An Introduction to Lean Production Management – Why and How...

August 2010

By:

Jeff Schwisow
Managing Director
Continuum Performance Pty Ltd
P.O. Box 1153 (postal)
4 Panton Spur Road (office)
Healesville VIC 3777
Australia
landline: +61 3 5962 2967
mobile: +61 414 829 070
email: jeff_schwisow@bigpond.com
web: www.strategicprojectsolutions.com

Introduction

As we have conducted discussions with various project delivery organisations over the last 6 months to see if there is an opportunity for "Lean Construction" to assist them meeting their performance goals, it has become clear that there are disparate views on:

- What is Lean Construction?
- Why will it assist in managing projects?
- How does it work?

This discussion paper attempts to provide some summarised answers to these questions. It is specifically written from the perspective of how Continuum Performance Pty Ltd and our partner organisation Strategic Project Solutions out of the US believe these questions should be answered. It is, by rights, our definition of what Lean Construction is, and should be, to organisations driven by the successful delivery of projects.

Background

Traditional project management is not always as effective at delivering the project outcomes that clients expect and that delivery businesses require to remain profitable and competitive. That is not to say that traditional project management approaches have not generate some highly successful results; however, the myriad of mediocre projects and the occasional "bad project" suggests that there are opportunities for development and improvement. Beyond this, there are those projects of such high criticality and/or delivery complexity that we recognise that they call for an extraordinary approach to management if they are to be successful.

We believe that one of the key shortcomings in traditional project management is that its systems and processes are focused on creating a "static plan" (for time, cost, resource deployment, etc) then measuring progress against that plan. There are limited structured processes to make the execution of work conform to the plan and/or refine the plan to conform to project outcomes. This lack of dynamic planning and control of work execution (or production) is a significant gap – a "blind spot" – in the dynamic project environment. We look to fill this gap with what we call "production management" processes – it is also what has attracted the catch-phrase "lean construction."

In the following few pages we will briefly discuss:

- The three components necessary to effectively deal with the dynamic design and construction project environment
- Some history and theory behind "Lean Construction"
- The approach and key areas of focus of production management
- Implementation and its impacts

Three Components of Effective Delivery

We believe that there are three key components to effectively delivering in the dynamic design and construction project environment. These are:

- Aligned values
- Effective teams
- Projects as a production system

Aligned Values

In economic terms, production is the creation of value; the producing of tangible benefits having exchange value. From an operations perspective it is the transformation of raw materials (ideas, natural resources, etc) into products and services that customers value and are willing to exchange value for. How effectively production of the product or service being produced is managed is a key factor in determining the value of the final product or service being produced. Production is a key factor because it is fundamental to quality, the cost structure and the service level associated with the product or service being delivered. All of which are key elements in the customer's determination of value. This means that to effectively manage production we must first define and align on what value is.

To properly define value we must first define the customer and where the customer operates within the economic chain. Is the customer the end-user of a product or service or does the customer consume the product or service as an input to their transformation process in service of a greater economic chain. For instance, a structural engineer may have a rail construction company as a customer, but the rail construction company has a rail operator as a customer. The rail operations customer could be seen as the end of the economic chain, since it has the ultimate responsibility for transforming civil infrastructure, rail staff and moving stock into an operational timetable. However, this transformation enables passengers to move from point A to point B – in this case the passenger is the end-customer. Of course that it unless the passenger is the same structural engineer going to work with another customer and so goes the economic chain. For this reason "there never exists a single customer but at least two and sometimes more."[1]

Over the last several years, owner/operators in Australia have come to recognise the importance of aligning values across the spectrum of the economic chain. This is one of the key drivers for the wide spread use of Alliance Contracting delivery models – not only is there an operational focus on value alignment, there is a commercial one as well. However, it is equally important that we ensure that this principle is cascaded throughout the project and the project team. This not only mean getting the entire project team to be aware of and focused on the high-level alliance or project values (i.e., KRAs/KPIs), it also means understanding where value lies in all aspects of project work – this is sometimes referred to as mapping the value stream in the Lean Construction world.

What does this mean by practical example?

We often see design teams produce design documentation that does not contribute "value" to the overall delivery of the project – procurement staff don't require it to buy things, construction staff don't require it to build the project and operations staff don't require it to operate and maintain the

[1] Peter Drucker

completed works. If we are able to map the value in design delivery then we are able to better define the documentation required and why. This means we are better able to understand the priorities of design works and the level of effort that needs to go into them. Ultimately, it allows us to do the most important things first, not waste effort on those things that we don't need and ensure that the work that is done is in service of overall project value. Conversely, we can draw distinct linkages between the work that the design team are doing and how it effects the value that expected by the customer that is ultimately paying the bill.

Effective Teams

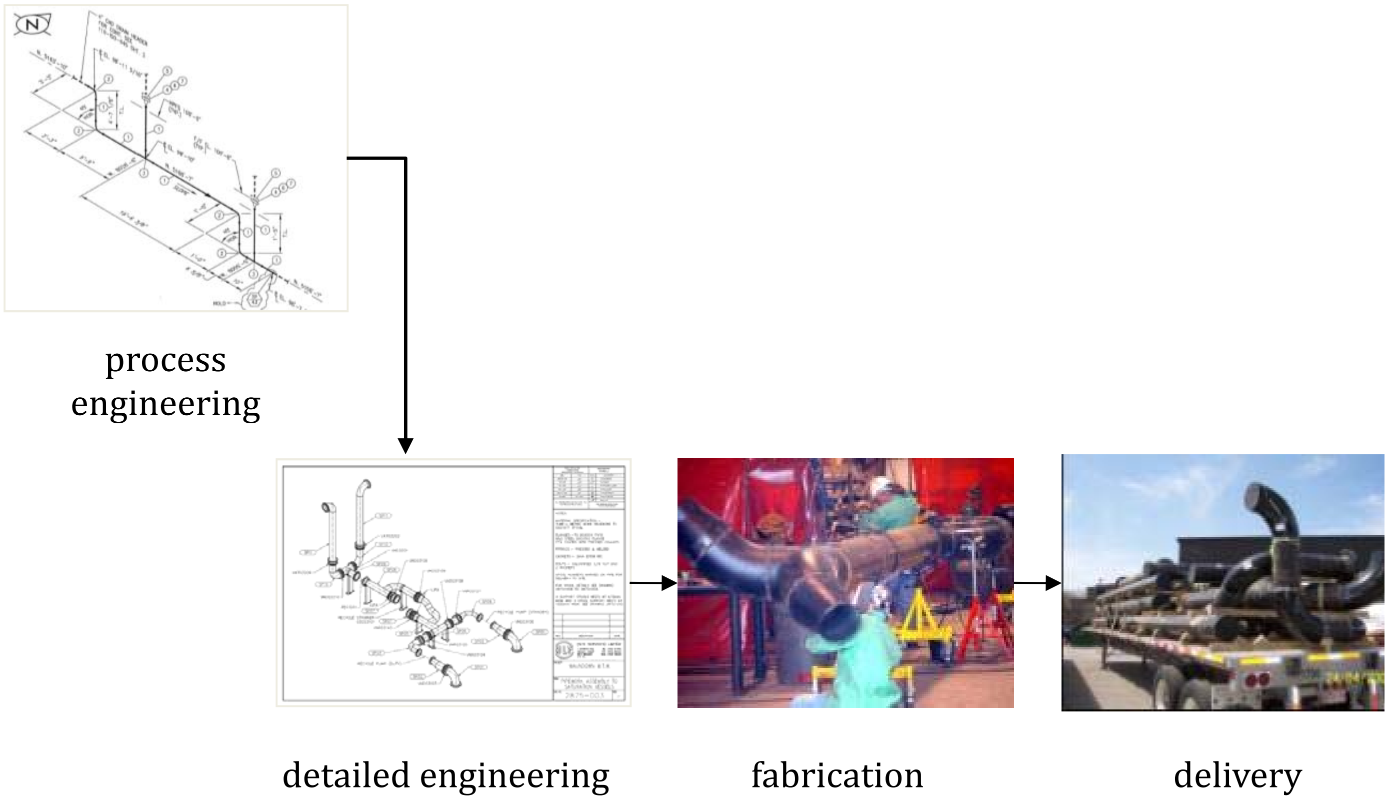
Often we see teams made up of relatively narrow specialities operating in relative isolation to the other functions on the project. The siloing of design, procurement and construction functions is almost a cliché of this effect. However, we see it within functional teams; for example, mechanical designers that don't communicate and coordinate with structural designers or site supervisors and foreman that have no role in planning the work. We also see it between the "project team" and the "project stakeholders"; e.g., system or plant operators that will be affected by (and have valuable input to provide to) an upcoming shutdown or asset handover.

The attributes that we look for in effective teams, at the work execution level, are:

- They are made up several cross-functional teams, each with the complimentary disciplines and delivery specialities necessary to design, procure, construction, and (if appropriate) operate/maintain the portion of the project for which they are responsible.
- To the maximum extent possible, the responsibility for planning and executing the work is driven down to the level where value is added to the "product"; e.g., responsible designers, site engineers and supervisors, lead process operators.
- These production or work area teams are dynamic in that they form and disband as the project progresses. Also, their membership evolves as the area of work progresses through the delivery process.

