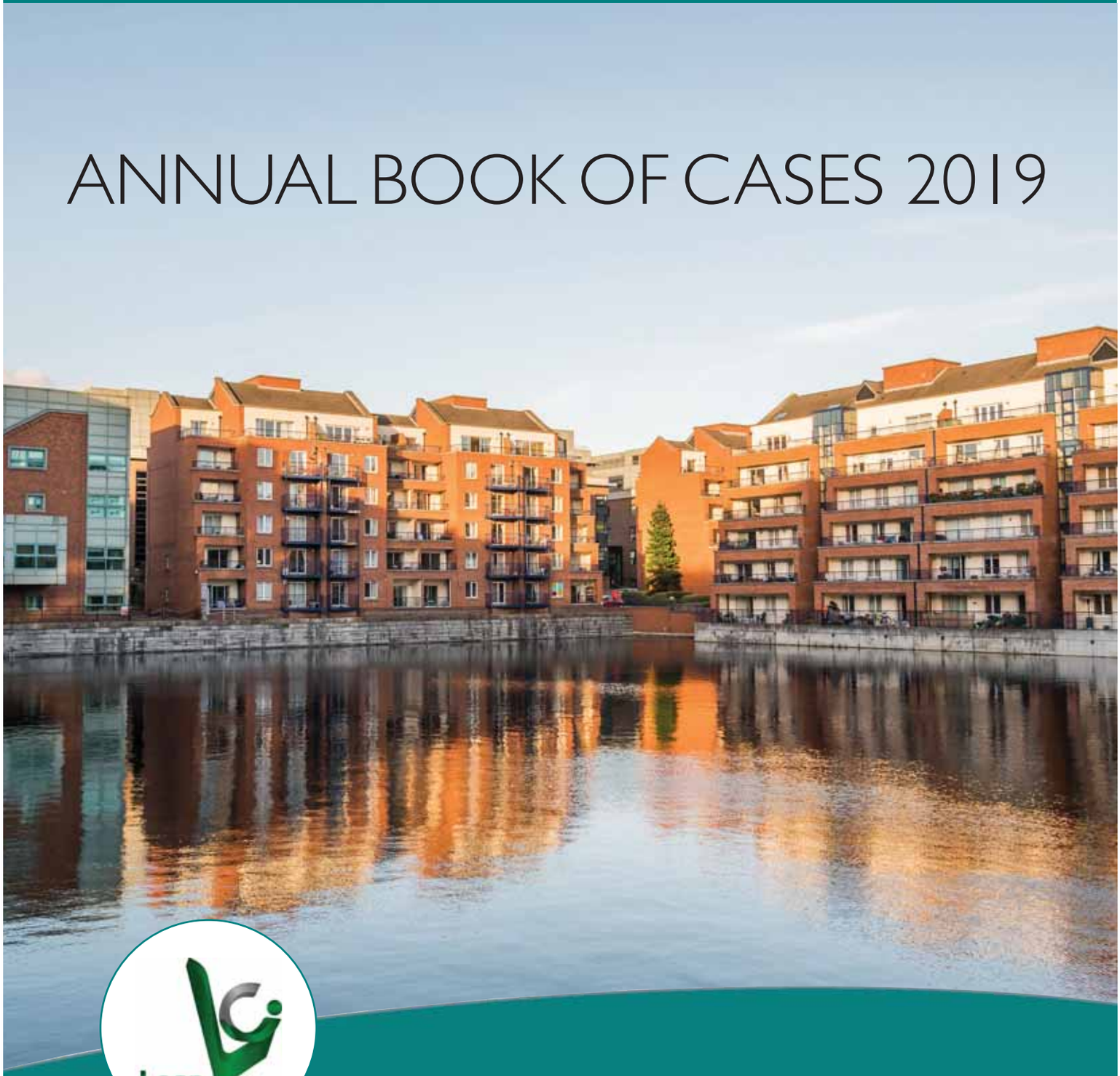
Lean Construction Ireland

ANNUAL BOOK OF CASES 2019



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Sales & Marketing: John McNamee

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Editor

Darrin Taylor, Waterford Institute of Technology

Darrin is a Lecturer in Management at Waterford Institute of Technology (WIT) School of Business. He is Joint Programme Director of the WIT Lean Enterprise and Operational Excellence portfolio of executive/practitioner programmes; a Faculty Member of the WIT RIKON Centre; and Principal Lead of the WIT Academy of Lean Enterprise Excellence.

Prior to entering academia, Darrin worked for over a decade in the private sector as an operations manager as well as in consultancy. He joined WIT in 2004, and lectures Lean and Operational Excellence modules on several executive/practitioner programmes, including: the Master of Business Studies in Lean Enterprise Excellence, the Diploma in Lean Fundamentals (Online), the Diploma in Supervisory Practice, the Executive MBA, and the Master of Science in Construction Project Management. He supervises postgraduate research on Lean management, operational excellence, continuous improvement, and Lean construction. Additionally, Darrin coordinates the Annual WIT Lean Enterprise Excellence Forum and the Annual WIT Lean Practitioner Seminar Series – hugely popular national and regional knowledge-exchange events built on extensive Industry-Academia-State engagement and collaboration.

Darrin continues to work extensively with industry, encompassing public and private organisations across all services and manufacturing sectors. He is a founding member of Lean Business Ireland, he is Co-Chair of the South East Lean Network, and he assisted in the establishment of the other Regional Lean Networks throughout Ireland. Darrin has worked with Lean Construction Ireland (LCi) since 2015 where he acts as Special Advisor to the LCi Board of Directors as well as Lead of the LCi Capability Development pillar. Darrin speaks at Lean and Operational Excellence conferences and events, and researches and publishes in the Lean space, including case books on Lean commissioned by LCi and Enterprise Ireland.

dtaylor@wit.ie

www.wit.ie/lean

www.witleanforum.com

Foreword

by Richard Fitzpatrick,
Chairperson of Lean Construction Ireland

On behalf of the Board of Lean Construction Ireland (LCi), it is my great pleasure to welcome you to the second publication of the *Lean Construction Ireland Annual Book of Cases* which is the key Lean Construction reference publication for the Irish construction sector – from Clients and Owners, to Contractors, Sub-Contractors, Consultants, and Suppliers.

This second *Book of Cases* demonstrates the Irish construction sector is beginning to recognise that embedding Lean thinking and practices into the project delivery process is the most appropriate mechanism by which value-add can be realised for all project stakeholders. The success of the inaugural *Book of Cases* in 2018 reaffirms the LCi's principle that the open exchange of knowledge, information, and experiences around good Lean practices, delivered through our website, our national conference, our webinars, regional network events, and this *Book of Cases,* are critical enablers for the Irish construction sector to understand the value and benefits of Lean.

