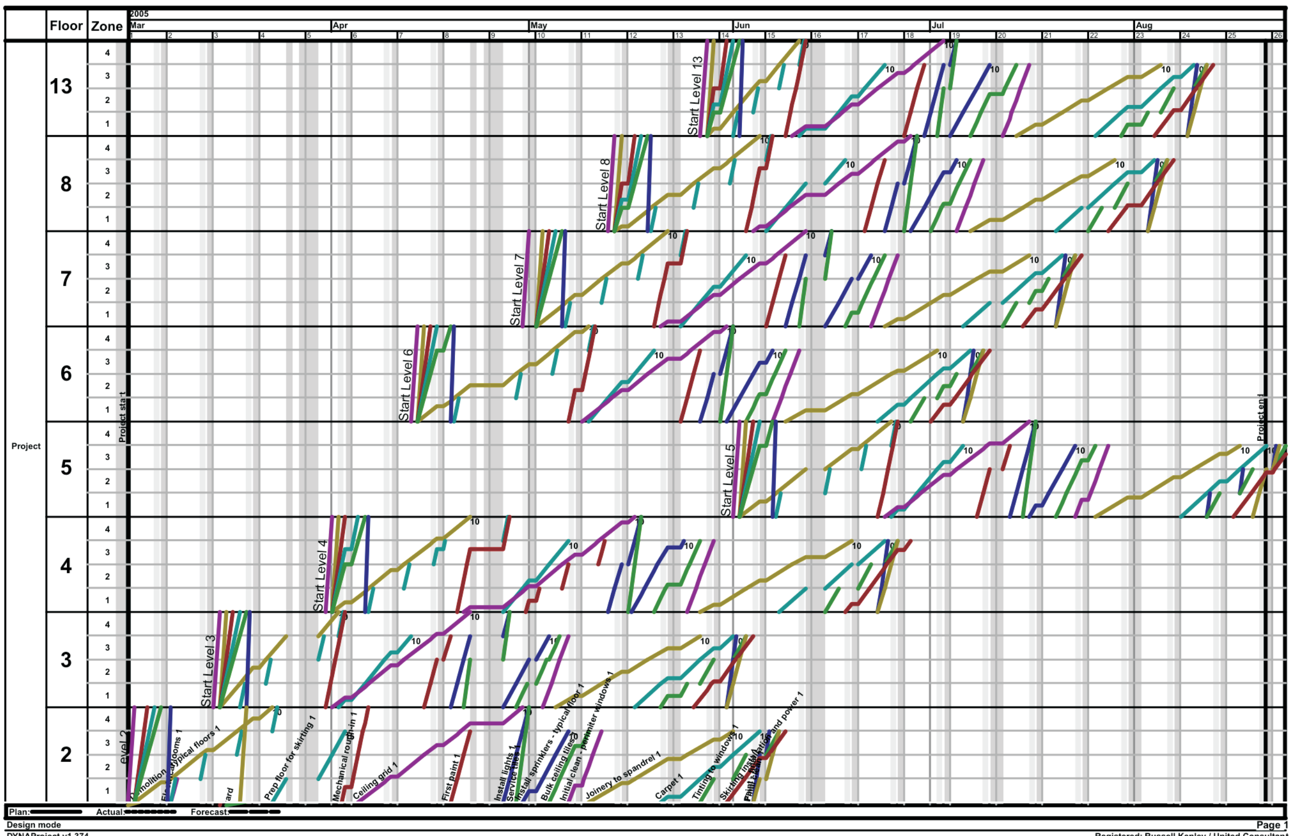

Figure 1: Flowline schedule using activity-based logic

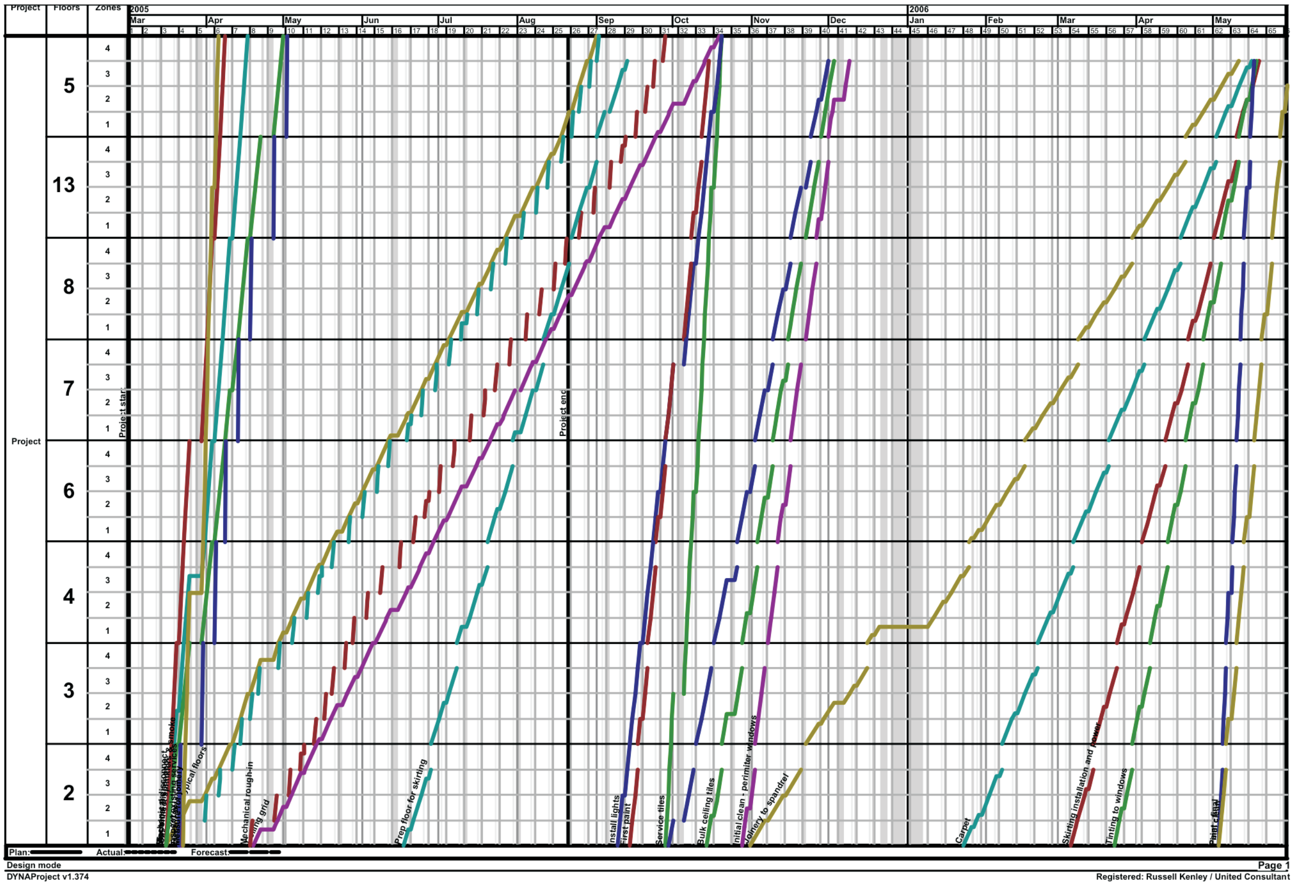

Figure 2: Location-based activity plan without production alignment

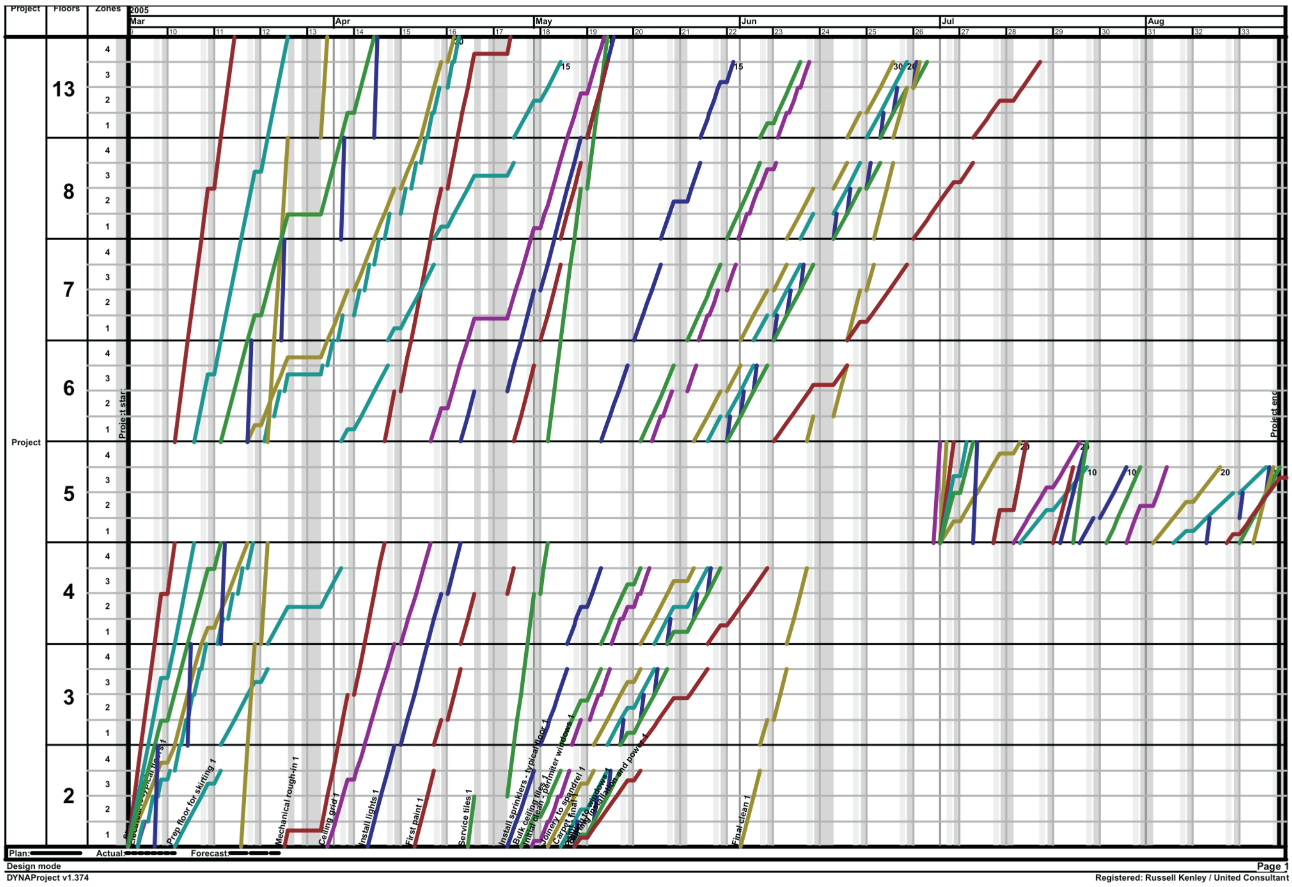

Figure 3: Location-based activity plan with production alignment. Level 5 is separated from the production of the other floors.

is no connection to their work on the next floor, which may occur earlier or later than their completion of the current floor. In the event that they are required later. They will either going off-site, with the risk that they may not return, or they will commence work out-of-sequence on another floor. In the event that they are required earlier. They will either delay the latter floor until they have finished the prior floor, and thus causing others to work out-of-sequence, or they will load up the site with additional resources. With all trades running without aligned production rates, site management is unable to reconcile the competing interests.

Lean construction particularly understands the importance of minimizing waste—non-value adding activities. Schedule 1 will inevitably result in waste. This will take the form of disruption, working out-of-sequence, demobilization and mobilization, irregular and unpredictable resources, quality reduction, loss of control, etc. This intense disruption will lead to the appearance of chaos on site, the generation of unpredictable events and the perception that projects are complex.

In contrast, Figure 3 illustrates clearly that, using flowline, each work crew operates within the following principles for micromanagement. These are:

- Each crew should come to site and then work continuously until completion
- All prior work should be completed before the work crew commences in a location
- No subsequent work should commence in a location until the work crew has finished its work
- All work should work in sequence