Project as a Production System

A project is a series of transformational processes – requirements are turned into design criteria, design criteria are turned into specifications, specifications are turned into materials and equipment, and materials and resources are turned into physical infrastructure. As a result, it can be approached as a production system and, as a production system, can be analysed and optimised using industrial engineering and production management principles. The resultant process optimisation can then be implemented and continuously improved. In the case of Lean Construction, the specific production management principles are those founded in Lean Production.



Project Transformational Process

It is the application of this analysis and optimisation process to the execution of work that makes "lean construction" truly unique. We apply analysis and optimisation to engineering problems and a high level of sophistication to measuring and analysing project management information (i.e., productivity data and forecasting); however, we rarely apply this level of analytical science to the manner in which we execute work.

The History and Theory of "Lean Construction"

The term "Lean Construction" has been adopted as the overarching catch phrase to describe the application of Lean Production Management principles to the project environment. This is an unfortunate nomenclature because it has the implication of something that is strictly applicable to construction work as well as being a terminology to which a number of different approaches are currently being applied and no clear definition exists. To better understand how broadly it is applicable within the project delivery environment and what we believe are the salient points of its application, it is worth understanding how the terminology came to be adopted and understand a bit of Lean Production theory.

"Lean Construction" – The Origin of the Brand

"Lean" traces its roots to the manufacturing environment; specifically, to the Toyota Production System. In the late 40s and early 50s, the Toyota Motor Company was looking to enter the passenger vehicle market (cars and light trucks). That market was dominated by the American car companies (Ford, General Motors, and Chrysler) with a 75% share of the largest consumer products market in the world. At that time, the predominant manufacturing production theory utilised by these

American car companies was that of "mass production" – an approach initially developed by Henry Ford and later refined by Alfred Sloan of General Motors. Toyota tasked Eiji Toyoda (second generation of the founding family of Toyota) and Taiichi Ohno with development of its production system. Toyoda and Ohno spent several months observing the operations of Ford and General Motors in the US. They concluded that these manufacturing processes, though impressive in scale and application, were inflexible in their ability to deal with changes in products and options, wrought with waste, and required too significant a critical mass to be applicable in a relatively small operation. It was from these initial observations that a new production approach was born – the Toyota Production System.

In the late 80s, the Massachusetts Institute of Technology (MIT) led the most extensive research program ever undertaken in reviewing the development, influence and fundamental forces of industrial change in the automotive industry – the International Motor Vehicle Program (IMVP). The IMVP reviewed the entire set of activities necessary to manufacture a car or truck: market assessment, product design, detailed engineering, supply chain coordination, operations of individual factories, and sales and service of the finished product. In 1990, this 5-year research project was popularised in a book summarising the IMVP findings, *The Machine That Changed the World* written by James Womack, Daniel Jones, and Daniel Roos – the three leaders of the research program. In this book they compared and contrasted two different approaches to automotive manufacturing: mass production (the predominant way of the American and European car industry) and *lean* production (the approach employed by the Japanese car manufacturers and, most specifically, Toyota). The term "lean production" was coined by one the program's factory specialists, John Krafcik, who observed that when compared to the approach taken by mass production everything about the Toyota Production System was "leaner" – fewer workers, smaller inventories, smaller factories (because less space was devoted to inventory stores and re-work areas), shorter cycle times and less waste. In *The Machine That Changed the World* the authors (correctly!) predicted some of the other industries, outside of manufacturing, where lean principles would be beneficial in streamlining business processes and services. As a result, lean production in the manufacturing environment came to be called "lean manufacturing" as a way of distinguishing it from lean production applications in other industries.

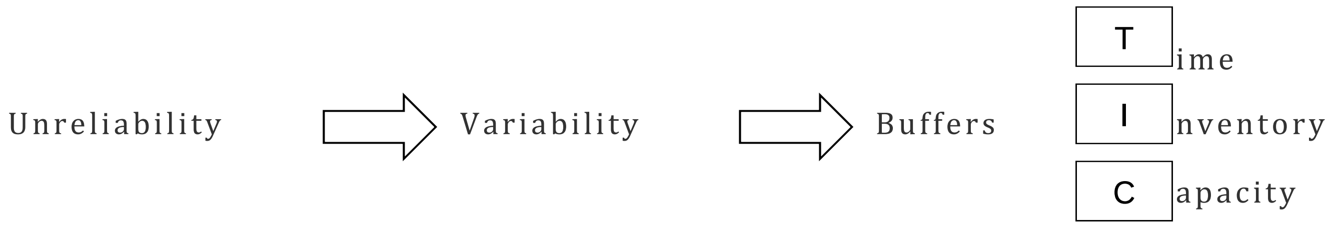
In the mid 90s, Lauri Koskela, Glenn Ballard and Greg Howell began challenging the traditional paradigm for managing construction projects based on their research into the recurrence of time, cost and quality problems. They suggested that there was an opportunity to begin looking at construction projects as temporary production systems and utilising the principles and practices of lean manufacturing to reduce the inefficiency and waste while increasing the quality from this system. They coined the term "Lean Construction" and in 1997 formed the Lean Construction Institute.

Lean Production Theory in the Project Environment

There have been PhD dissertations written on the application of lean production theory to construction projects. This introductory document is clearly not the place to reproduce this level of theoretical explanation. However, a brief summary of certain elements of lean production theory is valuable to understand the basis for some of the processes and enabling systems that we advocate in developing a lean production project approach.

The Impact of Variability on "Buffers"

As stated previously, our approach is based on viewing a project as a production system due to its transformational nature. It is in fact a *temporary* production system because 1) it has a defined start and end point 2) it is most often performed by a team that is assembled solely for that purpose and 3) the transformational process that is occurring is changing every day. This means that it is by its nature a highly *variable* production environment. Studies by the Lean Construction Institute have shown that it is also a highly unreliable environment with less than 50 percent of the activities planned for a specific day being completed as planned (an average of 47%). This unreliability further compounds the variability in the production environment. A law of production states that variability, no matter the source, will result in the expansion of one or more of the three types of buffers: capacity (resources), inventory, and time. This, of course, begs the question: "why do I care?" The project delivery organisation cares because expanding buffers <u>always</u> result in increasing direct or indirect costs – arguably, this means that a dilution of value is also taking place.



Relationship of Unreliability, Variability, Buffers and Cost

As pointed out earlier, because the construction project environment is inherently variable, then some buffering is in fact beneficial and necessary to achieving the value objectives. For example, you wouldn't want to tackle every task just-in-time because the variable nature of the construction environment would mean that your overall schedule would blow out. Therefore, it is best to create a time buffer around the majority of the work on the project to absorb normal variability and avoid having every activity be on the critical path. Re-work or quality defects, waiting for predecessor activities to be completed and producing more than or less than needed are all examples of detrimental variability that do not benefit the business but rather impact effectiveness through additional cost, time and less than optimal use of resources.

What is also true is that the variable nature of the project environment means that the further you look into the future the more unreliable your planning becomes. This is because the tasks that are necessary predecessors to future activities create a cascading level of uncertainty as to the point and time that the future activity can be completed. In other words, if I only complete half of the tasks that I planned today then the necessary prequisites for the tasks I planned for tomorrow are cut in half. This means that something akin to half of the tasks I planned for tomorrow are available for completion and if I only reliably complete half of them then the tasks available for completion on the following day are cut to 25%...etc. Although this analysis is not accurate in an absolute since, research has shown that, on average, a project team's ability to predict the specific day on which a single-day activity will be completed drops to below 10 percent as soon as you look beyond a 3-week window.

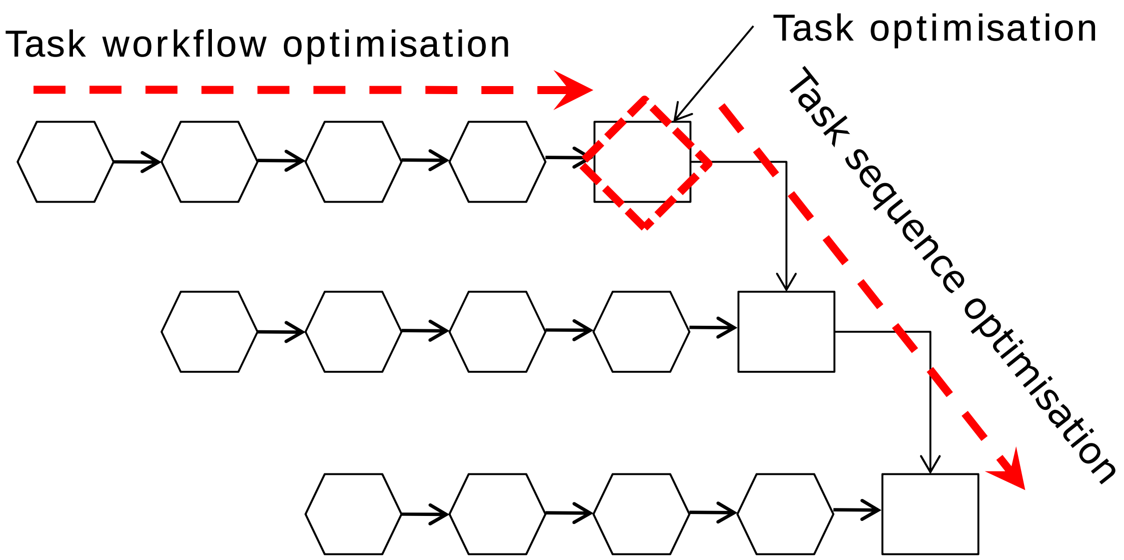
Therefore, one of the critical areas of focus in production planning and control is making work flow more reliably from one task to the next and from one discipline or functional area to the next. From the planning perspective, this is accomplished by looking ahead to a "foreseeable" window of work execution that our project management systems have established as being of the greatest value or highest priority. We develop the sequence of tasks that will be required to complete the work in this near-term window. We then look to actively identify and systematically address the constraints necessary to complete or perform the identified series of activities in a continuous workflow. From a control point of view, we do this by ensuring that only tasks for which the necessary pre-requisites are complete get released for action. This allows us to minimise the inefficiencies and waste associated with trying to execute work in sub-optimal conditions (i.e., without the necessary resources, materials or prerequisites).