The Board of LCi is delighted to have Professor Glenn Ballard from the University of California at Berkeley contribute the Book's opening chapter on Target Value Design (TVD). Professor Ballard is co-founder of the Lean Construction Institute (USA), the International Group for Lean Construction (IGLC), and Lean in the Public Sector (LIPS), and is a leading international Lean practitioner who is a co-architect of the Last Planner® System and the Integrated Project Delivery (IPD) model for Lean delivery of capital projects. This chapter on TVD highlights the integral role clients and owners have in the adoption of Lean thinking and practices, and it should be a prompt for Irish clients and owners to think about how they can deliver greater value through their capital programmes.

I would like to take this opportunity to acknowledge all involved in the publication of this second *Book of Cases.* Firstly, I would like to thank those companies that have contributed cases for the Book and for their collaboration and generosity in sharing their Lean journeys with the wider construction sector. Secondly, I would like to thank our publishers, Box Media, as well as those sponsor organisations that have supported the publication of the book. Finally, I would like to thank Darrin Taylor from Waterford Institute of Technology for his invaluable input as Editor and in coordinating and compiling this excellent publication.

I hope this second *Book of Cases* from Lean Construction Ireland continues to inspire you and your companies to adopt Lean thinking and practices and to work collaboratively to deliver projects better, faster, together.

Sincerely,

Richard Fitzpatrick
Chairperson of Lean Construction Ireland

Chapter 1

Target Value Delivery

Target Value Delivery

by Glenn Ballard,
Project Production Systems Laboratory at
University of California Berkeley

Target Value Delivery (TVD) is a process for delivering value to public and private clients/owners, as well as other project stakeholders, within their economic, social and environmental conditions of satisfaction.

TVD was adapted from manufacturing's Lean Product Development. When a manufacturer wants to add a new product to its portfolio, they decide what benefits they expect from the product over its lifetime, then decide what is the most they are willing and able to spend to get those benefits, namely, the allowable cost. This cost/benefit ratio is illustrated in Figure 1.

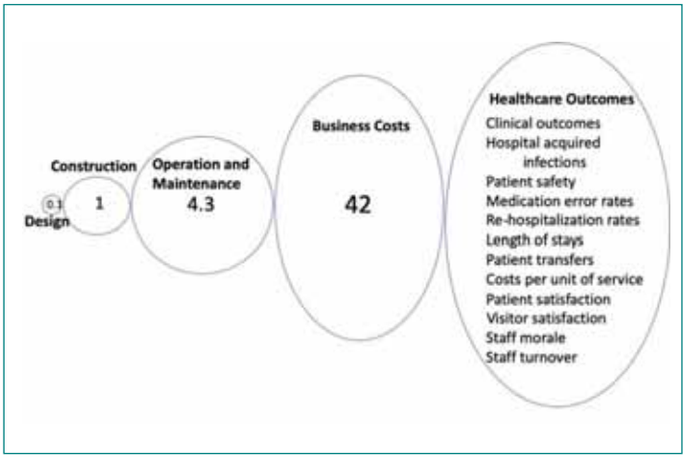

Figure 1. Costs and Benefits

The data for constructing this figure came from a study undertaken for the UK's National Health Service (NHS). "Healthcare outcomes" on the right lists some of the benefits expected from the use of the building to deliver healthcare. Some benefits, such as increased public awareness or projecting a desired image, may not be easily measured in Euros but may nonetheless be valuable to a client/owner. The costs of acquiring those benefits are the sum of capital costs (Design and Construction) and use costs (Operation and Maintenance plus Business) over 20 years. The unit of cost is *Construction* at 1.0; *Capital* costs are 1.1 units; and *Use* costs are 46.3 units. The value of benefits to the clients/owners must be greater than the sum of whole-life costs in order for the project to proceed. In other words, the area of the big circle on the right must be greater than the sum of the four cost circles.

Cost figures in this diagram are intended to represent the relationship between cost elements. By far the biggest costs are those for business use of the hospital (mainly staffing costs) and for operating and maintaining the physical facility. Engaging these users in designing how healthcare will be delivered in the hospital, and how the hospital will be shaped to facilitate both healthcare delivery and operations and maintenance, is strongly advisable. Otherwise, the risk is great that the cost of using the building for its intended purpose will push lifecycle costs beyond the allowable – or worse yet, the cost is controlled but benefits are not delivered.

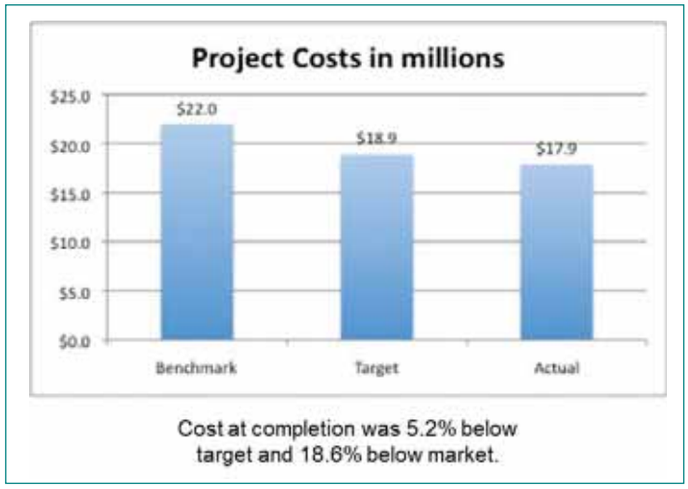

Figure 2. Early TVD Project Example

The Project in Figure 2 – Sutter Health's Fairfield Medical Office Building Project – had an estimated cost of US$22Million based on what Sutter Health and other healthcare companies in California had spent on similar facilities. The target cost for the project was set at US$18.9Million based on a desired return on investment from use of the building through its design life, and the actual cost at completion was US$17.9Million. The cost to design and construct the building was reduced as a result of a combination of factors, chief of which were integrating builders into the design team, providing rapid cost feedback on design alternatives, and shared risk and reward by the key design and construction firms involved in the project. As illustrated in Figure 2, cost at completion was 5.2% below target and 18.6% below market. The success of this early project, completed in 2006, persuaded Sutter Health to use TVD to deliver all of its acute care hospitals.

Key Points

1. Most clients are multi-faceted. They include the business owner, those who use the constructed asset for its intended purpose, and those who maintain and operate the physical facility. These are the primary clients. Additional customers

include the neighbors, regulators, lenders and 'patients', the customers of the client. Meeting the different needs of these clients and customers is a challenge every project faces. Even a developer that produces buildings "on spec", meaning that they haven't sold it beforehand, consider *Use* costs because that impacts sales/lease price.

2. Design to targets for net benefits in use – what is wanted and the allowable cost for what is wanted. Don't design and then cost.

