The End of Project Overruns

Lean and Beyond for Engineering, Procurement and Construction

I dedicate this book to Kathy Patty, my dear wife and companion of 35 years, for her inspiring and encouraging me to write it, and her many reviews and suggestions for improvement. Her natural patience, love and dedication to me, our four children and 11 grandchildren is exemplarity of many leadership principles that could well be emulated for benefit in the business world.

— *Robert M. Patty, Primary Author*

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&
Michael A. Denton

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The End of Project Overruns:
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Foreword

Building a Lean Foundation for Construction

The establishment of a "lean production system" — or rather a "learning organization" with "lean and efficient processes" — is a daunting task. Having personally been on such a journey for more than 20 years I know what it takes to translate the seemingly obvious principles and techniques into something useable and feasible for a business. In the late 1980s and early 1990s, many managers like myself were inspired to study and understand the working elements and success factors of *just-in-time/lean production*. In aerospace manufacturing, where I worked, the puzzle included the translation and adaptation of what had been successful in automobile manufacturing. Whether a system originally designed for high-volume, low-variety commodities could work for low-volume, high-variety durable goods such as commercial aircraft and military hardware was a mystery. Successful implementation managers discovered the road to achieving the adaptation and transformation had many twists and turns but the answer was, "Yes, it can be done."

In time, other industries started to ask the same question. In this book, Dr. Robert "Bob" Patty and Mike Denton show you that they also took the challenge to adapt and apply just-in-time/lean production in their heavy construction world. When they asked me to review their first drafts I immediately identified with their experiences. At the Boeing division where I worked we were fortunate to have access to former Toyota managers and other U.S.-based companies who guided us and shared with us their experiences. [See Postscript – Toyota: Present Challenges, p. 445.] From these collaborative activities we were able to develop and employ an effective framework for implementation and long-term sustainability. Bob and Mike have similarly developed a framework for heavy construction.

They have taken great care and time to bring you data and evidence of the power of using the methods, techniques and tools of lean production. They have appropriately identified key foundational elements and enablers. Don't be surprised about how much they emphasize the importance of top management commitment and leadership involvement. Many a company initiative has faded and fallen by the wayside when leadership forgets the "lean enterprise vision" must be communicated everyday in some way, form or deed.

Included in this work is the importance of selecting effective performance metrics for measuring implementation and long-term impacts of using lean production techniques and tools. The six categories I find to be universal — 1) Productivity, 2) Quality, 3) Cost, 4) Delivery, 5) Safety and 6) Employee Morale — are demonstrated in one form or another so any project manager can understand how to incorporate them. The obvious and superficial lean production mechanisms such as Standard Work, Work Place Organization, Kitting and Consumption-Based Replenishment are put in proper perspective with the goals of achieving Flow and application of countermeasures. Mastering rapid improvement techniques as a first step, is later linked to overall system improvement via Value Chain diagnostics and redesign. I am also impressed by how they have correctly communicated the need for every system, sub-system and process in the business to be examined in order to achieve what my Toyota teachers have characterized as "system harmony." From Bob and Mike

you also get a heavy dose of Supply Chain Management because even if your processes are fine tuned and operating well, your supply chain will still be subject to the natural chaos that occurs in logistics and human nature.

Finally, I suggest not rushing through this book and selecting only the pieces you prefer or think you can afford. Bob and Mike have deftly described the transformation to *lean* is not just at the lowest levels but transformation of the entire business model and all the supporting processes is what solidifies, sustains and perpetuates.

Don A. Blake, 2010

Don Blake was the Lean Production Implementation Manager and Director of Boeing Production System Implementation at the Boeing Company's Wichita Division from 1995 to 2005. His team's success at Wichita and his personal contributions as a strategist and internal consultant is the subject of several academic and cross-industry benchmarking studies. In 2005, the Wichita Division became an independent privately owned company under the name "Spirit AeroSystems, Inc." Since 2006 Don has served as Director of Strategic Initiatives and as Director of Operational Efficiency and Strategic Initiatives for Spirit AeroSystems – AeroStructures/Wing Segment. In July 2009 Don was also given responsibility for overseeing Lean Production and Inventory Control at the Oklahoma business unit. And in November 2009 began oversight of 737, 747, 777 and Government Programs production and order fulfillment for the Oklahoma business unit.

Acknowledgements

The work of researching and converting what was successfully done in other industries to what should be done during the early, facility-project planning and subsequent stages of project engineering, procurement and construction has required the help of many people, to whom we are very grateful. The inspiration to do the work came from the early success and publications of the many members of the Lean Construction Institute, for which references are included throughout the handbook. A special thanks is also certainly due the following:

Mike Denton (a senior-level internal consultant for value-improving practices, especially value engineering, at BP and now an Asset Consultant and Senior Risk Mitigation Manager for Chevron Project Resources Company) provided lots of encouragement and wisdom as we spent many days discussing lean methods. He was predisposed to many of the methods from his involvement with lean subcontracting implemented on a $5 billion deep-sea drilling operation in the Gulf of Mexico for BP. He provided deep technical review for the entire manuscript, drafted an introduction, provided numerous examples and prompted the development of many more detailed explanations along the way. The depth of his understanding for how to make practical lean improvements during front-end-loading was invaluable to the description of systems benefiting EPC processes that would follow.

Don Blake shared with us his perspective for lean conversion of the aerospace industry and lent his technical expertise to keep the process focused on the most important issues. Following his review, Don graciously wrote the Foreword reflecting on his similar challenge as the Lean Production Implementation Manager and Director of Boeing Production System Implementation at the Boeing Company's Wichita Division from 1995 to 2005. Don is currently Director, Operational Efficiency and Strategic Initiatives for Spirit AeroSystems AeroStructures Business Unit.

In 2003, Thomas M. Terris, PE, a Senior Project Engineer of some of the most challenging projects at Saudi Aramco, invited me to Daharan to share early results of lean implementations and research with selected senior project managers and their Value Improving Practice support team, which he managed at the time. When the book began to take shape, Tom became invaluable as a critical technical reviewer. He immediately perceived the value of many aspects and provided numerous examples from his vast experience of ongoing industry problems that could be avoided by lean implementation. Where implementation depth was lacking or suggestions made that did not align with his experience, he didn't hesitate to ask questions or play the devil's advocate until the meaning came clear and practical to implement. He also suggested many editorial improvements.

From his first introduction to lean principles in our workshop in Daharan, Gregg Magee has been a strong advocate for lean especially benefiting clients and subcontractors. Gregg's technical editing and challenges to assure any changes to current practices would benefit all project parties were of immense value to assure that would be the case. He provided many illustrative examples. Gregg was a senior internal best practice consultant and project manager at Saudi Aramco and currently manages a major independent consulting firm.