Determining how much beneficial variability the production system should facilitate, how to best mitigate detrimental variability and how to buffer against the impact of total variability in the production system is the focus of production management. In other words, production management occurs on every project – it can either be a structured process that drives decisions consciously or an unconsciously decision-making process that is driven through inaction or ill-conceived actions. Either way, the impact of these decisions manifests themselves on project management forecast reports.

Work Flow versus Task Optimisation

In optimising the production environment there are three areas that we can focus on (as depicted in the figure below):

- **Workflow to accomplish a task.** The flow of information, materials, and resources necessary to complete a task.
- **Sequencing of tasks.** The continuous flow of work from one task to another.
- **Task optimisation.** Optimising the efficiency of an individual task.



Three Areas of Production Optimisation

We often find that when optimisation does occur in the traditional project management environment, it tends to first be focused on task optimisation; i.e., completing a task or collection of similar tasks more efficiently. This is likely a result of the way that traditional project management systems measure productivity performance – as an expression of the level of effort (e.g., manhours per cubic metre of concrete, manhours per lineal metre of pipe, manhours per drawing). Therefore, if the manhours per unit are high then we need to address how efficiently the manhours are being expended on that unit. However, we find this is often the least effective point of optimisation and/or can create localised optimisation at the expense of overall performance.

Production management utilises a holistic optimisation focus. Therefore, it focuses on optimising the sequencing of tasks as the point of greatest optimisation value. Once task sequencing and performance are approaching optimum levels attention can be focused on the workflow of individual tasks. Then finally, once the task workflow is optimised it is beneficial to begin focusing on performing the individual task more efficiently.

By way of example, we can look at installation of a welded steel piping system. Time and motion studies of pipe fitters and boilermakers have shown that they typically spend 20 to 30% of their time on the tools. This suggests that there is actually limited benefit to be gained by focusing on speeding up the welding process. The first point of optimisation should be looking at the workflow for installation of the entire system – how might tasks be sequenced to allow the work to flow continuously. For example:

- what segments might be fabricated away from the workface,
- how will installation of those fabricated segments be sequenced to allow the most efficient assembly,
- how will installation of the connected equipment impact on the piping system installation,
- how will field fit requirements need to be translated into green pipe sections
- how will these green sections be incorporated into the piping isometrics

The next level of optimisation would be to address work flow for individual tasks. For example, identifying, procuring and supplying the materials necessary for the work crew to remain focused on installation activities and not materials supply activities.

Only after these levels of optimisation is it beneficial to begin looking as more efficient installation processes such as more efficient welding techniques.

The Key to Building a Lean Production Organisation – Implement and Improve

The truly lean project delivery environment has two key organisational features:

- To the maximum extent possible, it transfers the responsibility for planning and controlling the execution of the work to the staff that are actually adding value to the constructed product.
- It embodies a culture and incorporates enabling systems to allow continuous improvement of the delivery environment.

One of the most fundamental theoretical principles of lean production is that it looks to move away from the traditional approach of central command and control with staff that have a relatively narrow focus on <u>their</u> discipline within <u>their</u> work. Instead we look to have distributed control to work teams that are actively adding value at the workface. Central management then takes on the role of coordinating and synchronising the activities of these various work teams, measuring the effectiveness of the production system, and initiating/supporting corrective or improvement actions where required. The Last Planner System for controlling task reliability (discussed extensively in reference materials on Lean Construction) was developed by members of the Lean Construction Institute and is incorporated into the production management systems we utilise. However, from an implementation perspective it is important to recognise that the term "last planner" results from the emphasis on ensuring that the planning of work execution and the commitment to perform a specific task on a specific day comes from the person that will initiate it in the field (i.e., the last person with responsibility to implement the plan or "last planner").

A second fundamental theoretical principle of lean production is that once the production system is in place and optimised then you must continuously look to improve it. This differs from a traditional view that a certain number of defects, a certain level of inefficiency or an expected level of late delivery is acceptable and can be priced into the project. The ultimate objective ("the ideal") in a lean production system is a project delivery environment with zero defects, no effort that does not translate directly into value in the constructed product and perfectly smooth and continuous workflow that translates into a project that is constructed in the least possible time. Although there can be many techniques and tools for accomplishing this, the key elements are:

- A system for detecting defects (both in the production system and in the work itself) and, once discovered, quickly tracing them back to their root cause.
- Standardising work processes so that they are repeatable and predicable, then gradually refining them through practice.
- Setting objectives for the production system, measuring performance against those objectives and utilising the system's feedback mechanisms to take action to address areas of improvement. In other words, plan-do-check-act is alive and well in lean production management.

Our Approach and Key Focus Areas for Production Management in the Project Environment

With the historical and theoretical perspective presented above, we can begin to discuss the approach we apply in managing the project production system. In other words, our definition of "lean construction" based on the approach we take to optimising project outcomes through effective production management. Initially, this begs two important questions:

But what does "optimise project outcomes" mean?

Clearly there is the delivery of the benefit – the reason the investor is undertaking the project in the first place. Without deriving a benefit from the project there is no reason for undertaking the project. There is also ensuring that the benefit is delivered for the acceptable investment. Just as there must be a benefit, it is equally imperative that the benefit adequately outweighs the investment. Otherwise there again is no reason for undertaking the project. So the optimisation of a project outcome can be defined as ensuring that the project delivers the desired benefit for an optimum investment. Interestingly, this is also a very effective definition for "value" with the measurement of value relating to the quality of the derived benefit versus the level of investment.

How do you go about it?

Over the past ten years, SPS has proven that by focusing on design, planning and control of the work processes required to deliver complex and critical projects, business objectives can be effectively achieved in today's dynamic project environment. By first developing a robust definition of value then focusing on the critical processes that will enable that value to be realised, we can ensure that our analysis and optimisation efforts remain focused on delivering project outcomes. We then apply the systems, tools and skills necessary for enabling these work processes to be successfully implemented within the specific project delivery framework.

Project Management versus Production Management

Conventional project management has been blindly accepted (in part through the proliferation of computers) as the primary approach for delivering capital projects. The underlying concept is that projects are viewed as a cost (time and capital) that should be minimised, rather than an investment that should be optimised to deliver ever-changing, end-user/customer requirements. Project Management, as such, puts an emphasis on management of contracts and associated commercial relationships without sufficient, if any, focus on operational or production related issues that are at the core of delivering value. Through the use of techniques such as earned value measurement and productivity analysis, project management attempts to establish variances to a set of static plans and definitive objectives in a very dynamic environment. The need to lock-in schedule activities and budget line items to enable progress measurements and forecast results can, if used in isolation, inhibit the ability of the project team to optimise value delivered and respond to this dynamic environment with beneficial variability. It is fairly common to find schedules that have little if any resemblance to reality.

In its Project Management Body of Knowledge (PMBOK), the Project Management Institute has compiled a "generally accepted" subset of this knowledge and states that each program/project is responsible for selecting what is appropriate for that program/project based on five process groups and nine knowledge areas.[2] As can be seen from the PMI process groups and knowledge areas, conventional project management does not address management of production.

To support the activities of conventional project management, numerous tools have been developed by technology providers or are created in-house by those undertaking projects. These tools frequently focus on cost and time reporting / forecasting, risk analysis, document management and procurement activities that are all important functions in managing a project but not the only functions. With project management process and tools focusing on the realisation of baseline cost and time objectives it is difficult, if not impossible, to optimise the overall outcome.

Better managing production (versus relying solely on project management) is the most effective way

[2] PMI defines these process groups as: Initiating, Planning, Executing, Controlling and Closing; and the knowledge areas as: Project Integration Management, Project Scope Management, Project Time Management, Project Cost Management, Project Quality Management, Project Human Resource Management, Project Communications Management, Project Risk Management and Project Procurement Management.

to dramatically improve project outcomes. By managing production, we mean: determining how much variability should be accommodated in the system; designing how processes such as design, engineering, fabrication, and assembly/construction are planned and executed; how program/project processes and operations are controlled; including how buffers will be used.