How is TVD different?

Many, if not most, construction projects are launched with too little certainty about the challenges they will face and the resources needed to meet those challenges. Unlike TVD projects, it is common for the estimated cost to increase as the design becomes more detailed. Far from establishing a maximum amount that clients/owners might pay, the sum of bids for construction packages is actually the least a client/owner will pay. Better methods for setting and steering to project targets are needed.

Setting Targets and Deciding what Project to Build

The process for setting targets for what is wanted, and for conditions of satisfaction on the delivery of what is wanted, is outlined in Figure 3. Note that allowable cost is what the client/owner is both willing and able to spend to get what they want (benefits in use). Note also that these two (what is wanted and allowable cost) are two sides of one coin. A change in either should always trigger recalculation of the other. If the expected cost of what is wanted cannot be reduced to fit within the allowable cost, what is wanted must be changed. If what is wanted changes, the allowable cost must be recalculated

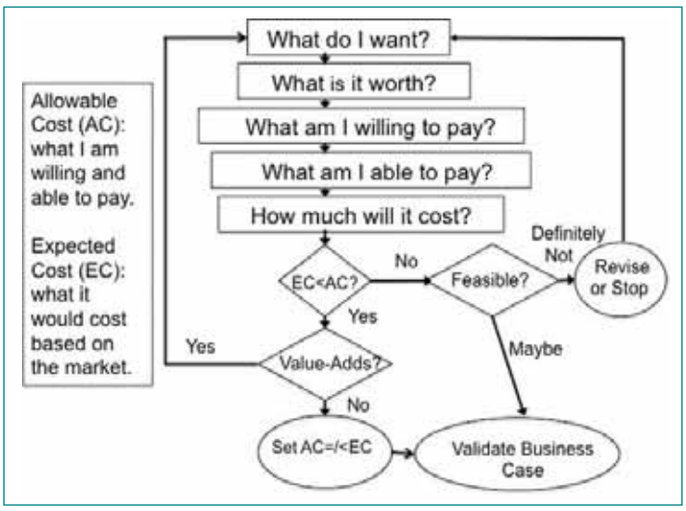

Figure 3. Project Definition Process (adapted from Ballard & Pennanen, 2013)

Both possibilities are illustrated in Figure 3. Once what is wanted and its allowable cost are determined, the next step is to compare allowable cost with expected cost. Common methods for estimating expected cost are unit pricing (cost per square metre, cost per hospital bed) and benchmarking against similar facilities. Unit pricing can be plus or minus 40% from cost at completion. Benchmarking can be closer to cost at completion, but how close depends on both the abilities of the estimator and the quality of data that can be used. A third method for conceptual estimating (estimating cost at completion prior to design, from programmatic data) is to first model the building and then cost it. More common on industrial projects than in building projects, this method, based on engineering logic, is used by Haahtela, a Finnish project and cost management consulting firm based in Helsinki (www.haahtela.fi) in its management of building projects. The average difference between conceptual estimate and cost at completion for Haahtela's most recent 32 projects is -1.0%, with a standard deviation of 5%.

Regardless of the cost estimating method used, decisions about keeping a project moving forward have to be made with limited information and some degree of uncertainty. That is a bit like trying to decide if to "hold'em or fold'em" in bidding games. If the difference between allowable and expected cost is so great that it seems unlikely that the gap can be closed, what is wanted must be revised. If there is reason to hope that the gap can be closed, the next step is to fund a feasibility study.

In the private sector, failure to align business requirements and allowable cost can even result in projects being abandoned. That can also happen in the public sector but can be more challenging because projects are initiated to deliver service value to the public as well as wider social and economic benefits – and may do so even when project scope must be sacrificed.

Feasibility studies can be done by client/owner personnel, by appointed external professionals, or by the key players that will deliver the project if funding is secured. The feasibility study consists of producing a plan for project execution, then testing that plan against potential risks and opportunities. What counts as acceptable risk is always the primary client's decision.

Three factors drive the superior performance of TVD projects:

1. The Lean Construction philosophy and methods.
2. Organisational integration – downstream players participate in upstream processes and vice-versa.
3. Shared risk and reward.

They are listed here in order of importance. The philosophy is absolutely necessary. Organisational integration is highly advisable. The 'one team' attitude can be promoted by shared incentives and by reminders that commercial success of each player is dependent on how others perform, not only their own performance. While collaborative contracts such as Project Alliancing and Integrated Project Delivery (IPD) undoubtedly help, other contractual structures, especially those that allow early contractor involvement, can fit with TVD. Such contractual arrangements can also be put in place for public sector contracts too.

The feasibility study may recommend funding or revising the project. If funded, targets will have been set for both what is wanted (functions to be performed, capacities needed for their performance, facility performance specifications) and conditions of satisfaction (cost, time, social impacts, environmental impacts).

In situations of high uncertainty, a client may choose to fund design to the point when it is apparent either that the gap between allowable and expected cost can be closed, or that the gap cannot be closed.

Another key decision to be made by the clients/owners is what instructions to give regarding the design phase. Is the project team to limit their search to designs that: a) deliver targeted net benefits within a fixed cost; or b) increase net benefits even if that increases cost? For this latter alternative, the clients/owners must be able to carry a contingency for funding such opportunities. For example, injuries to nurses could be reduced by installing patient lifting devices, or revenues from performing particular types of surgery could be increased by enabling such surgeries to be performed in less time, but at an increased cost for support services.

Key Points

- Decisions about moving projects forward are made with uncertain information.
- Different methods of conceptual estimating have different levels of uncertainty.
- Targets for net benefits in use can be either fixed or variable. If fixed, then the allowable cost is also fixed. If the target for net benefits is variable, the allowable cost is fixed relative to the net benefits target.

How to Enforce Targets

Once targets are set, the next step is to steer each phase of the project toward project targets. Doing that works best when it is in the interest of the design and construction firms to meet targets. That can be done through positive or negative incentives, or some combination of the two.

A client/owner may engage a construction manager or design-build firm to deliver a TVD project where those firms bear the cost risk. However, the greater the uncertainty and complexity of the project, the more premium the client/owner will be charged in order to offset that cost risk. If the cost risk is too great to shift completely, the client/owner will have to take on some or all cost risk. The benefit of doing so is two-fold, avoidance of premiums for taking on risk and the increased control clients/owners have over project delivery.

Capital projects at the University of California San Francisco typically employ rewards to all design and construction firms on each project for hitting specific targets, for example, schedule milestones. Their success inspired the Board of Regents that govern the 10 campus University of California system to demand that all campuses follow San Francisco's example.