Fred Harriman, *www.FredHarriman.com*, served many years as an interpreter for Nakao, the president of Shingijutsu (Toyota's external consulting firm). All the while, Fred learned lean methods improving hundreds of company work processes worldwide. Fred now has his own consulting firm. I became acquainted with Fred while he still serving as Nakao's interpreter, when Nakao and Don Blake invited me to participate in a worldwide lean workshop at Boeing. Fred reviewed our application of key principles of the Toyota Production System, especially when they varied from commonly accepted lean interpretations. His contribution to the technical accuracy, means to evaluate and prioritize among apparently competing goals was essential to the team understanding.

James Williamson, a former construction management student of mine while I served as an associate professor at BYU, and now a project and construction manager at a regional commercial building contractor, read and commented on most of the manuscript. His review helped in the transition between heavy industry and building construction. Much additional content was the result of his challenges, questions and examples.

Upon his review, Darryl Hertz, Manager, Value Improving Practices, Worldwide Kellogg Brown & Root, made me an offer I couldn't refuse to continue the development of constructability lessons learned systems which we began 10 years ago and to join his efforts to further improve work-processes at KBR. Darryl is one of the most innovative men of my acquaintance and one of the most successful actually implementing improvements in the industry.

Dr. Mike Miles, a BYU assistant professor of Manufacturing Technology, an experienced plant manager, lean systems engineer and consultant reviewed and commented throughout the book on technical aspects of lean. This helped us maintain purity of doctrine to obtain the greatest value during its application to the construction industry.

Aaron M. Patty, program manager, major subcontracts, for a major U.S. Department of Defense contractor, reviewed and commented extensively on the Primer, Chapter 11 on trust and many other sections of the document. His frank questions, subcontracting and leadership insight were provoking of major changes and examples inclusion. His edits and significant paragraph rewrites made the principles much more understandable.

Dale L. Little provided considerable detailed technical editing of the early chapters, made recommendations to improve the overall structure and facilitate publishing. His substantial encouragement was most appreciated throughout the long process.

Although recently retired, Dr. Dan Halpin, former department head of Construction Engineering and Management, Purdue, encouraged our efforts to complete the manuscript by declaring early in development, the book to be "very, very compelling, well ahead of others in this area, and a nice addition to available lean literature." Dr. Halpin has received the some of the highest accolades the industry can bestow on an academic for teaching and research contributions. He served as an outside reviewer on the first lean construction Ph.D thesis defense team at Helsinki University in Finland, and is very familiar with the current players and published literature.

Geoffrey and Linda Gioja of Telos-group.com provided invaluable leadership principles, direction and sources for improving trust.

Additional technical review was provided by Bryce Johnson, graduate of the Mike Miles master's degree program at BYU.

Gregg Sekscienski meticulously reviewed the entire document in preparation for publication. He suggested many improvements in consistency, sentence structure and the addition of explanatory paragraphs to assure cohesion and content flow. Many thanks to Gregg, Jeff Young and the Universal Publishers staff.

A Lean FEL & EPC Primer

Project Work Process Rapid Improvement Discipline

For Engineering, Procurement & Construction Operational Excellence

The authors' passion is to bring the reader a body of lean/six-sigma/constructability principles and methods not-yet formally deployed on most large facility delivery projects and programs. Our desire is to materially engage highly-experienced, forward-thinking industry professionals to add deep value through increased efficiency, cost-avoidance and months of schedule reduction. This handbook delivers an emerging discipline and tool set for the heavy construction industry's progressive thinkers, at every level, selected or desiring to differentiate themselves and their team's performance on the world stage. The correlated vision and sense of urgency justifies unseen executive sponsorship of alignment for work-process excellence between clients, engineering disciplines, construction and supply chain companies. The improved fitness will secure major value-added strategy, tactics and outcomes on mega projects. Some top skill and stakeholders will seize the opportunity to customize the tools to be just right for their projects, and save millions and months in quick impact. Evidence is that well-developed strategic improvement is often restrained because the traditional way, current means and methods, fit squarely in everyone's comfort zone. Through early impact, typical outcomes of the best traditional systems are soon to be rendered "not-good enough" by top client leadership demand-to-improve. What will constitute the new market-differentiating performance of individuals professionally and of project teams and companies is being rewritten within emerging lean enterprise relationships. The transformation to *lean* — not just at the lowest levels but for the entire business model and all the supporting processes — unleashes the ingenuity to achieve, solidify and perpetuate a new level of performance of profound mutual benefit. Differentiation now and dominance in the future is achievable by greater commitment of time, resources and intellect to learn and implement these key foundational elements and enablers.

Consider – Presented is a Rapid Improvement Discipline:

- for better integrating project planning and execution work process
- to sustain reliable performance excellence during facility engineering, procurement, construction and supporting business management
- supporting executive efforts to establish a culture sustaining rapid improvement

Dr. Robert M. Patty & Michael A. Denton, Authors

Overview

The discipline provides executives and existing engineering, project and construction management employees a repertoire of ideals, principles, tools and methods for recognizing the root causes of excellence, facilitating invention and work process improvement. Companies, associated by project, use the discipline to extract, align and normalize excellence and facilitate opportunity (to involve an increased set of skill and stakeholders) to leave inefficiency of time and resource, literally no place to hide. Responsible executives, trusted at the highest levels, will resolve all skill and stakeholder concerns, achieve alignment and pilot best practice standards with improvements they create. This book is intended for facility clients to learn how to ask for and get beyond the introductory 10% cost and schedule savings from their lean facility delivery service providers. To learn and operationalize this discipline is of profound benefit for every member of the facility-delivery-service team.

> "There is no earthly reason why we build plants the way we do other than we've always done it this way and the means and methods fit squarely in everyone's comfort zone. But there are more efficient approaches and Dr. Patty can provide the expertise to guide your teams to those approaches. . . Commitment must come from the top. It's not a flavor of the month undertaking."
>
> *Joint Venture Site Manager for $6B plant in Nigeria*

Change in large organizations is seldom easy. Beyond the mechanics of lean, the rate of work process improvement (whether benefits are realized in months, years or at all) is largely a people issue involving leadership of profound change, improving inter-departmental and intra-company trust in mutual benefit. What are the human factors that induce the highest individual commitment? How will executives deploy policy for mega-project teams to create and sustain best practice task alignment and sequencing for corresponding project excellence? Stakeholders in the facility delivery chain

from clients to suppliers can use the discipline to evaluate current policies and best practice as well as quantify opportunity to further improve work processes, deployment policy, supporting software[1] and communications within and at interfaces between companies.