In highlighting a gap that traditional project management does not fill (and is not well suited to address), one could be forgiven for thinking that we are suggesting that all traditional beliefs about project management should be scrapped. On the contrary, we are not advocating completely replacing these traditional systems and processes with a “new way” of managing projects. It is still extremely important to create an overall roadmap by which the project is meant to be delivered, to measure progress and performance against this roadmap and forecast the likely final delivery performance outcomes – clients expect it and senior management demands it. This is a role that project management systems fulfil very effectively. What we do recommend is the use of production management as a supplemental and companion approach to the project team’s suite of delivery processes. When done effectively, the result will be a “new way” of *delivering* projects that creates broad-based improvements in time, cost, and quality – not trade-offs between them.

Project management and production management can and should compliment and inform each other. Project management sets the overall project objectives and creates the values framework through which these objectives will be met. Production management is the mechanism for achieving the objectives in a holistic way and translating the framework into execution of the work.

project management

cost budgets

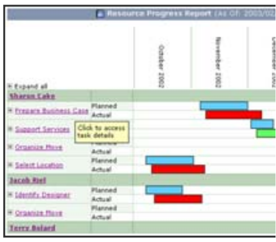
master and progress schedules

forecasts (time and cost)

progress measurements (EVA, productivity reports, etc)

scope management

risk management



production management

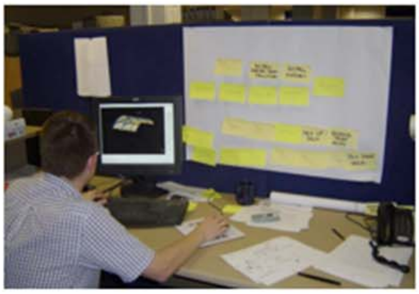
task-based work schedules

coordination

logistics

resource management

production control



Comparison of Project Management to Production Management

A somewhat simplistic sporting analogy that one can use to contrast the two areas of delivery management is to think of project management as what goes on in the coaches' box (e.g., high-level view of the whole field, strategic approach, statistical analysis of each player's and the opponent's performance, making positional changes to suit the circumstances of the game) whereas production management is more closely related to the play that is occurring on the field (e.g., specific tactics, reading the play of teammates or the opposition to determine the next move or play to be called, looking for the open space that will create a smooth run of play). Successful teams do not succeed without one complimenting the other.

The Basic Approach

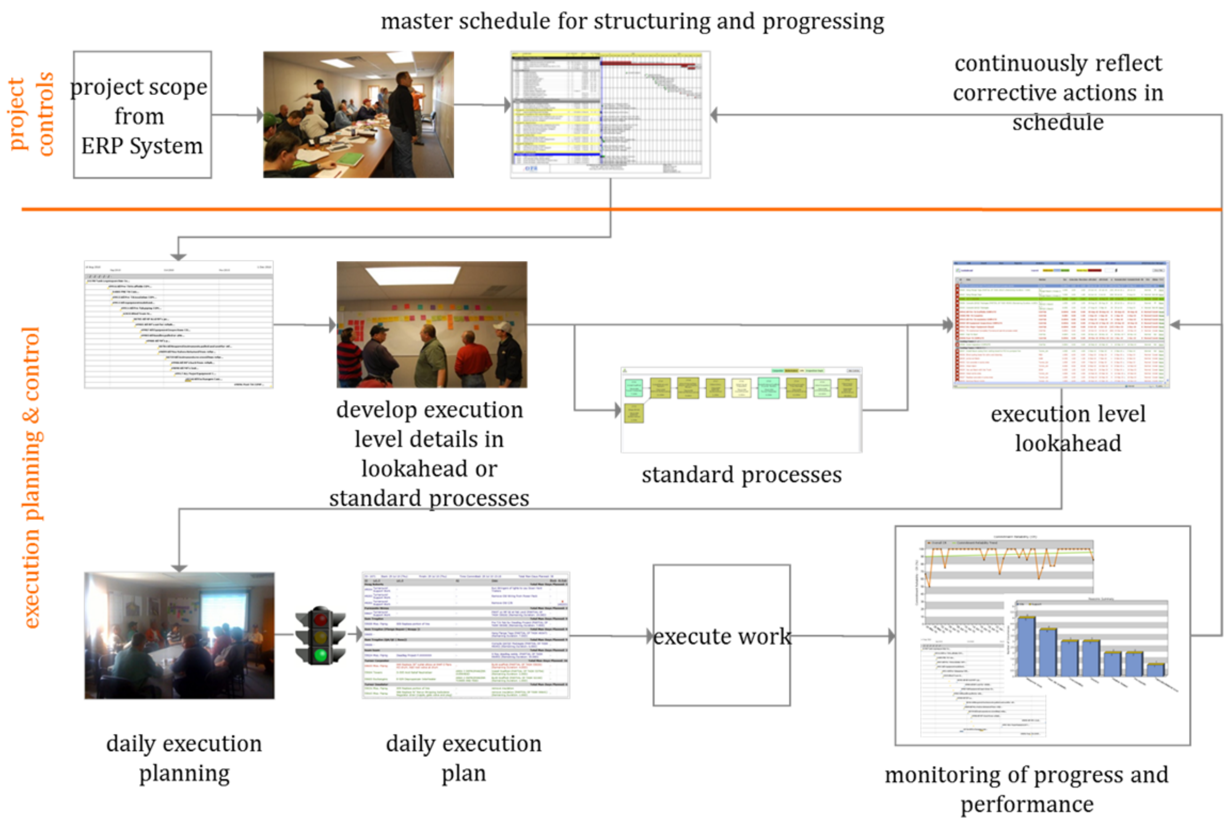
Our basic approach to production management is focused on what we call production planning and control. It consists of three inter-related components:

- Lookahead planning
- Production planning
- Production measurement and review

The production planning and control processes are then linked to the overarching project management systems.

Production planning and control embodies all of the key elements and principles previously discussed. It has as its prime objective to improve the reliability of work execution thus decreasing detrimental variability and minimising the cost impacts of capacity, inventory and time buffers. It does this by having the cross-functional teams that are tasked with executing the work, plan it and then commit to performing it based on "bite-sized packages" that are prioritised in accordance with the objectives and values defined in the project management systems. As an element of production control process, we provide measurement of the effectiveness of the production system so that the project team can take action to address areas of improvement.

The three component parts of this approach are discussed briefly below.



The Basic Production Planning and Control Process

Lookahead Planning

Lookahead planning consists of creating a detailed plan of the activities required to achieve a near-term milestone for a package of work. Typically, this milestone (be it a key milestone or interim one) should come from the project's overarching milestone program – at a minimum, it should be informed by it. The typical planning window should be between 4 and 8 weeks depending on the nature of the work that is being planned (e.g., a procurement activity may need to look at a longer window to provide meaningful feedback). Although the specific level of detail for each task will vary and takes a bit of experience to get right, it is generally desirable to define tasks that are of a day or less duration and/or flows from a predecessor task that is being performed by another member of the work or project team. For example, in installing the welded steel piping system previously discussed, we would not typically break it down to the detail of each individual weld but we might break it down to installation of each fabricated spool because it would be constrained by a preceding task – transport from the store to the workface.

The specific methodology that is used to develop the lookahead can vary depending on the way the team likes to work, access to supporting technology, and the nature of the work being planned. However, there are a few critical attributes that should exist:

- To the maximum extent possible, it should be a collaborative planning effort involving all members of the team that will responsibility for the tasks that make up the package of work.
- The timing of each task in the lookahead plan is based on the "Last Responsible Moment" for completing the task, unless a specific fixed date is known. In scheduling terminology this loosely equates to Late Start/Late Finish. The reason for this approach is that the LRM date becomes the benchmark for successfully delivering the milestone being targeted.
- The sequence and logic of the plan is driven by a constraint analysis. In other words, predecessor tasks are linked because that are a prerequisite (or constraint) – not simply because it is the desired order in which you would expect to do the work. Going back to our welded steel piping system, it may be that the preferred (or anticipated) sequence of work is to install the pump suction piping before the discharge piping; however, if there was no physical or workflow driver for this sequence then the suction piping should not be linked as a constraining predecessor to the discharge piping.
- Lookahead planning for a particular package of work is done weekly with the time period being approached as a "moving window" until such time as the work is complete. Generally speaking, this lookahead window should include ever increasing detail as you move closer to the present. For example, an initial lookahead may have a task out in week 4 that extends over 5 days. As the project progresses and this task moves to week 2 of the lookahead window then one would expect that this 5-day task would begin to be broken down into several tasks of shorter (and ideally 1-day) duration.
- As the work progresses on toward a milestone that represents the hand-off from one discipline to another (or one team to another), you want to ensure that the downstream discipline or team begins their lookahead planning for the subsequent work early enough to allow a smooth workflow transition. This means ensuring that the constraining activities that will allow them to commence work as soon as the preceding milestone is completed are included in their lookahead plan.