When BAA undertook the Terminal 5 Project at Heathrow Airport, the project's expected cost was fully 80% of BAA's net worth, and it was entirely possible that the complexity of the project would result in cost increases that would have pushed BAA into bankruptcy. Faced with this situation, BAA decided to take on all cost risk. By doing so, they could avoid paying the premiums that come with risk shifting, and equally or more important, they were able to deliver the project using Lean management methods, including TVD, to increase the probability of getting what they wanted within an acceptable cost. Framework suppliers (design and construction) had positive incentives through shared cost savings. The project was completed successfully. Given the positive achievements attained with the T5 delivery model, BAA is re-embracing the T5 approach on its new high-risk runway project which will provide greater certainty and control of cost through the adoption of Lean management methods.

Sutter Health's recently completed US$1.5Billion hospital in San Francisco was undertaken using a form of IPD in which a target cost for the project was set. Sutter Health bore the risk of paying costs in excess of that target cost. Some design and construction firms were engaged on fixed price contracts, but key designers and builders were reimbursed for their cost of work and had the risk of receiving reduced or zero profit. If project cost exceeded the target, that excess reduced the profit pool. The project was completed successfully for all parties.

Steering Design to Targets

To decide if to fund a project, the only estimate of cost needed is for the capital cost of the project and for the cost to use the constructed asset over its life. However, design decisions are made system by system and component by component. Hence, in order to steer design to cost targets, the cost must be broken down into the systems and components of the asset to be designed. Otherwise, there is no way to know what systems and components should cost, and hence no basis for providing feedback to designers. Table 1 provides an example of the level of detail in cost targets used to steer design and construction.

"Steering" design is done through feedback, both prior to and after the production of design alternatives. Designers can see from the cost model what funds are allocated for different parts of the asset to be constructed, and alternatives can be assessed for their conformance to those allocations. Designers are not told how to design, but are rather provided feedback about those designs meeting targets. Generally speaking, if a solution is not found that meets the allocated cost for a specific function or component, the cost overrun must be made up through cost underruns elsewhere.

Table 1. Target Costs for a Healthcare Project (courtesy of The Boldt Companies)

Healthcare Client
Facility Replacement – Working Program Project Totals
Projected Start: 1st April 2019
Projected Completion: 16th January 2022

BOLDT

			Target Cost (US$)
A		**Substructure**	$ 3,172,817
	A10	Foundations	$ 3,087,317
	A20	Basement	$ 85,500
B		**Shell**	$ 16,183,875
	B10	Superstructure	$ 8,204,601
	B20	Exterior Enclosure	$ 6,029,706
	B30	Roofing	$ 1,949,569
C		**Interiors**	$ 17,366,284
	C10	Interior Construction	$ 11,603,617
	C20	Stairs	$ 650,950
	C30	Finishes	$ 5,111,716
D		**Services**	$ 33,071,923
	D10	Conveying Systems	$ 1,316,744
	D20	Plumbing	$ 5,425,734
	D30	HVAC	$ 13,391,111
	D40	Fire Protection	$ 1,079,576
	D50	Electrical	$ 11,858,758
E		**Equipment & Furnishings**	$ 867,143
	F10	Equipment	$ 672,998
	F20	Furnishings	$ 194,146

Key Points

- Only the primary client can change targets.
- There are a number of ways to structure commercial terms and to allocate risks and rewards that enable enforcing targets.

Steering Construction to Targets

Design provides the recipe, but construction prepares the meal – steering is still much needed until the constructed asset is delivered to the client/owner. Typically, construction is executed through contracts of one sort or another with firms that are capable of performing each type of work. Using a building as an example, these types of work vary with the construction phases: substructure, superstructure, envelope, interior framing, mechanical, electrical, fire protection, etc. Steering is done by comparing allocated costs to prospective costs for each type of work or work package, and acting to reduce any negative differences. Actions can be taken in awarding contracts, in purchasing materials and equipment, and in installation and testing. When needed, overruns on one work package can be offset by underruns on another – depending, of course, on commercial terms.

Key Tools for TVD

TVD can be understood as a big tool that includes smaller tools for performing specific functions. TVD produces better outcomes using methods such as Set-Based Concurrent Engineering, Choosing by Advantages, A3 reports, and the Last Planner System.

Set-Based Concurrent Engineering (SCBE) originated in Lean Product Development. 'Concurrency' refers to the fact that everyone who touches a product over its life is involved in its design. 'Set Based' involves aligning stakeholder requirements before designing, then generating multiple design alternatives for each system and component of the product (Kennedy et al., 2014).

Choosing By Advantages (CBA) was created by Jim Suhr of the U.S. Forest Service as a method for evaluating and selecting from alternatives against multiple must-have criteria (requirements) and nice-to-have criteria (preferences), and was first applied to the domain of construction projects by John Koga of The Boldt Companies. CBA differs from other such methods by not weighting requirements, by first agreeing on how well each alternative meets requirements, and by deferring consideration of cost until the total importance of advantages of each alternative have been agreed (Suhr, 1999).

A3 reports are used to record proposals and agreements about choosing from alternatives so the knowledge is not lost. 'A3' is the metric size of paper to which the report is limited. The standard structure of these reports facilitates a process of reaching consensus among different stakeholders in the decision or action (Shook, 2008).

Last Planner® System (LPS) is a method for coordinating action; for planning and controlling. Once targets are set, planning how to achieve them is needed, then proactive steering to targets in sometimes stormy seas. LPS provides organisational alignment but also promotes flexibility in project teams to develop new pathways to existing targets or even to new targets. Its principles include:

- Plan in greater detail as the start date for planned tasks approaches.
- Produce plans collaboratively with those who are to do the work being planned.
- Reveal and remove constraints on planned tasks as a team.
- Don't start tasks that you should not or cannot complete. Commit to perform only those tasks that are properly defined, sound, sequenced and properly sized.
- Make and secure reliable promises, and speak up immediately should you lose confidence that you can keep your promises (as opposed to waiting as long as possible and hoping someone else speaks up first).
- Learn from breakdowns (unintended consequences of actions taken).
- Underload resources to increase reliability of work release.

Key Points

- Steering design and construction to targets continues by the project team until turnover, then becomes the responsibility of users throughout the life of the product.
- Steering construction requires cost allocations to serve as provisional cost targets for work packages.

Conclusion

It is hoped that Clients/Owners reading this will see the value that TVD provides and look to adopt TVD on their projects. Here are a few things to keep in mind:

- Be aware that TVD (and Lean generally) is not magic. Even if properly executed, TVD and Lean projects can go wrong for reasons outside the project's control. Improper execution includes failing to follow the recommended process and, even more important, leaders' failure to adopt and live the Lean philosophy.
- Be prepared to play new roles. Clients/Owners will be more directly involved in project execution, and must have the needed competencies and capacity. Builders must learn how to add value in design. Designers must learn how to design for net benefits in use over the life of the constructed asset.
- Don't neglect the importance of selecting the right project team members. Some form of best value selection is needed in order to assure that low price doesn't conceal needed attitudes and willingness to learn.
- There is a lot written on TVD (see recommended readings below), and much that can be learned, but organisations should also learn from those who have implemented TVD and Lean before. Reach out to peers (client-to-client, designer-to-designer, builder-to-builder). They will be glad to share their experiences.