The principles and methods are scalable, from small and medium projects to more effective management of mega projects of international scope, with thousands of enterprise employees from many organizations joined in a project effort.

> **Following an intense week of training by the primary author, Salmon al-Aradi** presented to his Vice President at Saudi Aramco, "*Lean is applicable wherever engineering, materials, people and equipment are brought together in a Project Process.*"
>
> *Saudi Aramco Director – $25B Ras Tanura Integrated Project*

The discipline enables teams to achieve quick wins. Then, with increased training and experience, success is balanced between and through increased sensitivity to client needs and concern for people, teamwork, participation and consensus. Improved client value with lower net cost and schedule are deliverables. Included is timely information that leaders, or heads of the organization, need in their quest to mentor.

Discipline leadership principles help executives and team members sustain high operational fitness on projects, maintaining a very friendly place to work, where people share a lot of themselves. Focus is on work-face visibility and supporting task level performance of people (e.g., discipline task leads and foremen), where the primary value is added. Fitness methods enhance vision and clarity of purpose, and then deliver a performance-risk-catching net, woven with loyalty and peer expectation of consistent excellence.

Discipline experts facilitate teams' learning and profoundly reducing cost and schedule, expertly balanced to also improve safety, reliability, quality, environmental protection and employee morale. We have extracted the discipline focused on applicability to facility project front-end-loading, detailed design, procurement and construction. Overlapping programs and individual utility is included from Lean, Kaizen, Just-in-time, the Toyota Way, SixSigma, Constructability, Design-for-Assembly, Value Engineering, Value Improving Practices, Factory Physics and other programs of excellence in leadership and trust. (See Postscript – Toyota: Present Challenges, p. 445.) As a matter of convenience, within this treatise, we will often refer to the entire integrated rapid improvement discipline of principles and tools as ***lean***.

When evaluating the value added to a company, it is useful to focus on how the added value enables executives to enhance the company's culture to support more frequent, and a broader base of, improvement. Our effort is to bring as much value to the construction industry as our experience to date allows, circumscribing applicable technology, principle and practice into a usable handbook for the implementation practitioner. The authors and others have achieved introductory improvement levels using *lean*. This handbook contains the authors' current understanding of what will be required to achieve in facility delivery, the full benefits experienced in other industries: rapid, sustained organizational improvement that leaves competitors flatfooted and unable to follow, and therefore allows the successful practitioner to dominate industries. (see Foreword by Don Blake, Boeing & Spirit AeroSystems)

The Foundation of Sustained, Market-Dominating Excellence

World-class clients and industry-leading senior managers of front-end-loading (FEL), engineering, procurement and construction (EPC) periodically assess remaining project vulnerability (to cost, schedule and productivity over-runs). During such assessment, there is value to be gained by improving current work processes and procedures through *management by lean work process standards*. Sometimes called *norms*, their development and use provides a promising opportunity to take FEL & EPC project performance and reliability to the next level.

Consider – Creating a Foundation of Sustained, Market-Dominating Excellence

- *Work process standards* are the resolution of engineering and management expectations regarding the specifics of what will be done, how, by whom and in what sequence in order to achieve desired measurable results during actual circumstances faced by employees.

- *Lean work process standards* are derived with performance measures established to provide *just* what is needed for those doing the job to consistently enable best practice.
- *Lean management by standards* requires both policy deployment (calling commitment to the standards by those responsible to execute them) and actual progress of the *workface* to be visible to management. If any standard does not cause the right things to happen, consistently and reliably, it is not considered lean; the standard itself and/or the standard's deployment policy and/or *workface* progress *visibility*, must be improved until it does.
- It is now evident that nearly everything done in engineering, construction or business can and should be performed according to the best work process standards or their equivalent by some other name (e.g., norms). Standards should be defined jointly by those who are responsible to manage and those who perform inside the company or within their supply and subcontracting chain.

Short of doing all the work themselves, standards are, in fact, the best current way that engineering discipline leads or management at each level can effectively assure their ideals, principles and expectations are understood and implemented by those they manage. Lean standards at the work process level constitute the foundation level extension of corporate governance into the *workface*.

The *workface* is where information or material can be added or manipulated to add value. During design, it is where information is assimilated, calculations or decisions made, drawings rendered, program code or specifications written. During manufacturing or construction, it is where material is added, cut away, altered or assembled to add value. Workface should not be consumed by most contributory work, idleness or rework (in engineering, fabrication or construction), which are all considered waste and to be reduced or eliminated by further application of lean principles (see principle and tool sections below).

An *available workface* is where design, manufacturing or construction work can be productively performed without such work rendering any other work less than fully productive. The establishment of *lean work process standards*, policy of use and systems that provide *transparency* to achieve aligned progress of value added work at *every available workface*, profoundly benefits cost and performance reliability.

The Benefits – Reliable Best Practice Performance: Traditional project planning and management systems harness considerable control of risks and associated chaos that would otherwise exist. If they did not we would not get things done as well as we do. By establishing management by lean work process standards, aligned with a sequence and system transparent for balanced progress of *every available workface*, management eliminates substantial remaining chaos among able and diligent troops who are trying to figure out how to most effectively serve. The content of standards, their sequence and transparency become the basis upon which improvements can be derived and evaluated. Lessons learned for safety, quality, productivity, constructability, maintainability, environmental improvements, etc., are institutionalized quickly by building them into the standards. Management and engineering skill and stakeholders build their experience, e.g., what they know about how to avoid problems, into the standards and expect them to be executed and improved. Employees are more effective and confident when they are operating within established standards and being evaluated accordingly. Employee trust and morale are improved. Continuous improvement is enabled by management's expectation that employees will anticipate problems before they happen and improve the standards they use while executing them.

If, notwithstanding the employees' best efforts, circumstances prevent performance at the standards, then employees are generally expected to halt execution and seek immediate reevaluation of the standard and its content, sequence or transparency improvement by applicable skill and stakeholders. The benefits of employee empowerment to do so are similar to those experienced by authorization to halt work that an employee considers unsafe. Employees know halting the workflow is extremely expensive, and ownership of standards they use coupled with management trust and dependent peers' visible expectations, will motivate them to anticipate problems and eliminate them before they happen. All the universal performance measures and their reliability are profoundly improved: 1) Safety, 2) Quality, 3) Productivity, 4) Cost, 5) Schedule, 6) Environmental Protection and 6) Employee Morale.