Production Planning

A Production Plan is the list of tasks that a production team intends to perform in the next planning period. Typically, the planning period is either one day or one shift for construction work and a week for design or other developmental work. However, a production plan is more than just a To-Do list – it has some important attributes:

- The tasks that are selected to go on a production plan are only those tasks for which the constraining processor activities have been completed (or will be completed in the planning period). We want to ensure that only high quality assignments are making their way into the field so that we improve the reliability of completing those assignments.
- A task that is added to a production plan is a commitment by the team member responsible for it that he (and his support staff) will complete it during the planning period.
- A production plan task can be of no longer duration than the planning period and is incremental; i.e., can only be characterised as having been completed or not completed at the end of the planning period.
- Generally speaking, the tasks that go on the production plan should be an extension of the lookahead plan (i.e., it identifies the tasks and sets the logic and priority for execution). Clearly there will be times that unforeseen tasks emerge or that the day's capacity or workflow dictates that unplanned tasks be completed. However, these should represent the exception not the rule.

The production planning process itself consists of a brief meeting (15 to 30 minutes) of the production team once per planning period – either daily or weekly. This meeting starts with a review of the previous period's production plan where the status of the task commitments is determined – the task was either completed or not completed. For those tasks that were not completed, the responsible team member is asked to identify the "root cause" for non-completion. This root cause analysis is an important element of continuous improvement, so team members are encouraged to delve as deeply as possible into the fundamental causes – the 5-whys approach was developed specifically to assist in this type of analysis. The root cause is documented then put in broader "reasons categories" to allow quicker diagnostic analysis when evaluating production system performance.

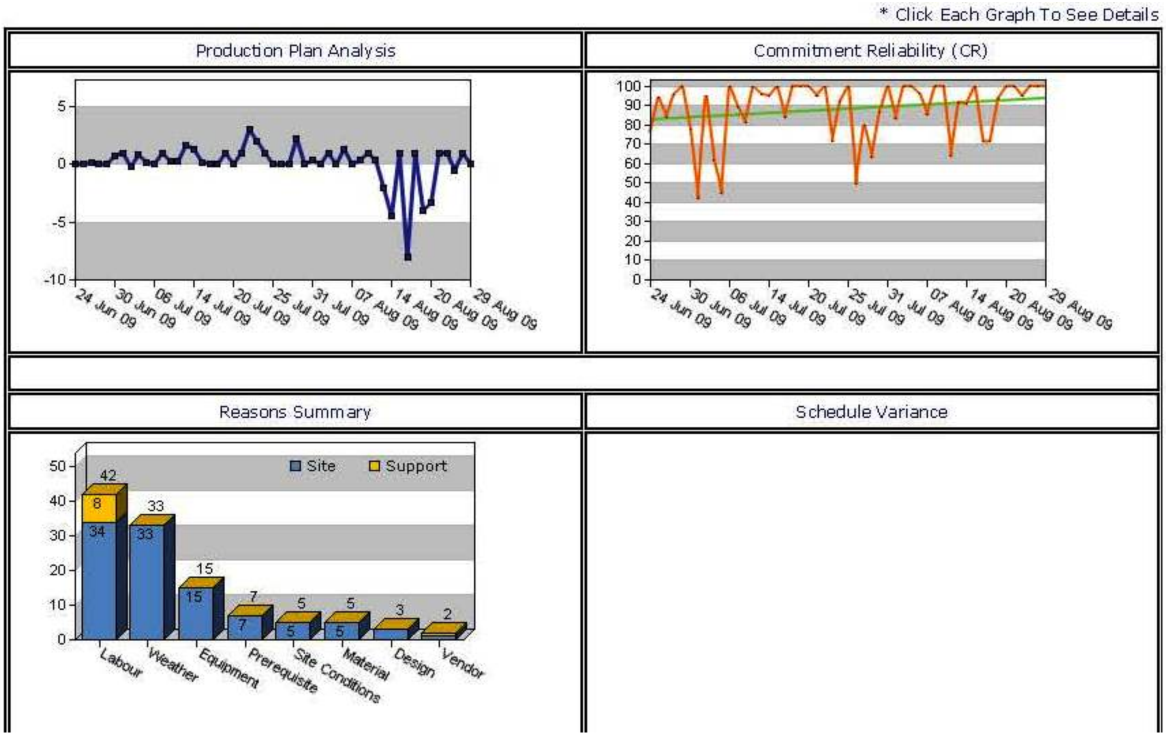
The second half of the production planning meeting consists of the development of the next planning period's production plan. In simple terms, the tasks that are available for execution (released from any upstream constraints) are reviewed to identify those that the production team, and specifically the team member responsible, are committed to completing. After completing a draft of the production plan, a brief review is conducted ensure that 1) the work committed is appropriate to the available resources (not too much or too little), 2) no higher priority tasks are being passed over in favour of less critical ones, and 3) a final check that no unidentified constraints have emerged since the last lookahead analysis.

Production Measurement and Review

Although the production planning and control processes outlined above are effective in their own right at improving work execution performance, the most powerful element of production planning and control is the continuous improvement aspect. While executing the work, you are constantly gathering information about production performance that can be used to measure the effectiveness of the production system. The value of these performance measurements can only be realised if the project team regularly reviews it and then utilises it to identify areas where they can improve.

We recommend that, for a typical moderately-sized project, the project's delivery leadership meet on a weekly basis to review their production system performance metrics, look for areas of sub-standard performance and seek to identify any systemic issues that need to be addressed. There are a range of analyticals that we utilise for reviewing production system performance. The most common are included in what we refer to as the Executive Dashboard. These include:

- **Production Plan Analysis.** Measure of the consistency of production plan development. Negative numbers indicate where production plans have not been prepared; large negative numbers indicate cause for concern regarding compliance with the production planning requirements.
- **Commitment Reliability.** This is a measure of how effectively the team is completing the tasks that it has committed to on their production plans. Average CR above 80% is indicative of a team that is highly effective at day-to-day planning and control over their workflow. A highly variable CR suggests that a high capacity buffer would be required to maintain program or that the schedule is slipping.
- **Reasons Summary.** This shows the categories which are the greatest contributors to non-completion of tasks. By identifying the key contributors the leadership team can delve into the actually root cause explanations to further diagnose the areas where remedial action can be taken.
- **Schedule Variance.** Although it is important to improve reliability and decrease variability, it is still crucial to analyse whether enough tasks are being completed to remain on schedule. The schedule variance reported here is forecast completion versus LRM completion of a target milestone – it is real-time based on the current lookahead and the tasks currently completed. By transferring these forecast dates to the milestone schedule, you get a real-time status of the overall program based on actual production activities.



Executive Dashboard of Production Performance Measures

In addition to these commonly used performance measures, there are other analytical tools that can be used to assess very specific elements of production system performance.

- **Lookahead Reliability.** This measures the effectiveness of the team's lookahead planning by determining how many tasks were completed on the day they were forecast at 5 and 10 days in advance. Although specific benchmarks are difficult to define, it should be considered that 5-day lookahead reliabilities of greater than 50% and/or 10-day lookahead reliabilities of greater than 30% are indicative of a team that are very effective at planning the work that is in front of them. More important is to look for trends – you are looking to see improvements in this forward planning ability.
- **Forecast Drivers.** By selecting a task or milestone it will show what predecessor tasks are driving the forecast completion date. Effective in allowing the team to focus their attention on those activities that are driving a forecast date for the purposes of mitigating those drivers. For example, where a key shutdown or handover has a fixed milestone date the Forecast Driver tool can be used to target activities as priorities.
- **Constraints Network Analysis.** By selecting a task or milestone you can see a network view (PERT chart) of the tasks that constrain it. Effective in identifying the workflow for a specific task to allow the prerequisite activities to be actioned. This is useful where a particularly critical, complex task is approaching and you don't want to be "caught out" by something that will inhibit your ability to successfully complete it.
- **Impact Network Analysis.** By selecting a task you can see a network view of tasks for which it is a constraint. Useful in understanding the impact of a specific task on downstream works to either prioritise it or know what might be impacted if it cannot be completed. For example, if a key permit or approval has been delayed then the extent of this impact can be quickly ascertained.

- **Interface Report.** Shows where the work of one team member (or team) interfaces with the work of another's. Most useful when used in conjunction with filters to determine the interfaces between a particular provider (team or person) and a particular dependent (team or person). As discussed later, this is a particularly useful tool to analysis design team work execution.

Enhancements to the Basic Approach

What we would describe as the "basic approach" is primarily concerned with creating improved reliability and continuous workflow by focusing on *tasks*. To enhance this approach and thus further improve the performance value achieved, we can expand this focus. Included below are the enhancement steps that we generally take in an ever-broadening planning and control focus:

- Tasks
- Tasks plus resources
- Tasks plus resources plus materials management
- Overall work package management

Where an organisation or individual project chooses to manage production along this enhancement continuum is largely driven by the specific business outcomes that they are looking to address and where they determine the criticality lies in delivery of those outcomes.

It is worth noting that we utilise the term "criticality" rather than "risk". We feel quite strongly that production management is a means to help drive the *critical* success factors to achieving project (or business) objectives. It is not a risk management tool even though it positively impacts the key areas of historical project delivery risk (i.e., time, cost, quality and safety).