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Bio

Glenn Ballard is a Research Associate at the Project Production Systems Laboratory, University of California Berkeley. Glenn entered the construction industry as a pipefitter's helper, transitioned to construction engineering, and in 1980 was named Manager of Productivity Improvement for a construction division of Brown and Root. He subsequently became an internal management consultant with Bechtel Petroleum, working on all aspects of project delivery, and supporting projects in other Bechtel divisions such as the South Texas Nuclear Plant. He began a management consulting business in 1987. In parallel, he began lecturing on productivity and quality improvement at the University of California Berkeley in 1989, and completed the transition from industry to academia in 2005 when he was named Research Director for the University's *Project Production Systems Laboratory.* He co-founded the *International Group for Lean Construction* (IGLC) in 1993, the *Lean Construction Institute* (LCI) in 1997, the *Project Production Systems Laboratory* in 2005, and *Lean in the Public Sector* (LIPS) in 2007. Glenn retired from his position as Research Director in 2019, but continues in a support role as a Research Associate for the Project Production Systems Laboratory. With lots of help from others, Glenn developed the Last Planner® System (LPS) and Target Value Delivery (TVD) – two key Lean Construction methods, both of which he continues to improve. A new *Current Process Benchmark for the Last Planner System* is due to be published by the end of 2019, and Glenn is now leading research groups to develop better methods for use in Target Value Delivery, namely, conceptual estimating (estimating cost at completion prior to design) and using trade-off curves in aligning potentially conflicting stakeholder requirements. These will be incorporated in a future update of the *Current Process Benchmark for Target Value Delivery*. Glenn has a long list of publications (see Google Scholar), many of which are available at the website of the IGLC (www.iglc.net).

Project: Academic Hub and Library, Grangegorman.
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Chapter 2

Case Studies

COMPANY OVERVIEW

COMPANY WEBSITE
www.dpsgroupglobal.com

DPS Group is a global consulting, engineering and construction management company, serving high-tech industries around the world. DPS has sector experts in key locations in Europe, the US, Asia, and the Middle East, bringing world-class resources and the latest innovative technologies to every project. DPS delivers Full Service Engineering with a 'client first' mentality and personal touch across a range of disciplines: Project and Programme Management, Procurement, Design, Construction Management, Health & Safety Management, Commissioning, Qualification, and Start-up. DPS employ more than 1300 people worldwide, including 250 in its DPS Group Cork Operations where this case study is based.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

William Power

Aidan Mullin

DPS Group modestly prides itself as being an early adopter of Lean thinking and practices in both Irish and International construction sectors. The company invests heavily in staff subject matter experts, Lean education and training, and in internal process improvement initiatives. The company attributes, in no small part, increased competitiveness and recent project success to that investment in its capability development. DPS support local and national Lean Construction (LC) conferences and events and bring International LC experts to its offices to share best practices and research with its own staff and clients. DPS also contribute to the LC body of knowledge presenting latest research findings at global, national, and local LC conferences and events.

A common concept in construction is that there are three legs to a project: Schedule, Cost, and Quality. Typically, a client is advised to pick any two at the expense of the third, for example, you can have cost and schedule but not the quality you want; or you may get the quality and schedule that you want but not within your budget. This traditional approach was unacceptable to both the Client and the Engineering, Procurement, Construction Management, & Validation (EPCMV) provider on this case study project – instead, the fast-track nature of the assignment called for proactive management of all three legs of cost, schedule, and budget. The client in this case study is a global pharmaceutical company with several facilities located in Ireland.

Initial thoughts were to use a proactive methodology that would drive cost downward from the start to avoid commencing with an excessive estimate laden with contingency. DPS was familiar with using Last Planner® System (LPS) in design, construction, and commissioning and had also used another Lean Construction approach, namely Target Value Design (TVD), on a previous project. The concept and principles of TVD were presented to the client and it was agreed to use the process on this project.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Target Value Design

According to Glenn Ballard, a pioneer of Lean in Construction, Target Value Design (TVD) is a management practice that drives the design [and construction] to deliver customer values within project constraints, and it is an application of Taiichi Ohno's practice of self-imposing necessity as a means for continuous improvement.

The primary concept of TVD is to drive down the cost – or maintain cost and increase value – of a project through the design and delivery phases without reducing the quality provided or the schedule for completion (see Figure 1). TVD is a proven and effective process to ensure the owner receives all three legs of schedule, cost, and quality.

Figure 1. Driving Force of TVD *(Source: Target Value Delivery: Practitioner Guidebook to Implementation Current State, 2016)*

The Lean Construction Institute (LCI USA) assert that "TVD is a very different model from the traditional, large-batch process of design, estimate cost, and value engineering — a process replete with waste. Clients do not value the process of rework and loss of quality that comes from this traditional "value engineering" process. The driving force of TVD is to increase value while decreasing cost for all team members".

In his 2011 publication *'Target Value Design: Current Benchmark'* Ballard notes that "In the building sector, it has been customary for architects to work with customers to understand what they want, then produce facility designs intended to deliver what's wanted. The cost of those designs has then been estimated, and too often, found to be greater than the customer is willing or able to bear, requiring designs to be revised, then re-costed, and so on. This cycle of design-estimate-rework is wasteful and reduces the value customers get for their money. Cost has been an outcome of design".

TVD, therefore, is a design strategy and process that offers designers an opportunity to engage in the design conversation concurrently with those people who will procure services and execute the design. It focuses on designing based on the project values, which become design criteria rather than mere aspirations. Using TVD, the design and construction is steered towards the target cost. A continuous and proactive value engineering process is utilised during the design phase to quickly evaluate the cost implications of design options. Cost is a constraint (one of many) rather than an output of the design process.

Benefits of TVD include:

- Proactive rather than reactive problem-solving.
- Less fighting and more collaboration.
- Better value delivered for the money.
- More satisfied clients - designs that fit stakeholder values.
- Better work-life balance for contractors and architects.
- Continuous improvement and kaizen within projects and between projects.