The effect is that the site coordination problems are resolved by the planning method. There is no disruption arising from disparate production rates. The work crews work predictably and continuously.

Unpredictable events may still occur, just as on the factory floor. These can be managed by deliberately inserting buffers between work crews, and by using over-time and weekends as buffers. This is exactly as done in factory-based production.

It can be seen that site confusion arises from traditional planning systems providing a plan to the site which cannot be executed. The problem is one of mathematics. On more complex projects than the example, where the extent and type of work varies from location to location, the complexity of the optimization problem rapidly exceeds the capacity of people to manage the solution using either CPM tools in planning, or indeed in their heads on site.

Under these conditions, the typical behavior is for the site staff to abandon the schedule and to dynamically manage the site by driving performance. The following behavior may be observed:

- Calling work-crews to start early
- Demanding more resources and early completions
- Preventing departure from site
- Demanding work continue out of sequence where sequential work is not available
- Allowing incomplete work until prior trades complete
- Loss of control over location
- Difficulty in completing as work-crews are reluctant to return
- Activity compression as all work piles up leading to a mad rush at the end

That last point, activity compression at the end, is extremely notable. Figure 3 should finish with only the last trades on the last floor. In contrast, Figure 1 will have delays on each floor and in all trades due to disruption and out-of-sequence work. Under these conditions the project will conclude with multiple trades in multiple locations. Effectively this is managed chaos.