To take an example from the roots of lean production, Toyota did not develop the Toyota Production System as a means of addressing the risk that the American car companies would encroach on their market; they saw it as critical that they develop a production system that was more efficient and flexible than that used by the American car manufacturers for them to meet their business objective of carving out <u>any</u> of the market dominated by the Americans. The result was that in 30 years time they went from an annual car production equal to one-half of Ford's daily production to producing about 60% as many cars as the Americans. In doing that, they were utilising about half as many manhours per car to assemble them and fix about one-third the number of defects per car. In other words, they were not managing a business risk they were creating business value.

Key Focus Areas

Lean production management has been used successfully on an extensive range of projects and programs. This includes everything from large capital projects to roll-out programs to maintenance programs. It has also been used across an extensive array of industries; e.g., civil infrastructure, power and process plants, mining, general building, shipbuilding and ship repair, aerospace, IT and telecommunications. Therefore, it is very difficult to provide a summary of the key focus areas for the use of production management techniques that is applicable for all project types. However, we can generalise their application to the following three areas:

- Design and engineering
- Construction and commissioning

- Supply chain management

Design and Engineering

Design and engineering can be expanded to include other “developmental” functions such as project planning within a program, permitting, environmental impact assessments and other types of complex regulatory processes. They are lumped together here because, in the project environment, they tend to be heavily linked to design development as well as sharing some common production characteristics with design.

Design and engineering is a particularly challenging production environment for a number of reasons. These include:

- It is an inherently iterative process often requiring that work be completed to determine if the approach or solution is viable thus resulting in the “two steps forward one step back” sense that people can often get from the design process. This iterative nature of design means that it is even more variable than the more linear processes of procure/supply and construction. In other words, it is not just about what you did today informing what you will be able to do tomorrow, it is what you did today telling you if what you did yesterday is correct.
- Design is an “interface intensive” delivery function. The work of a single design discipline must interface with: other design disciplines, procurement, construction, permitting, and regulatory approvals. Many of these interfaces are as a prerequisite or constraining activity – the design task must occur before the interface activity can commence. Without some mechanism to coordinate and prioritise these interfaces the likelihood that deadlines will be missed or downstream activities will proceed on poor quality information (leading to re-work) is high.
- Design progress is almost always resource constrained; that is, with very few exceptions, there is almost always more design work to do than there are people to do it. This means that it is extremely important to manage the deployment of resources and tasks to the available resources based on priority and the likelihood of successfully completing the task.
- Traditional design management focuses on the management of deliverables (drawings and specifications) and rarely focuses on the tasks/activities required to produce a deliverable. Defining and mapping the design workflow at a task level is a skill that many designers have never been asked to develop. This lack of technique combined with the iterative design environment means that design lookahead planning tends to be extremely dynamic; particularly, in the developmental stages where it is most valuable that design work be interactive. This is an ideal example of where variability can be beneficial but must be closely managed to ensure that high value is derived.

Given the specific nature of the design production environment, there are two key areas where we tend to focus planning and control of work processes beyond the basic identification and reliable completion of tasks:

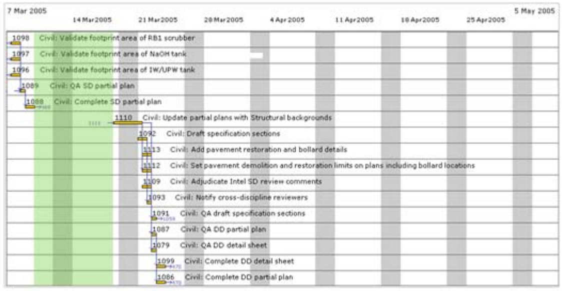
- Management of resource allocation
- Design interface management

We utilise the basic production planning and control processes discussed above by conducting both lookahead planning sessions and production planning sessions on a weekly basis. We use weekly production planning (as opposed to daily) because it can be difficult to break down design tasks into daily activities that are meaningful. The enhancement that we make is to assign level of effort (man-hours/man-days) to each of the tasks in the lookahead and production plans.

Management of resource allocation

There are two techniques that can be used to assess resource allocations. First, at the lookahead planning level, the lookahead plans can be sorted by team or team members to identify significant gaps or overlaps that signal an upcoming resource allocation problem. To address these gaps or overlaps, we want to ensure that we re-plan the work to allow high-priority, high-quality assignments to smooth the workflow.

Over-allocation of design resources



Gap in allocation of design resources

The second technique is reviewing the total man-hours for each team or team member that has been included in the current (next week's) production plan. By comparing the man-hours that are associated with the tasks that a team or team member has committed to with the available man-hours allocated to the set of task, you can assess whether the current production plan is over/under-committed and/or whether a re-allocation of resources should be undertaken to better match the production plan tasks.

Design Interface Management

One of the most important elements of progressing a project quickly through the design and procurement phases and into construction – with a minimum of re-work – is management of the complex array of design interfaces. By collaborative lookahead planning and constraint analysis, we are able to identify the interfaces necessary for continuous workflow as well as the points where iteration is necessary and beneficial. We can then utilise Interface Reports (with the appropriate filtering) to prioritise these interface points and ensure that critical interfaces are included in the production plan. We can also look for "the holes" by identifying where necessary interfaces have not been identified (e.g., where a stakeholder approval is required but has not been allowed for in the lookahead plan).

Construction and Commissioning

Construction (and we include commissioning as it has similar production characteristics) is generally a linear production process. That is, its work flow requires minimal iteration and tends to be made up of sequential tasks (often from multiple disciplines) that, when arranged in a logical and efficient progression, will result in significant improvements to time, cost, and quality. The key attributes of production planning and control in the construction environment are:

- The environment changes daily as the project progresses. Unlike manufacturing production where the specific features of a product may change day-to-day but the production environment (the assembly line) is relatively stable, the construction environment is a temporary production system where not only is the product changing daily but the environment in which the work is being executed is changing daily as well.
- The cost of resources and time tends to be quite high relative to the overall cost of the project. This means that with the intrinsically variable nature of the construction environment that a great deal of control must be exercised to ensure that buffers for capacity and time do not expand resulting in increasing costs.
- Traditional construction management systems incorporate structured approaches for measuring productivity and forecasting results, but tend to count on the skills and experience of individual managers and supervisors to manage work execution. This lack of a structured approach for managing work flow creates a blind spot for both management and the teams executing the work.

As a result of these characteristics, we tend to focus on three important elements of planning and control in construction:

- Improved reliability
- Allocation of resources to critical tasks
- Utilising repetitive work to continuously improve

Improved Reliability

The key to efficient, cost-effective construction is maintaining a smooth workflow with an absolute minimum of <u>unnecessary</u> variability. We accomplish this by

- Creating a short-term plan that conforms to the overall milestone program for the project.
- Anticipating the constraints to completing each of the tasks in this plan and systematically addressing them in a manner that ensures the successor task is not impacted.
- Creating a <u>daily</u> plan of activities made up of tasks that are unconstrained by pre-requisite works, are high-value from the perspective of progressing the project, and contains a "buffer" of tasks that will allow the project to continue to progress if work is completed more quickly than anticipated or if constraints present themselves during the execution of the work.
- Indentify the cause for non-completion of tasks and systematically work to mitigate these root causes.

Once again, we utilise the basic production planning and control processes discussed above. We conduct the lookahead planning sessions on a weekly basis; however, we hold production planning sessions on a daily basis. We use daily production planning for construction work because we find that by monitoring daily activities we achieve a more meaningful control of the production process.

Allocation of Resource to Critical Tasks

As discussed above in the Basic Approach section of this paper, it is not enough to merely complete a high percentage of the tasks that were planned. These tasks must be selected to address the most critical needs of the project if the overall delivery outcomes are to be achieved. One of the more common root causes for non-completion of tasks and/or a negative milestone variance is inadequate, unallocated or diverted resources. In this case "resources" refers to both labour and supporting plant and equipment.

To address this in construction, we look at it from the lookahead planning level as well as the daily production plans. Unlike resource analysis in a design lookahead, we tend to expand the filtering on a construction lookahead to obtain a bigger picture view. We can look holistically at a single trade, all the work of a subcontractor or all the work being undertaken in as individual facility to get an overall sense of areas of over-commitment or possible logistical bottlenecks. As individual work teams are likely to be progressing their work without the benefit of knowing the detailed plans of other work teams. This holistic view of the work allows construction managers and site superintendants to prioritise work based on the most critical activities. This prioritisation process then allows those teams that have planned lower priority activities to be aware of any resource constraints and re-plan accordingly.

As a part of the production planning process, every production plan should undergo a brief resource assessment prior to committing the next day's production plan. At a minimum, this assessment should be a qualitative review of the work force and equipment available to complete the tasks.

An enhancement that we may or may not make to the basic planning and control approach (depending on the nature of the project and the work package) is to assign level of effort (man-hours/man-days) to each of the tasks in the lookahead and production plans. This would allow the review of labour resources to be conducted on a numerical basis. You can determine if the tasks that are about to be committed require significantly more labour than is currently assigned or, conversely, if the production plan will under-utilise the assigned labour. Labour allocation and/or task commitments can then be adjusted accordingly before finalising the production plan.