Implementation on the Case Project

In assessing a cost budget for this project, previous experience would have pointed towards a figure of €100Million (± 50%) for the project. The project leadership team would then use TVD principles to steer and direct the design teams' efforts towards achieving this cost target. The principles of TVD were introduced at design concept stage because if a budget is not in place for concept design then the project could emerge with a figure that is unacceptably high and causing further investigation to remove scope to achieve a cost figure agreeable to the client. Using TVD pre-empted this on this project and avoided the non-value rework tasks of shrinking the scope back – such outcomes traditionally emerged from initial over-design or over-specification. Therefore, the concept design stage commenced with a predetermined target budget in mind. However, towards concept completion it could emerge that the budget target figure was insufficient to accommodate all project scope and specifications, thus requiring re-examination of the budget. For example, at pre-concept the client would have had a figure of €100Million in mind, but post-concept this could have crept up to €105Million after addition and removal of various elements of scope. A decision must then be made regarding the 'value' that is being added by the additional €5Million. This analysis and decision on the cost target must be made and agreed before proceeding to the next stage of design development, namely "Basis of Design" (BOD).

At this point, an increased level of detailed design commences and some initial purchase orders (PO) are placed for specialised equipment, but everyone is directed by the overall agreed TVD figure. The team was mindful that BOD phase carried a contingency estimate of ± 25% that, after 4 months of engineering the estimate, can then be tightened and fixed at 10% contingency. At this point the original TVD figure of €105Million could have reduced to €95Million or increased to €110Million. This figure now becomes the agreed project TVD sum. The client may, having assessed the confidence level of the TVD figure, consider reducing the contingency element of the TVD sum. The team has at this stage been working with the concept of TVD for over 6 months and from concept through detailed design have been working towards a target project cost figure, thus enabling confidence in a reduced contingency. This aligns with recent research on TVD, as illustrated in figure 2.

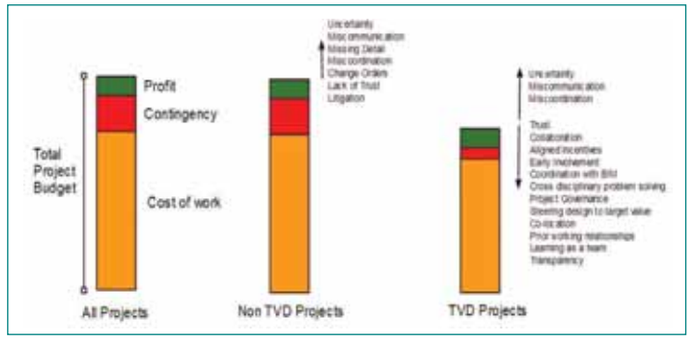

Figure 2. TVD Project Forces (Source: Do et al., 2014)

Figure 2 illustrates the breakdown of a project's costs. The total project cost includes the cost of work, contingency, and profit. The cost of work can be further broken down into direct and indirect cost – it is the sum of all the participants' costs of work. Compared to projects that do not use TVD, less contingency was required using TVD here because the entire project contingency was pooled together instead of being carried individually by each participant. By pooling the contingency together, the project team needed to allocate less contingency to cover the same amount of uncertainty in the project.

Examples of Decisions & Impact

At concept stage, the TVD figure and process are managed by the leadership team. At detailed design (DD) stage there may be up to 10 design teams inputting to the project. The project leadership team will initially sit with each team, for example, process, electrical, mechanical, HVAC, civil – structural – architectural (CSA), and collaboratively validate their assigned pool of money for the design deliverables. The designer must consider each decision they make in relation to achievement of the quality goal and assess whether this decision will add or subtract or will not change the TVD figure. An example is where the designer proposed a type 1 surface finish cladding solution to the building and the client

is now requesting a more expensive type 2 cladding with a high gloss finish. In the traditional costing model, this design change would have been added to the drawing and the extra cost would not have been recognised until the price was returned from the contractor. Whereas with the TVD method, the designer immediately advises the client that the client's decision will negatively affect the TVD fund. The cost increase can be assessed and advised, and the client can promptly adjudicate on the cost versus value benefit of the request. While awaiting the client's decision, the ?50k increased cost figure is added to the weekly TVD reporting tracker as a 'potential' increase and the impact is immediately visible to all on the tracker dashboard.

It was important at this point to also assess potential added value offered by the specification and cost increase, and the decision-making could not rest on cost alone. In this instance, the designer advised that the €50k cost increase was mitigated by a €25k material and labour-install saving as the type 2 cladding incorporated a built-in weathering trim, resulting in an overall net uplift of €25k to the TVD figure. This discussion occurred weekly with the design leads to ensure visibility and clarity of the impacts of each request and decision on the TVD fund. By implementing this element of weekly standard work, a culture of ownership for awareness of the cost impact of decisions in design was developed and a realisation that any deviation from the agreed specification and scope would generate a cost impact became embedded within the project team. The responsibility, therefore, was to recognise the impact, either positive or negative, and report this to the client immediately for review of acceptance of the financial impact. The client may respond by stating that the request is a critical value-add element that has been approved at board level and therefore the TVD figure can be increased with no impact to other scope elements. The client may also decide not to increase the TVD figure and insist on a review of the scope, either within this discipline or across disciplines, to achieve savings and align with the TVD figure. This required certain behavioural norms and changes to traditional thinking across design disciplines, as the process piping dept may find themselves looking for savings within their design scope to allow the €25k uplift for the type 2 cladding. In this instance CSA proposed changing the brick paving footpaths and other landscaping features to more cost-effective alternatives which were acceptable to the client – this balanced the uplift to allow the type 2 cladding be specified.

Cultural Change

On previous projects the design engineers wouldn't have had a culture of owning that budget. "We considered this to be the role of the cost department and not of a designer." noted a design lead, adding "After BOD we would have listened to client feedback and incorporated this into the DD. Costs would have increased but that wouldn't have been a concern of ours as the quantity surveyors dealt with all cost related issues with the client". An example from this project related to a client request to add five lifting beams to new locations, in addition to the 10 beams already in the design. Traditionally the designer would have complied with the client's request and added five beams to the drawing. However, with the new awareness around the concept and culture of working with TVD, the designer advised the client of the cost impact and together both client and designer examined the location and purpose of the original 10 beams to ascertain if all were required, especially with five more being added. This exercise led to a reduction of three beams, and thus a net increase of only two beams and with a qualified value increase to the functionality of the facility. The principles of TVD compelled the assessment of the need for each beam. One was found to be required once every three years, and it was decided to use a mobile lifting solution in that case. The traditional mindset and thinking of 'put it in just in case it will be required' is challenged by the principles of TVD and a much deeper consideration of the value versus cost argument is advocated.

The culture around a new way of working was critical as some disciplines had to surrender some of their fund to finance a client request for extra scope in another discipline. A success on the project was the early design and tender of the CSA element, resulting in early visibility of the contractor's costs for that work. This tender was 10% under budget allowing a portion of this saving to be reallocated to the process kit as this was trending towards 10% over target, thus creating a balance on the overall TVD trend.