Current Opportunity, Senior Resource Leveraging: In an industry strained for expertise and experience, standards can close the performance gap quickly between ambitious young engineers or managers and their highly experienced senior peers. The standards enable reasonably trained and experienced employees to quickly come up to performance

at best practice. Managers who have built what they know and expect into standards for about 90% of what their subordinates do, can use transparent systems to more effectively manage 20 to 25 people than they can 5 to 7 subordinates with conventional oversight. Overhead is correspondingly reduced.[2] Corporate knowledge and experience is captured in the standards and made available when and where it is needed — not lost by transfers, attrition or loss of people to a competitor.

It is the most-senior management's fiduciary responsibility to their clients, shareholders and employees to recognize any project vulnerability resulting from current policies and procedures. They must engage a lean subject matter expert to quantify the benefits of establishing lean standards at the work-process level, together with visible workface optimization planning. With this evidence, senior managers resource the work process standard development function at the workface then set the example by deriving lean work process standards in support of the workface with their middle managers at every level. Each must assure agendas are not stacked too full so that there is time available (about 5%) for reflection on how to eliminate the source of problems and build what it will take to prevent problems into the standards.

Consider what is wrong with the response of a well-compensated Oil & Gas Company Project Manager to a well-evidenced lean introduction. *If we hire a lean consultant, he is going to expect us to do the right things, not just look good, and that is going to be a whole lot of work. As long as projects continue to go more or less as they have before, we're just fine. If not, we are victims of circumstance and not responsible.* While few will argue against experience being the best teacher, it is usually the most expensive. Knowledgeable stockholders cringe and clients' satisfaction wanes when employees learn by experiencing critical (and avoidable) incidents at client or stockholder expense. Managers can and should reliably know before it is too late. Cultures can and should support employee use of fully aligned skill and stakeholder expertise and experience. Lean methods, such as *management by lean work process standards*, are operational on FEL (design basis, preFEED, FEED) and EPC (Detailed Engineering, Procurement, Construction, Commissioning and Startup) projects and in their supporting organizations. Both motivation and increased team enthusiasm for differentiating performance are created by managers with a healthy recognition of current project vulnerability who choose to benchmark current status and measure the opportunity specific to lean tools (see Primer Figures 17–19). To do so now, racing the industry to generally adopt the tools and supporting culture, *is a promising* current FEL & EPC opportunity to leverage senior resources for sustainable performance excellence.

> Consider what is wrong with the response of well-paid executives of a major Oil & Gas EPC service provider to a well-evidenced lean introduction. *If lean is so important, clients would be willing to pay for it. If we begin to experience loss of work that a client acknowledges is a result of our not using lean, then we will just do it.*

With the advantage of the primary author's training from Boeing and Shingijutsu and an extensive technical review team (see Acknowledgements), we have deftly described the transformation to *lean*, not just at the introductory levels but transformation of the entire business model and all the supporting processes to solidify, sustain and perpetuate.

- More effective metrics and timely tools for measuring performance and long-term impacts of using Lean Production techniques are presented. The metrics provide universally needed management information for transparent control of project performance, safety, quality, productivity, cost, delivery-schedule, environmental responsibility and employee morale.
- The tricky part is to change the mindset of just accepting tradeoffs, e.g., improving schedule at the expense of cost or vice versa. Lean principles, tools and methods improve most, if not all, simultaneously, i.e., in harmony.
- The obvious and superficial Lean Production mechanisms such as Standard Work, Work Place Organization, Kitting, and Consumption Based Replenishment are put in proper perspective with the goals of achieving Flow and application of countermeasures.
- Mastering rapid improvement techniques as a first step is later linked to overall system improvement via Value Chain diagnostics and redesign.
- We give you a heavy dose of Supply Chain Management. Even if your processes are fine tuned and operating well, your supply chain will still be subject to the natural chaos that occurs in logistics and human nature.
- While to achieve quick wins it is not necessary to implement sweeping changes all at once, to create and sustain market-dominating excellence short and long term we suggest not rushing through this book and selecting only the pieces you prefer or think you can afford. Eventually, every system, sub-system, and process in the business has to be examined in order to achieve "system harmony."

- Further, nearly every performance issue affects the trust that project people experience. The level of trust and unity impacts the speed of just about everything, including the feasibility for rapid, sustained organizational improvement. We provide supporting principles and intervention tools to assess and improve trust, unity and culture to solidify, sustain and perpetuate.

Before we describe some additional tools for getting started, consider a few examples of the benefits and the implementation structure for skillfully achieving them.

Examples of Introductory Lean Application to Construction

One universal principle is the need for increased direct executive involvement to profoundly improve well-established and functioning work processes. That is not new or unique to lean. It is also a SixSigma principle and taught by leadership consultants the world over. So, this book provides EPC's executives with what to measure, appreciate and encourage to normalize excellence and perpetuate improvement.

About three decades ago, people at DuPont created a breakthrough in safety performance improvement by successfully working the way up their chain of command to committing their executives to taking personal responsibility for safety in addition to operations.[3] The cascade of ingenuity and commitment of so many people and resulting safety improvement was not foreseen at the time. In hindsight, conventional wisdom of the time was reversed; when all the costs were finally considered, a safe process was found to be a less expensive process. The quality movement reversed conventional wisdom again. Ultra-high-quality work processes with far fewer defects were not only possible, but highly profitable. More recently, it has been shown numerous times that less polluting, more environmentally responsible processes can also be more profitable, (albeit often because considerations include a longer term, market and/or societal trust perspective).

The lean discipline has demonstrated conclusively that it is well worth the journey to help executives together with every employee take personal responsibility to learn and apply principles of rapid improvement. Lean operational fitness principles help teams assure consideration of all related issues for a balanced, unified *performance partnership*, we call *project fitness*. Teams seek to simultaneously improve reliability, safety, quality, productivity, cost and schedule with environmental responsibility and employee morale. Thereby, they create new standards of excellence that can be implemented quickly and more reliably.

Again, all sorts of improvements in safety, environmental protection, engineering design, construction efficiency and reliability have occurred over the past 30 years. At the same time, many energy and chemical projects have become larger and more complex. Industry consolidation by acquisition has occurred, but not necessarily normalization of best work processes between the acquired entities. For companies providing project services, the various departments, subcontractors and supplies have not always pursued their improvements in ways that best integrate the efforts across divisions and disciplines, let alone the rest of the stakeholders involved (suppliers, subcontractors, etc.).

Increased requirement for local supply, subcontracting and labor content in emerging nations such as Nigeria, has often doubled project costs. On one major project, government quotas for hiring of Nigerian nationals, created expectations among the locals that they would be hired and retain their job regardless of their productivity. Believing they would not have another job upon the project's end, many locals were deliberately slowing the job and even damaging finished work in order to extend their job duration. Team application of lean principles of mutual benefit for increased efficiency can change this environment such that productivity improves profoundly to mitigate these enormous cost increases. For example, under consulting by the primary author on a mega project in the Niger Delta, the project management team gained credibility and eliminated the above-noted incidents by training the locals before and on the job and coaching them to achieve productivity levels. This enabled them to compete on the national or world market. Risk mitigation needs to extend to root cause analysis (e.g., including the human factors, trust in mutual benefit) to reduce or eliminate risk on the current and future projects.