Utilising Repetitive Work to Continuously Improve

Construction work on many projects has elements of work or work processes that are repetitive. This repetitive work lends itself to standardisation; i.e., utilising the same workflow each time it is undertaken. By defining what we call "standard processes", the work team is able to define the optimal workflow through detailed planning, trial-and-error/experience or field trials. At the most basic level, it makes the development of a lookahead plan that contains a standard process(es) a more streamlined activity. More importantly, it allows the work team to better anticipate the sequence of tasks that they will need to perform to complete the work and to anticipate the constraints that they will need to address (and when) to maintain a smooth workflow.

Perhaps most important of all, the application of standard processes creates the platform for continuous improvement. Once a standard process is established it can be refined to the highest level of optimisation. It can also be transferred to other work teams and other projects to broaden the influence of this optimisation. Conversely, if a work team creates a workflow for a particular activity that proves to be particularly effective it can be captured as a standard process then applied wherever it is applicable.

As you can imagine, standard processes are largely applicable as part of the lookahead planning process. As part of our lookahead planning tool set we have a standard processes module that would be developed to include a library of standard processes for the project and a utility for creating or editing a standard process. As part of the lookahead plans there is also an ability to select a section of workflow to be captured as a standard process and placed in the library for future use by work teams.

Supply Chain Management

One of the most common constraints to reliable and continuous workflow is the supply chain. The supply chain can be viewed in a quite expansive way and include: materials, design deliverables, and working plant and equipment. Incorporating all of these aspects of the supply chain would be what we call planning at the work package level – work package management provides tools for this level of production management. However, for the purposes of this brief discussion we will look primarily at materials flow optimisation.

In optimising the flow of materials during construction, we look at off-the-shelf, made-to-order, and engineered-to-order materials, components and equipment. We want to match supply with the demand in field so that we reduce the lead-times necessary for materials supply, increase the reliability of material supply and optimise the inventory levels. It is worth noting that when we talk about materials flow optimisation that the supply chain extends from the point that it is delivered to the work face back through the on-site store to any off-site storage to the supplier's warehouse to the fabrication (or batch) facilities to any pre-fabrication engineering to the ordering/procurement process. Obviously not every material supply has all of these elements, but to truly optimise material flow the potential impact of each must be considered.

As both the nature and the criticality of materials flow can vary quite widely from one project or organisation to the next, there is no typical application. However, we can employ an array of processes to address the challenges that materials flow can impose on a project.

Materials Manager

Our Materials Manager module provides a place for creating a library of materials that will be used on a project and specifying a lead time for each item. These lead times can be based on delivery times established with key suppliers before the work starts or based on delivery times from an on-site or off-site store. If the Materials Manager module is utilised, then any work task can have quantity and type materials from this library associated with it. By creating these materials association it allows the work team to: 1) assess the potential constraints of materials flow as a lookahead is being developed, and/or 2) initiate a materials supply order once the task is committed in a production plan. If we were to use our welded steel piping system example again, we could have associated a range of specific materials with each of the tasks associated with the assembly (e.g., number of welding rods, flexible couplings, lengths of green steel pipe and specific fabricated spool numbers). As the various assembly tasks are included in a lookahead plan we would be able to see that flexible couplings need to be ordered from the supplier 4 days in advance of installation and include that in an advance order that our piping specialties supplier is automatically provided on a weekly basis. Then once these tasks are committed to a production plan, they would effectively create a bill of materials that the storeman and his support labour could receive, pull out of inventory (or have delivered) and transport to the job site. This allows the fabrication team to focus on assembling the piping system and not chasing down materials in the laydown yard or the store.

Standard Processes

Standard processes can used to define a suite of materials flow processes that can then be incorporated into lookahead planning work. This approach is particularly useful for made-to-order and engineered-to-order materials where it is easy to under-estimate the number of activities it takes to translate detailed design into the delivered product. For example, the project might establish standard processes for:

- procured major equipment,
- fabricated metalwork,
- electrical switchboards,
- precast concrete elements.

Each of which have consistent workflow requirements for procurement, fabrication engineering, fabrication, delivery time, and materials receiving. By "connecting" these standard processes to a lookahead for design (forward looking) or an installation point in construction (backward looking) we can identify the last responsible moment for initiating these processes so as not impact their installation schedule. We also create milestone dates on which elements of the materials flow process must commence (or be completed) and use that as a trigger for on-site tasks or expediting activities.

Production Plans

As eluded to in the earlier example, the production plans themselves can be utilised as a "pull signal" for materials delivery. This is particularly useful in the following circumstances:

- Limited space is available at the workface to store materials and hence the inventory buffer must be kept at the lowest possible level.
- The nature of the material supply is such that an on-the-day delivery avoids costly double handling (e.g., granular fill material or crushed rock) or it must be utilised immediately (e.g., concrete).
- Transport of materials to the workface would severely impact the work crew's productivity (e.g., remote storage areas or specialised materials handling requirements).
- Large, complex on-site stores that require a structured ordering process to operate efficiently.

Implementation and Its Impacts

Two common questions we are asked are:

- "What does it take to implement a Lean Construction approach?"
- "How is my team's day-to-day work impacted?"

Although the accurate answer is "it depends" we will provide a bit of guidance on these two questions below.

Implementation of a Lean Production Management Solution

The nature of our implementations can vary quite dramatically depending on their stage of the project delivery life cycle development and where in the value chain the solution is being implemented. A very high percentage of the projects that we become involved in are already underway and have recognised a significant delivery problem when they decide to utilise production management processes to address the issue. Usually in these cases, implementation time is of the essence. On the other hand, where we are implementing a solution as part of the start-up of a new project it can be important to spend a bit more time in the developmental and design steps to ensure that the stage is set for extracting the greatest potential value. The following table shows the steps we would "typically" use to approach the implementation of a lean production management solution. We have also included the timeframe we would expect for each of these steps assuming a fast-track implementation.

Step No.	Activity	Timeframe
1	Meet with key members of the project's (or organisation's) leadership team to identify the specific outcomes they are looking to deliver, the critical success factors required to achieve those outcomes, and the potential impediments to delivering in these areas of critical success.	1 -2 weeks
2	Given the above assessment, identify areas where a production management focus could positively impact the delivery outcomes by impacting the critical success factors.	
3	Given the areas of criticality, design a lean production solution that is focused on the needs of the project (or organisation). This design would include both the processes to be utilised by the team and the enabling tools that would be hosted as a part of SPS's web-based systems.	
4	Configure the system based on this design, including the modules that we agree are appropriate to meet the project's specific needs.	3 – 7 days
5	Begin to work with the project team's management to identify and align production teams with the manner in which the project will be delivered. This is an extremely important element of successful implementation.	
6	Train the project team. Typically, the production team training consists of two 4 – 6-hour days. The first day is a small amount of theory (what we are looking to accomplish with production management) and the basics of how to use the system. The second day we actually begin to use the processes and systems	2-5 days

	to create production teams, build lookaheads, and/or create standard processes. Extended training may be provided for "power users" or for enhanced functionality – always configured around developing the project's production management system.	
7	Remote monitoring and support. Our technical services team will be available to provide technical support to the production teams in using the system, definition of production management strategies, and maintaining the system database.	Continuously through the life of the project
8	Periodic production performance assessments to review performance against objectives, address any implementation challenges, and/or look for areas of enhancement or improvement.	1- to 2-monthly or as requested.

There are a couple of areas to note with regard to implementation (based on questions and concerns we have addressed previously).

- The design and configuration of the production management system is based on techniques that have developed and refined over the last 10+ years and the application of highly-customisable modules to a specific, secure project area. In other words, this is not an IT roll-out project. There will be unique elements for every organisation and every project, and we want to ensure that we develop the production management system to address these uniquenesses. However, this customisation does not require extensive software programming or database manipulation.
- We strongly believe that most people learn best by "doing." Therefore, our training and development programs are built around a small amount of theory and principles then beginning to use the techniques and systems to execute the work as quickly as possible. By supporting the team through this initial hands-on learning phase, we can demonstrate how it is directly applicable to their job responsibilities and execution of their work, begin to gather data immediately about the production environment to focus improvement opportunities, and develop the production management culture at the same time we climb the learning curve.
- Because of the distributed nature of our production planning and control approach and the short-term focus on the work to be executed, the project is beginning to develop the production management system as it is executing the work. As we are not re-planning the entire project, the overall time for implementation to filter through to the work face is relatively short – as is the disruption to the project if it is already underway.
- We stressed early on that production management is a "compliment to" and not a "replacement for" project management – in essence it looks to address a blind spot that we believe exists in traditional project management approaches. However, the relationship between production management and project management can be that of two hard edges butted together or a seamless interface that is zippered together. If a production management approach is adopted at the start of a project (or as an organisational initiative) there is the opportunity to fully consider how this complimentary relationship is configured. You will build a more comprehensive lean organisation by considering issues of: supplier relationships and up-front supplier agreements, how procurement of subcontractors and

consultants will enhance their involvement in the process, configuration of work teams to mirror the optimum production team, and work packaging to allow the production management process to track the work execution lifecycle from initial design right through final handover. The more extensively lean principles permeate traditional project delivery approaches, the greater the value potential that will be realised. However, it is not necessary that you go to this extent for a lean production management implementation to successfully enhance project outcomes. A basic task-based production planning and control implementation can add significant value to project execution and create the platform for enhancements as the project moves forward or the organisation applies it to a greater number of projects.