These consequences of human reactions to site activities appear to have the properties of complexity, and to be best solved pull scheduling and work-reliability methods such as Last Planner. A better solution would be to solve the planning mathematics, and then to apply work-reliability methods within that improved context. "Making-ready" is just as applicable in location-based methods as other planning systems. Material and design

Prerequisites. and control mechanisms are still needed are needed to ensure that the locations are actually finished when the crew leaves.

DISCUSSION

There is a tendency evident in the lean construction community to treat planning as bad practice, because it is "command and control". In all reviews of papers dealing with flowline, at least one reviewer will argue that flowline is a return to command and control methods. This is a strange argument, and implies that the best way to manage complexity is to allow chaos and for order to emerge – the complexity myth. This is done using lean methods such as Last Planner with pull scheduling. However, the criticism is spurious. Just as no one would produce in a factory without a production sequence, so one should not produce in construction without the equivalent—a flowline schedule.

CONCLUSION

The problem is mathematical, and the solution is also mathematical. Rather than requiring the sites to coordinate trades around the production rate problem, it is better to preplan. It is better to establish the factory production on the site. The method to do this is location-based planning—flowline.

The epistemology of lean production methodology requires a location-based method. Flowline therefore should be the natural planning method to support lean construction. It is believed that lean methods will be greatly enhanced by flowline planning systems.

As to complexity; it remains a useful myth for teaching purposes but offers little to aid in understanding the true nature of construction production.

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