Leadership of integration and alignment of work process with the best talent a company can bring to a project, constitutes a current opportunity for breakthrough performance improvement using lean. Like all acts of real leadership, it takes courage to investigate root causes of project vulnerability beyond the experience of one's industry to resolve. It takes real executive leadership to change the focus, from solving problems after they happen; to better correlate across the broad EPC technical and business divisions, how a company performs to assure reliable best practice. Commitment-based safety must become partnered with quality, productivity and environmental responsibility to bring comprehensive project operational fitness.

In 1988, the primary author was a Vice President and General Partner of Paulsen Construction Company, a regional contracting firm headquartered out of Salt Lake City, Utah. I managed a project we publically bid, to site-cast eight conventional munitions storage igloos for the US Air Force. Client delays in project award forced us into winter construction. The project was lump sum and stipulated stiff liquidated damages for late completion. So, instead of site casting, we rented an idle steel fabrication building with a couple of overhead cranes and designed a heated casting bed to force-cure the concrete. We applied principles of visual control, flow, sense of required task time, design-for-assembly and ergonomics to the plant operations management. See summary in Figure 1: Example of Lean Principles Application to Precast.

- All tasks were engineered to assure material, labor, equipment and information availability specific to performance. Structural redesign optimized casting, picking, shipping and erection with final in-place engineering performance criteria. Cycle-time reduction methods were applied to rebar placement, forming and stripping systems. A first run casting was performed to assure tolerances and fit-up. The concrete mix was designed to achieve 2,500 psi in 16 hours. All tasks were planned for execution around a recurring eight-hour shift followed by 16 hours of cure. Thus, stripping, forming, rebar placement and casting and forced-curing processes were repeated with a sense of urgency for completion in every 24-hour period.
- Setup through the first run took 45 days of the eight-month contract. The balance of the contract was completed in two months, 4.5 months ahead of schedule. Field and office overhead were reduced by 50%. Rebar costs were reduced from 18 cents / lb. labor in our bid for site casting to 3.5 cents/ lb. Forming labor costs were similarly reduced. Our estimated 10% job profit ballooned to over 40%.
- Our Air Force client was so pleased with our schedule and quality performance that they effectively sole-sourced us on the next phase of the project. All of this got our attention and I began an investigation that led to a Ph.D. and eventually consulting with lean principles and practices to improve many project engineering and business systems by similar margins.

Situation-at-a-glance

- Hard dollar open bid to *site cast*
- Precast – to avoid winter construction resulting from late contract award
- Designed, Built & Managed 200 ton/day Precast plant

Challenge

- Establish
  - Visual control
  - Flow
  - Sense of required task time
  - Design for assembly
  - Ergonomics

Results

- Rebar bar installation labor
  - From $0.18 to $0.035/ lb
- Similar drop in forming cost
- 40% net job profit
- 38% schedule reduction
- Sole sourced on next phase

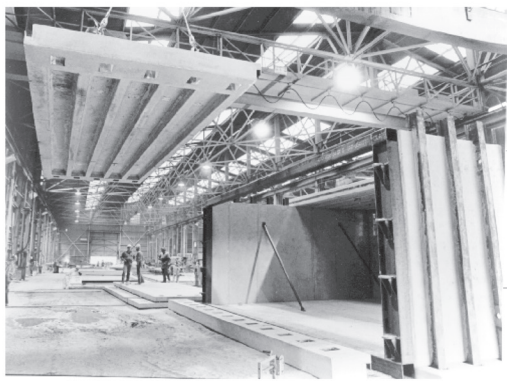

Figure 1: Example of Lean Principles Application to Precast Plant

Emerging from past and current management decisions is a company's culture and invention machine, generating their flow of cost-reducing devices, improved materials and more effective work processes during their project phases. The potential from supplier engagement was illustrated by facilitating a team of structural bolting experts, suppliers and manufacturing stakeholders to apply lean principles to tension critical bolts and their bolt installation work process:

Application of Lean to Tension Critical Bolts and Bolting

At the time, LeJeune® bolts, with twist-off ends or direct tension-indicating washers (DTIs), were the available advancements over turn-of-the-nut or torque systems for installation of tension critical bolts. (See Figure 2.)

Situation at a Glance

- **LeJeune® Bolt** – Metallurgy limited twist-off end bolts to 1.125-inch diameter or smaller. Further, the twist-off function was dependent on friction for its indication of proper tightening. Dirt or rust could cause premature twist off. Further, as a means of quality control, a carriage head was used for the bolt, which had the downside of making installed bolts difficult to remove and infeasible to reuse. However, the advantages were ergonomic installation with a non-impacting electric wrench, by a single operator.
- **Direct Tension-Indicating Washer** (DTI) – Installation of tension critical bolt with a DTI often required the operator to stop to check the compression of the washer. Inspectors also had to use the feeler gage to check compression. It was more accurate over a broader range of bolt size and surface conditions due to its lack of dependence on friction to indicate actual tension. However, it was not as ergonomic, usually requiring two operators and impact tools.

Challenge

The team challenge was to combine the best features of both systems, to create a new application of existing technologies with full cooperation of skill and stakeholders.

- **Assure better safety** – The twist-off ends were sometimes dropped by installers, causing the bolt ends to fall down through the structure. Moreover, shorter installation time will naturally reduce steel erector exposure to elevated work.
- **The final installation process must produce robust quality** – This would include elimination of the tension/friction interdependence, because rust and dirt make it too variable.
- **Reduce the installation cost by 40%** – For example, enabling a single installer to tighten until tight without ever stopping. Enable ergonomic use of non-impacting wrench. Make inspection quick and visual.
- **Increase flexibility and scope of application** – Try to eliminate the size limits. Larger bolt diameters often reduce the number of bolts required. The installation cost of small and large bolts are almost the same, so using larger and fewer bolts can often reduce cost. Also, make an installed bolt easily removed and reinstalled if needed.