Value Aspect

TVD can also drive up cost; however, if this exposes opportunity for increased lifecycle value to the project then the client may be satisfied to increase the fund. An example of this occurred on this project when the existing roof on the building to be refurbished was found to be fit-for-purpose but would need remediation work within 5 years. This prompted an extensive survey to be carried out, resulting in a finding that investment of €200k would be required in a piecemeal fashion over the next 20 years to maintain the roof integrity. However, it was also established that an initial investment as part of this project would get the work completed for €75k as the roof was clear and accessible without plant, cable trays, or penetrations. The client decided to spend the €75k upfront to save on the €200k spend over the 20-year lifecycle cost plan. This emphasised the "Value" element of TVD by considering the lifecycle maintenance investment costs at the DD stage.

Tracking TVD

Each discipline had its own tab on the TVD tracker and each design occurrence was recorded live as it happened on the cloud-based system. The relevant QS received a notification if the tracker had been updated, which prompted the need to review any cost impact noted by the design engineer. DPS project leadership team reviewed the dashboard with the engineering leads at the weekly governance meeting. An important part of this inter-discipline meeting was the collaborative evaluation of the impact of changes in one department on work and costs in other design departments. Referring again to the extra lifting beam example, other disciplines' design elements were impacted as lighting, fire protection, and ducting air

flows would have required modification, thus necessitating extra design hours to address compliance and quality of the completed product. This review meeting then raised new items on the tracker as the impact on the lighting, fire protection (extra sprinkler head), and ducting had to be added, resulting in a more accurate and complete impact assessment to carry forward to the client. The weekly TVD review meeting with the client examined the TVD trend and compared planned with actual to ensure visibility of any need for further attention. A critical aspect of the meeting was the importance of visiting each individual cost increase as any creep, despite being within the trend parameters, still had to be challenged and not blindly accepted. Figure 3 illustrates the cost analysis performance within the overall process discipline as discussed in the weekly governance meeting.

Figure 3. Process Department TVD Cost Tracking (Source: DPS Group)

LEAN INITIATIVE IMPROVEMENTS & IMPACT

The TVD process was consistently developed over the course of the project and has since been brought forward onto current and future projects with this client. The culture surrounding TVD is also developing, ensuring designers are becoming more aware of the impact of their decisions on the cost fund. Designers have become more vocal in declaring change and assessing its financial impact. This is of huge benefit to the Project Managers as there is less reactive work in seeking financial approvals for client changes in design packages that have already been delivered.

Probably the greatest benefit of TVD was the challenge posed by the necessity to differentiate a business "need" from a "want". Business case needs are the project team's prime delivery objective and should be captured in the project baseline concept report. Business wants or "nice to haves" must be challenged through strong project change control and by offsetting of other items and maintaining focus on achieving the target value through relentless pursuit of alternatives and resisting scope creep is a critical accomplishment of TVD.

Care is needed around reporting everything as being an extra cost. Effort must be made towards mitigating the impact of the change by examining the request to assess if alternatives exist that will still provide the client with the outcome or value required, but without necessitating major extra investment. The client testified to the increased visibility and improved financial reporting and could also assess the broader financial impact of a change request in a much timelier manner than with the traditional cost reporting mechanisms.

The value and impact of TVD is captured by the client's Project Manager who noted that:

> "The ongoing value of the TVD process exists in it being a leading indicator of change to come on the project. It creates an environment of shared responsibility of costs between engineering disciplines, for example, a small change within one discipline driving a large saving or cost increase being flagged and discussed in real-time is valuable to schedule and cost control."

COMPANY OVERVIEW

COMPANY WEBSITE
www.graham.co.uk

The company works on building, civil engineering, and fit-out projects for both public and private sector clients across the UK and Ireland and is currently delivering more than 100 projects. GRAHAM has offices in Dublin, Belfast, London, Edinburgh, Glasgow, Manchester, Leeds, Birmingham, Hillsborough, Aberdeen, Dumfries, Durham, Cambridge, St Albans, and Bristol. To align with our guiding principle of "delivering lasting impact", along with our culture of finding a better way we are focused on improving productivity, reducing error and embracing modern methods of construction to create a business which has a positive influence on the planet. We have delivered a number of iconic projects in Ireland including the Samuel Beckett bridge over the River Liffey in Dublin. GRAHAM currently employ over 2000 employees across the business.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

Katie Jones

Luke Kolakowski

GRAHAM's *Travis Brow Link Road* project has been described by Tim Lawton, TCAP Project Director, as "probably the single most important new strategic highways connection in Stockport". Awarded through Highways England's Collaborative Delivery Framework, this GBP£8Million project has delivered a new 400-metre long link road including retaining walls supporting the Grade II listed Stockport Viaduct dating back to the 1840s that carries the West Coast railway line.

Figure 1. Project Scheme

The project received the CIHT (Chartered Institution of Highways and Transportation) *Northwest Project of the Year Award* which stood out due to GRAHAM's intelligent design solution enabling a two-lane dual-carriageway to be formed through a single arch, and significantly improved access to and around Stockport, to the M60, the railway station, and to key sites within the town centre. It includes a series of highway improvement works along Travis Brow, George's Road, and Wellington Road North. This Project's major works included road cutting up to 12m deep with various geotechnical structures including soil nailed 1V:1H slopes, concrete gravity retaining walls, cantilevered and anchored contiguous piled walls to 8m in height, and pre-stressed rock anchors.

The soil nailing became a critical path activity due to dependencies on other contractors' ability to mobilise and start work on time or early within their retrospective sections. Lean work studies were conducted to improve the productivity of soil nailing which projected the programme and provided further efficiencies.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Soil nailing is an efficient construction solution to prevent horizontal movement in unstable soil slopes and retain earth that will steepened. The technique utilises hollow bars which are drilled and grouted simultaneously by the use of a sacrificial drill bit and by pumping grout down the hollow bar as drilling progresses.

Equipment Used

The equipment used was a drilling rig excavator mounted feedbeam and telehandler used to deliver the soil nails to the works area. The Travis Brow soil nailing design consists of 555 soil nails varying from 3m to 7m in length. The maximum height from ground level is 6m.