Impact on Day-to-Day Project Activities and Execution

A second area of interest is the impact that adopting a lean production management approach will have on normal day-to-day project activities. By "impact" we mean what is different to what is traditionally done on a project – as opposed to what differences can be expected with regard to performance results. This is a tricky area to address because on one level we are advocating a fundamental paradigm shift from centralised project controls to distributed planning and controls and the implementation of structured systems and processes for work execution where often none exist. However, on another level, although the difference in approaching the execution of work is quite profound, the impacts to the project and project team are quite subtle.

For the purposes of this brief discussion, we address this topic in the following areas:

- The additional staff required to support successful implementation.
- The time commitments required of existing staff.
- New competencies required of team members.
- Impacts to the project's organisational structure.
- Impacts to consultant, supplier, and subcontractor relationships.
- Impacts to the project infrastructure.
- The administrative requirements.

Additional Staff Requirements

There are two key roles that we find need to be filled to have a successful implementation: work team leader and production planning facilitator. The work team leader should be an existing member of the project team. The production planning facilitator is someone that facilitates the consistent completion of production planning and control activities (e.g., lookahead planning and production planning). In this role, he/she would ensure meeting times are set and distributed to participants, the room is prepared at the appointed meeting time; e.g., computer and projector are set-up, supporting work visualisation tools are in place (drawings, 3D model views, GIS maps), and Production Manager application is up and running with the appropriate team selected. This facilitation role is important because it creates an expectation that these production management activities are the way that the project is expected to do business - it is a systematic activity not an ad hoc one. In the past, this role has been successfully staffed in a number of ways: 1) existing project controls staff, 2) a selected site engineer from each work team, or 3) a specialist production planning and control facilitator. Only (3) above requires additional staff. The approach that will work best for a specific project will be based on the size and nature of the project as well as attributes of the existing project team.

A further role that can be highly valuable to a successful implementation is what we call a "power user". This is someone within the project team that has a particular aptitude and depth of knowledge of the systems and processes that allows them to be a resource to the rest of the team for addressing questions and providing support on certain techniques and applications. Although we are happy to provide this support remotely on a day-to-day basis, we find that the team tends to utilise the systems more effectively if there is someone within the team that can help to increase the overall skill and confidence levels. This is not typically an additional staff requirement and we would provide some "train the trainer" support if an appropriate resource is identified.

Time Commitments Required of Existing Staff

The time commitments required of most team members has been indicated above but is summarised below:

Activity	Time Commitment	Frequency
Training	2 days	once
Lookahead planning	1 -1 ½ hours	weekly
Production planning	15 – 30 minutes	daily (construction) weekly (design)
Continuous improvement (e.g., standard process development)	1 -1 ½ hours	Monthly (on average)

Above and beyond this, certain team members will require additional time commitment. Members of the project delivery leadership team will spend approximately 1 – 2 hours per week in production performance review meetings where the effectiveness of the production management system will be assessed and improved. Additionally, certain members of this group may choose to sit in on the production planning and control activities of multiple work teams.

There will be times that the result of lookahead planning sessions will require transfer of information to the Production Manager system (although the tool has been developed to minimise the "outside work" required). This will mean that a single individual will have an expanded time commitment for lookahead planning on an occasional basis.

New Competencies Required of Existing Staff

Generally speaking, our approach to production management is to have project teams use their existing competencies in a slightly different way – and in many cases take advantage of capabilities in frontline engineers and supervisors that are poorly leveraged. However, there are some new competencies that we will be asking existing staff to develop. One, of course, is the use of a new computer software tool. Another is the ability to plan the work in a collaborative environment. As can be imagined, the challenge in developing this competency will vary broadly from person to person. A senior project engineer or construction manager that is used to "controlling" the project with an iron fist may struggle to involve frontline supervisors or designers in discussion on construction workflow. Conversely, a supervisor who has never been asked his view of the best sequence to perform the work may struggle to express his view (even though he has an inspired one). Importantly, we believe that these new competencies will not only make them more effective at the production management aspects of their job but will help them develop and grow in their careers more broadly (e.g., making a supervisor more effective a collaboratively planning workflow will make them more effective at identifying risks to safe work methods or the potential for defects).

Impacts to the Project Organisational Structure

Project organisational structures are generally set up around reporting lines. From a project and human resource management perspective this is completely appropriate. However, as stated earlier, one of the key components of successfully delivering production management results is an effective team structure at the work execution level. For us, this means cross-functional, collaborative work teams with execution responsibilities for a package(s) of work. These work teams can exist as a sub-structure within the overall project organisational structure without impacting the imperatives of organisational reporting. However, it is worthwhile ensuring that the two structures interact with each other effectively – once again, ensuring that project management compliments production management.

Impacts to Consultant, Supplier and Subcontractor Relationships

In assessing these relationships, it is important to note: <u>the more involvement you have in the production planning and control process from those that have the potential to impact your workflow, the more effective the project will be in delivering performance results</u>. Virtually every organisation that has adopted lean production as a cornerstone to their business processes has found that by going up the supply chain they achieve more effective business outcomes. This means that to achieve maximum value from a production management approach, the project team should actively seek to involve key consultants, subcontractors and stakeholders in their production planning and control activities. It also means that the project team should look for opportunities to increase the reliability of supply chain flow – the nature of the direct involvement will depend on the situation.

The commercial relationship does not necessarily have to change dramatically – many highly successful supplier/subcontractor relationships are maintained in lean organisation with quite traditional contracting mechanisms. However, from a production management perspective, the project is much more likely to deliver on its business outcomes if the working relationship is based on the mutually beneficial attributes (i.e., greater profitability) of creating a smooth and reliable workflow for both the supplier/subcontractor <u>and</u> the project.

Impacts to the Project Infrastructure

In nearly every case, the answer is <u>none</u>. The project infrastructure we recommend to implement our basic production planning and control approach is:

- A location for the work team to meet.
- Computer(s)
- Java Runtime
- Access to the internet and an internet browser (most common browsers are supported).
- A means for the work team to simultaneously view the "live" lookahead plan or production plan contained in the Production Manager system – usually this is a data projector.

As the production management systems are hosted through an off-site Tier 1 data centre, there is no need to load application software on the local server or individual computers. There are also no licences or licence keys that need to be applied – access is simply through an internet browser and login credentials. Different access levels can be set to restrict user access and editing functionality. This means that access to the system and associated system information is open to everyone that the project team deems appropriate, while being secure from a data integrity and privacy perspective.

Finally, because no software is loaded onto the system and no applications are being downloaded during use, IT security is very minimally impacted. Usually simply setting up the Strategic Project Solutions IP address as a secure site in your internet security settings is all that is required.

Administrative Requirements

As with all management systems there is some level of administration required. However, these requirements are generally quite minimal with our systems and are predominantly accomplished as a matter of course in implementing the production management processes. Because the enabling system is built on an interactive database, inputting information in one area flows through to all modules – for example, inserting a constraining task in a lookahead plan will flow through to the variance forecast and to the tasks available for a production plan. Lookaheads can be accessed/edited through any of three views (list, Gantt chart, or network) – a change in one view is instantly reflected in the other three. All diagnostics and reports are built into the system as a direct extraction from the data. They can be filtered in multiple ways, at multiple levels, and can be accessed/viewed directly from a web browser without "administrative intervention".

Because this is a remotely hosted system, there are no onsite system administration requirements. All system administration is done by Strategic Project Solutions as a part of their remote support services.

The administration that is required of the project team includes:

- Establishing users in the system, including defining access level settings. This is typically done as a part of the initial system configuration (for the initial system users) or by a member of the project team that has administrator access to the system (for users being added as the project progresses).
- Establishing the production teams. To input or edit tasks in the lookahead, to be listed as a team member responsible for a task, and to commit or status tasks in a production plan a person must be assigned to the production team responsible for that work. Therefore, there is an administrative task to create and/or update production teams in the system.
- Data entry for Materials Manager and Work Package Manager. Should the project elect to implement these enhanced system modules, there will an element of data entry required to establish the data library necessary for these systems to be customised to the specific project.

The other system activities outlined previously (e.g., creating lookaheads, creating/updating production plans, creating/editing standard processes) we would typically consider to be requirements of production system implementation rather than administrative tasks.

Final Thoughts

As we set out in the introduction, the objective of this paper was to raise the awareness and understanding of what “Lean Construction” is, why we believe it has significant potential value for project delivery organisations and how we approach application of lean production principles to the design, planning and control of work processes to deliver this potential. The foregoing summary is a reasonably comprehensive introduction to Lean Construction and, to some extent, our definition of what this broadly used terminology should mean in project delivery. It is however just a summary of a broad and complex approach to delivering outcomes in the project environment. As such, we have presented a number of generalisations that may or may not be applicable to each project, program or organisation’s circumstances and business drivers.

The detail that sits behind this overarching view can only come from a focused assessment of what an organisation is looking to achieve and understanding what the critical delivery factors are to achieve performance success on a given project or program. Only then can specific techniques and processes be defined that will apply to your specific situation.