Results

- **Implementation** – The team invented a new DTI that squirts beyond the installing socket upon the advent of proper tensioning of the bolt. This constitutes just-in-time delivery of what the fellow on the end of the wrench needs to know. Further, the manufacturer altered the metallurgy in the twist-off end, so that it no longer twists off.
- **Benefit –** Installer tightens to proper tension without stopping — faster
- **Benefit –** Inspection is visual or with feeler gage — faster and of highest quality
- **Benefit –** Non-impacting wrench is used from one side, single operator — less labor, less effort
- **Benefit –** No size limits, reduces number of bolts — less time, material
- **Benefit –** Friction, rust- and dirt-independent tension is indicated — the highest quality available using current technology
- **Benefit –** Bolt is easily removed and reinstalled if needed, albeit with a new squirting DTI — flexible for changes without damaging surfaces, e.g., no torch removal of bolts
- **Benefit** – Safety is improved with no twist-off ends and less installation time and hence elevated exposure to falls.
- **Benefit** – Manufacturer/supplier estimated several hundred million dollars in sales increase — salesmen reported customers coming right across the desk at them, so excited were they about the improvement to bolts and erection

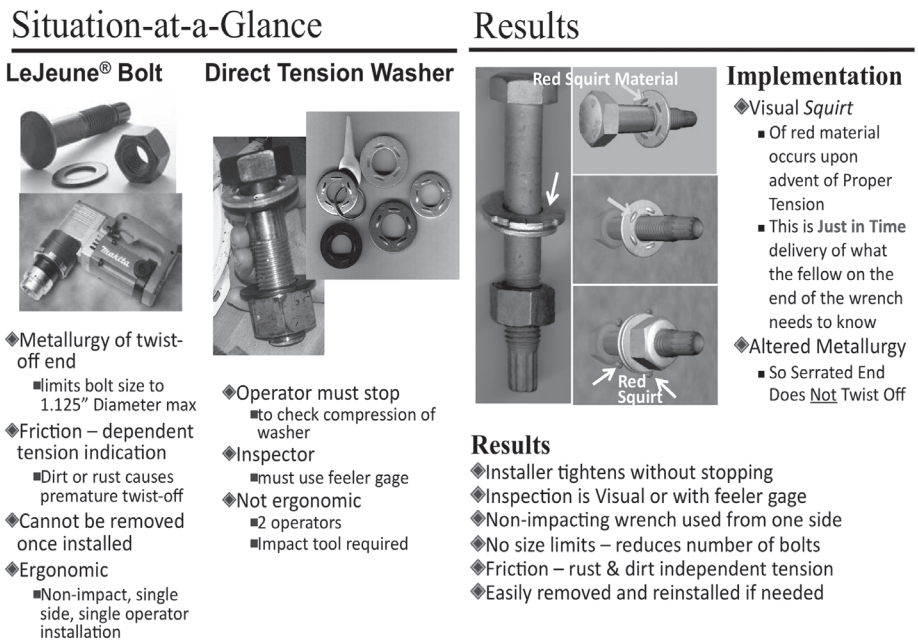

Figure 2 Example of Lean Application to Tension Critical Bolting

We hope in this and the following examples that the reader will focus on the discipline for improvement, keeping in mind that benefits are more frequently shared than under traditional procurement. Under lean project delivery, the client also benefits profoundly from invention and the many other types of improvement. How teams apply the discipline to make more benefits happen — to share mutually in their environment — is discussed in *Chapter 5 Lean Supply Chain Development – Relational Competitive Partnering*. The next example is for Tower and Vertical Vessel Erection. We are not trying to prove the following is the best way to erect towers or vessels; only to illustrate how several years ago one team applied lean principles and achieved significant results in one improvement cycle of its work process.

Application of Lean to Tower and Vertical Vessel Erection

Situation at a Glance

The EPC teams were using matching steel templates in the vessel fabrication shop and for bolt setting on foundations. Bolt cans were also used to provide bolt adjustment after the pour. However, a large crew and crane would still often spend hours to align, guide the vessel and adjust bolts to fit into the base plate simultaneously. Further, during the many cycles of placing the vessel on and off the bolts to make the adjustments, sometimes the vessel would rotate on the base of perhaps 25 bolts. If rotation was discovered after the bolts were through the base plate, re-lifting the vessel would often strip some bolt threads, requiring rethreading and sometimes welding to rework them.

Challenge

Management's challenge to the team was to define a work process that would reduce installation time and cost by at least 30% while making it mistake-proof for achieving alignment quality and safety. The process should flow without stopping, making vertical vessels and columns easy to align and guide onto their foundations.

Results

The team decided to oversize two anchor bolts, one each on opposite sides of the pattern. One would be larger than any other, extend 2 inches above the rest and be tapered on top. The second, on the opposite side would be smaller than the first, but still much larger than the rest, and extend 1 inch above the balance of the bolt pattern. Both of these bolts would be fabricated to be tight in visually unique holes. Surveying would focus on accurate location of these two bolts. All other bolt holes would be significantly oversized and the nuts supplied with large washers.

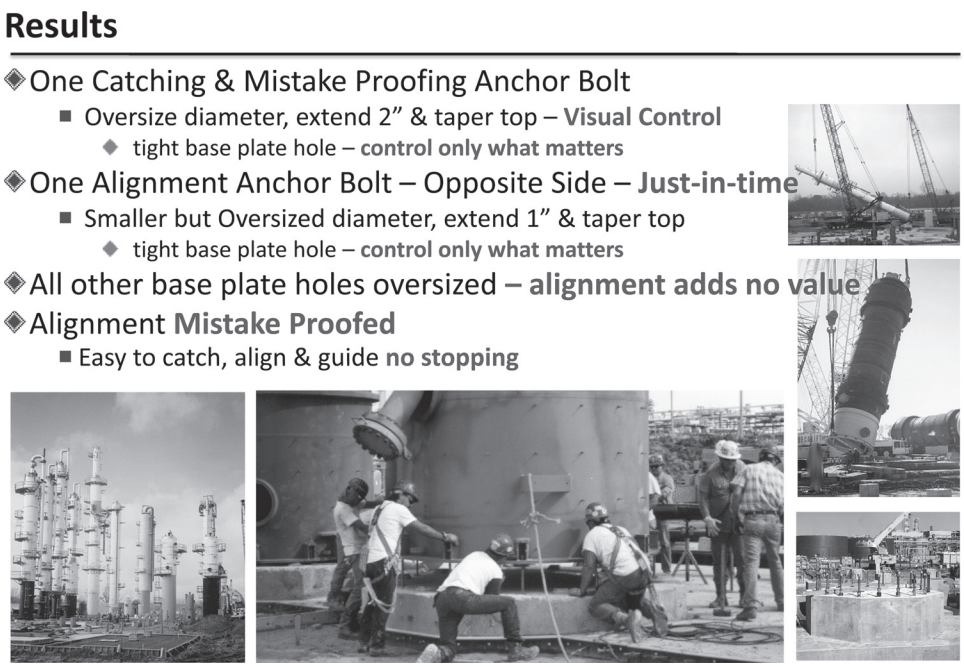

Figure 3 Application of Lean to Tower and Vessel Erection

Installation Work Process

The crew would lift the vessel and lower it onto the largest and highest extended bolt, in the only hole which fits. They would rotate the vessel around to the other extended bolt, the only place it fits. Then they would lower the vessel onto the balance of the bolts, passing quickly and easily through oversized holes. Lean principles include visual delivery to the erection crew just what they need to know when they need to know it. They tightly control just what matters — i.e., two control bolts to control the whole pattern. Mistake proofing and no stopping are also illustrated.

For work tasks to flow, teams will need to decide how to make the flow visible, as it happens, to those who need to know, at any dependent skill or stakeholder in the value chain. Teams will align people and management systems, and make performance transparent to assure everyone gets just what they need when they need it, with no unplanned waiting, multitasking or back loops. Again, they should decide to commit each task lead to duration according to the standard, and to keep their manager apprised about any task duration variance as or before it happens. Task leads could be expected to anticipate problems before they happen and, together with management, resolve them in time or shift resources to avoid being late.

More prominent will be that mega-project success and supporting-program (e.g., overhead) effectiveness is largely composed of reliable individual work-task performance at best practice and effective resourcing and work-process flow between task leads. Increasing the reliability of systems to do so is another subject of this discipline handbook. Consider one team's application of lean to its project planning:

Application of Lean to Large Project Task-Level Planning

The project was a $500 million tar sands pretreatment project in Northern Alberta, Canada. The site team reached a maximum of about 3,000 people.

Implementation

The lean implementation was focused around last-planner-to-create and use best practice work packages. Buffers of work packages were prepared ahead of execution. The preparation emphasized quick setup and assurance of the availability of all materials, equipment and information to complete tasks without stopping.

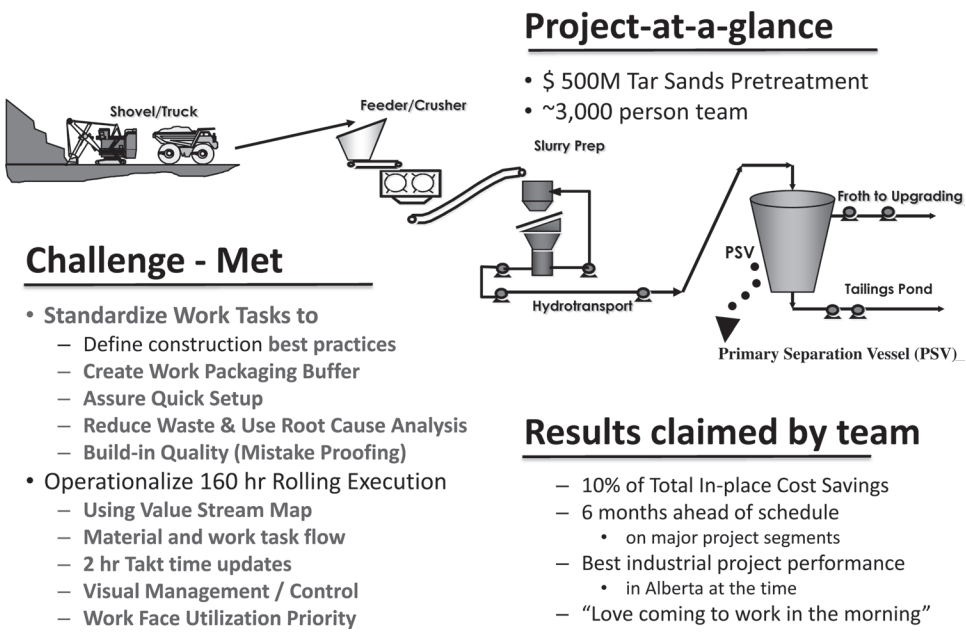

Figure 4 Application of Lean to Project Execution Planning

Teams also applied mistake proofing and root-cause analysis of problems and rapid feedback to eliminate recurring problems on future tasks. The team created a four-week rolling value stream map, visually sequencing prepared-to-proceed work tasks to achieve material and work task flow. This task-level sequencing was owned by the foremen and updated to maintain two-hour accuracy with visual management and control to maximize work face utilization.

Results Claimed by the Team

The team claimed a total in-place cost savings of 10% as a result of the lean initiative and were six months ahead of schedule on major project segments. This was reported to be the best industrial project performance in Alberta at the time. Area managers reported that they loved coming to work in the morning because they *"built what they knew into a plan that actually got executed."* This was a very unusual experience in their careers.

Testimonials

Michael A. Denton – Chevron, 20+ year Oil & Gas Industry Veteran, Project Risk Reduction Manager, former Asset Manager and Senior Value Improving Practice Consultant, worldwide: "I served on the $5 billion Mad Dog deepwater project which achieved world-class results using the Lean Project Delivery process. My opinion is the lean discipline contains the best set of practical principles and practices to improve world-class KBR projects that I have ever seen. Lean is what Chevron is asking KBR to do, with us, beginning now, to achieve more consistent, reliably superior project performance for us and corresponding financial reward for you, your suppliers and subs."

Don A. Blake, former Lean Production Implementation Manager and Director of Boeing Company's Wichita Division (1995-2005), current Director of Spirit AeroSystems, Inc. – 20-year lean veteran, provided technical review and requested to write the foreword for this book: "Bob and Mike have developed a [lean] framework for heavy construction. They have taken great care and time to bring you data and evidence of the power of using the methods, techniques and tools of lean production. They have appropriately identified key foundational elements and enablers. Don't be surprised about how much they emphasize the importance of top management commitment and leadership…"

Randy Walker, KBR Vice President, N. America Construction: "Lean manufacturing concepts…principles and practices…very effective in supporting our internal and external initiatives regarding transforming

our approach from a traditional 'constructability' program to lean construction…very effective working with our customers and site construction teams to implement lean principles…surveys and workshops to increase the efficiency of our operations."

John G. Palmer, Strategic Initiative Consultant, Office of the Vice President, Saudi Aramco: "As you know, Saudi Aramco has been researching Work Process Improvements for the last several years. We have managed to adopt several lean principles and we recognize the potential for vast improvements in the way we execute capital projects. In an effort to further our understanding of Lean Project Delivery, we would like to know if KBR would be interested in collaborating with us to this end…We would like to invite KBR to join us in this effort."

Tom Terris, PE, Senior Project Engineer and former General Supervisor, Project Performance Optimization Division, Saudi Aramco: "Your presentation added great impetus to our research into Lean Project Delivery methodology — so much so, a decision has been made to identify a pilot project that would be slated for implementation of lean principles."

In various capacities, the authors have assessed the value of lean systems to major engineering, procurement and construction (EPC) project operations, facilitated department and discipline leads' recognition of potential improvements. We held dozens of workshops with senior people to infuse the necessary knowledge and raise the expectation of project performance improvement. We aligned project and department-level EPC middle managers for early recommendations to their corporate level executive leadership team. Representative and used by client permission, but without names (due to the sensitivity of the topic) are the following:

"To achieve the full value of the Lean Work Process, this process needs to be implemented early in the preFEED stage of a project; but the Lean Work Process, principles and practices can be implemented at any stage of the project and improved results will be achieved."

—Seasoned Mega Project Construction Manager

"Having complete skill and stakeholder sets early in the project assures successful project execution. Team members will develop plan for the tasks that they are responsible for, take ownership of the tasks, and commit to complete them in an efficient manner. This Lean Work Process principle was applied on an ethylene project, resulting in a 15% reduction in overall project schedule."

—Sr. Project Manager, EPC

"Strive for continuous improvement using 'Lean' principles as a guide… vision of potential…realization that the current productivity and performance goals that have been used for years can be improved upon, provide emphasis to the activities that rely on each other and create enthusiasm in the path forward because everyone likes to feel they are contributing."

—EPC Contracts Manager

"Many of the concepts of the Lean Work Processes, when implemented, will provide a positive and dramatic step change for the planning and execution of […] projects. The processes do require a strict disciplined approach; therefore, a casual support by management will surely lead to implementation failure. A complete embracing of the processes by all management levels is a prerequisite for successful implementation."

—EPC Planning and Scheduling Department Managers

"By incorporating lean principles into our existing management system, […our company] will recognize increased efficiencies and cost savings. These radical changes must be incorporated into our systems immediately…Our projects will operate more smoothly and best of all, we will eliminate waste and barriers that prevent us from delivering timely information that people need to do their jobs. The quality of our service will increase thus making […our company] the contractor of choice and the envy of our competitors."

—EPC Director – Quality

"The lean execution concept has enormous potential to improve […our company's] project execution and provide a significant differentiation from our competitors. Successful implementation will require significant changes in the activities of individuals and organizations. This will require a visible commitment from the ELT, and a process champion to ensure participation by all functional departments."

—EPC Director, Commissioning & Startup Services

> "[The] need to reduce costs…is obvious from recent design FEED and EPC competitions…application of these lean principles would result in […our company] becoming a lean mean organization and will result in a quantum jump ahead of the existing E&C competition."
>
> **—EPC Sr. LNG (liquefied natural gas) Process Consultant**

■ Tools for Getting Started

Enumerated in the handbook and in CII[4] publications, are many effective tools with specific descriptions on how they have and can be applied in EPC. A few of the most important tools for getting started are briefly described in the paragraphs that follow, including:

- Set Design
- Concurrent Engineering
- Critical Chains & Strategic Buffers
- Value Work Packaging & Stream Mapping
- FEL Workface Push Flow Programming
- Making & Keeping Commitments
- EPC Workface Pull Flow Control
- Relational Competitive Partnering
- Visual Control

Note that nearly all engineering and construction value-stream items can be improved by these key tools. See figures 17, 18, 19 and 22.

Set Design

Consider – Design Ranges and Organization by Functional Process Unit

❍ Lean Design Basis or PreFEED teams extract client criteria *in ranges* (called *design sets*) avoiding point solutions (i.e., single value design criteria) where feasible. Interface parameters between process units and between major components are also defined in ranges. The engineering organization itself and design information are modularized to match major process unit modules and process streams. Project teams deploy the range-sets during *concurrent engineering* to make interfaces more flexible between all process plant stream, process unit, and major components. This reduces design time, iteration and increases reusability of design, manufacturing setup and construction planning.

Concurrent Engineering

Consider – Complete Skill & Stakeholder Derivation of Criteria, Standards & Plans

❍ Teams strive to use all applicable skill and stakeholders concurrently to extract client criteria and to benchmark and balance plant engineering design sets in order to provide the client a world-class competitive edge. The concurrent effort continues to assure plant design set criteria are further broken down into fully aligned stream, process unit and major component criteria sets. Further, the full-(skill and stakeholder) teams should concurrently

value engineer work tasks to include the design sets and assure work process standards include world-class process and deliverables, and that they are used to define each work package before it is delivered to an engineering lead for execution. Once packaged, the concurrent team sequences the packages to create a plan for balanced workface progress.

Critical Chains & Strategic Buffers

Consider – Scheduling by Workface Availability with Contingency in Buffers

- This tool simplifies and improves the utility of critical path scheduling. Lean teams do not create schedule network relationships to balance flexible resources. This avoids substantial, unnecessary complexity. Lean schedules are called critical chains and only include *relationships* necessary for the flow of information and material, so that every available work face is fully utilized. This cuts substantial schedule duration. Resources are planned for the critical chain and then reasonably balanced as a secondary function by altering task durations or start times.
- Further, teams remove contingency buried in tasks. Contingency has been added to deal with the traditional experience of not receiving information or material when it is needed. Planners ask responsible task leads how long the task would actually take if everything they needed to complete the task is available to them right at the start, so they would not have to stop or wait for anything. The answer is the shortest responsible duration using current technology and cycle times. Any additional duration is buried contingency and must be extracted and dealt with separately.
- Lean planners sum the extracted contingency along each network chain and discard 50% of it (another major schedule reduction because it is no longer needed). Planners then strategically place the balance of summed contingency (formerly buried in individual tasks) as managed, duration-only tasks called strategic buffers. They are placed where non-critical chains frame into the critical chain and in front of truly constrained resources or client critical dates and at the end of the critical chain (i.e., the project). The amount of time left in each strategic buffer is made visible to the team to serve as gages on project health and enable more effective progress management. The process immunizes against many project risks.

Value Work Packaging & Basic Stream Mapping

Again, teams use applicable skill and stakeholders to define standards for best practice in packages for each engineering, procurement, manufacturing and construction work process.

Consider – Work Tasks & Sequences from Standards & Confirmed by Task Leads

- Lean teams assure work task packages, derived from the standards are, in fact, *just sufficient* information, detail, material and equipment to complete each package without stopping. This fact must be confirmed by the responsible task lead before starting. Performance indicators are built-in to measure and assure that best practice happens. Teams select applicable standards, derive work-task packages to achieve them and establish the sequence, commitment and visual controls to assure task streaming. Streaming is defined as value (e.g., information or material) flowing with no stops, as fast as it can be utilized. Management is performed by work packages defined from standards at all levels. Teams further simplify and improve the standards while executing them.