Lean Methodology

The Lean soil nailing work study followed the DMAIC

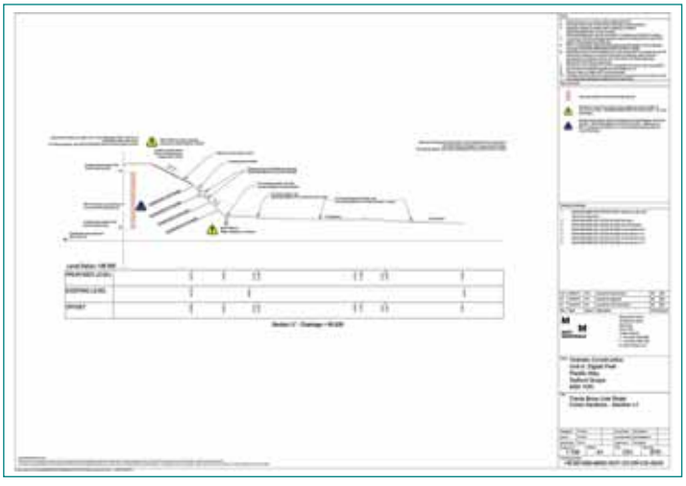

Figure 2. Drawing of Soil Nailing Requirements

(Define, Measure, Analyse, Improve, Control) methodology in Lean.

Define – The define stage of DMAIC established opportunities for improvement, current problems, and the main aims and objectives of the process. We defined that, at a critical phase in the scheme programme, the soil nailing was affecting other contractors mobilising and starting work on their respective works. The goal was to improve production from original planned average of 23 soil nails per day to an average of 30 soil nails per day to deliver programme benefits for other work activities.

- Stakeholders & Benefits – The customers of the process included the principal contractor, sub-contractor, and client. For Lean to be successful, all parties need to see the value and benefit of the initiative. As principal contractor, GRAHAM sought to improve the programme that allows the next dependencies to start earlier, protecting the programme, promoting success, and enhancing the reputation of the project. Additionally, the Sub-Contractor, Aarsleff, had the opportunity to develop a more efficient process to replicate on other schemes. Due to their sub-contract being a lumpsum, financial incentives were negotiated for delivering a certain rate of productivity. Removing waste from repetitive work also allowed Aarsleff to move on to the next project much sooner. Finally, the client gained confidence that the programme would be delivered on time or earlier.
- Deliverables – The deliverables of the project were: live footage of the process in action; data collection sheets; KPIs; a new best practice process and standard operating procedure for the sub-contractor.
- Measures of Success – The Lean Team measured their success by reducing planned programme, maintaining zero incidents, and developing increased sub-contractor engagement from both management and operatives.

Measure – The measure phase entailed data collecting to provide real evidence of production and performance.

- Data Collection – Data collection sheets were developed for the gangs to collect the respective output rates.

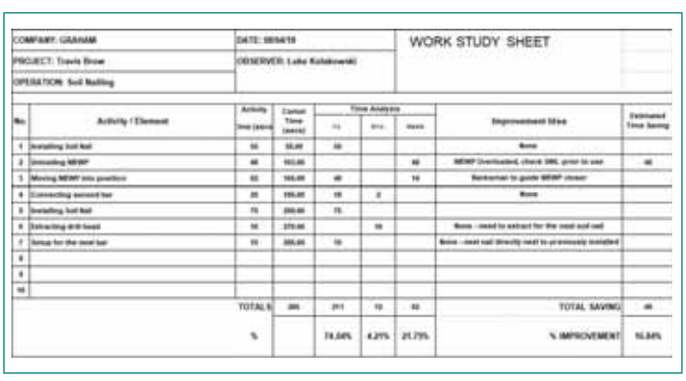

Figure 3. Data Collection Sheet for Production Rates

From these data collection sheets, the 'as is' data was collected for week 1 to understand planned versus actual output rated of the soil nailing activity (see Table 1).

Table 1. Production Rates Prior to Lean Analysis

Soil Nailing – Week 1 Data Collection				
Date	Soil Nails Drilled (Planned)	Soil Nails Drilled (Actual)	Number of Operatives	Process Efficiency (Actual/Planned*100)
05/11/18	0	0	4	0
06/11/18	20	0	6	0
07/11/18	25	21	5	84%
08/11/18	25	30	5	+120%
09/11/18	20	19	5	95%

- Gemba – This is the Japanese word, made popular by Toyota, for visiting the place of work and productivity. During the Gemba visit the process was documented, photographs were taken, and the activity was filmed. During the go-look-and-see activity, a typical working day was documented as follows:
  - 07:30 – 08:00: Arrive on site & briefing
  - 08:00 – 08:30: Set up plant, prime lines, load out materials
  - 08:30 – 09:30: Installing soil nails
  - 09:30 – 09:45: Wash out grout plant ready for break
  - 10:00 – 10:30: Break
  - 10:30 – 11:00: Set up plant, prime lines, load out materials
  - 11:00 – 12:30: Installing soil nails
  - 12:30 – 12:45: Wash out grout plant ready for lunch
  - 13:00 – 13:30: Lunch
  - Repeat above until finish at 16:00
  - Week 1 average installation = 23 nails per day

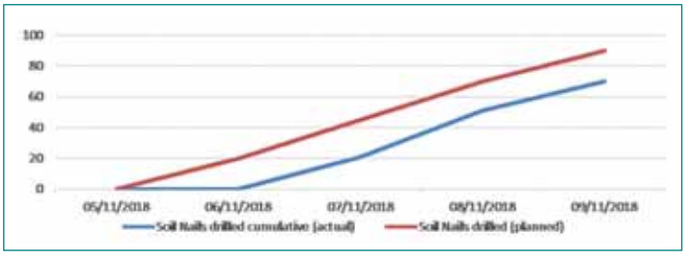

Figure 4. Soil Nailing Tracker Week 1

Analyse – During the analyse phase, a number of graphs were produced. The below shows the cumulative actual versus planned. We knew from calculating the process efficiency that we were more often than not losing 10% on wasteful activity. It was found that 1 cycle was 5-minutes 23-seconds and that there were no real improvements within the cycle other than Mobile Elevating Work Platform (MEWP) was initially overloaded which could have saved approx. 40-seconds. This meant the slow productivity for the day was elsewhere outside the actual value adding activity, that is the drilling installation. In order to understand where the missing productivity had gone, the team looked to understand the root causes of the waste. It was found that the root cause of delays included:

- Soil Nailing Materials were stored approximately 300m away from work area.

- Access to the work area was single traffic only which meant other activities working nearby delayed material delivery.
- Gangs were not working together, the MEWP operator unwrapped plastic around soil nails and placed the nails in the basket himself. This sometimes took as long as 10-minutes to load whilst the drilling rig was idle waiting.

LEAN INITIATIVE IMPROVEMENTS & IMPACT

Improve – An improvement workshop was held and a number of improvement ideas were suggested, including:

- GRAHAM could assist loading out material at the end of each shift by staying later so the sub-contractor was prepped in the morning.
- Other less critical activities were stopped and moved to other sections of the site to remove delays during material deliveries.
- The washing out of grout plant at break times was stopped and moved to only lunch and end of shift.
- Telehandler driver assisted with loading MEWP and placed nails closer to working area so less carrying by hand.

The improvements were implemented and tracked using a continuation of data collection recording planned versus actual output rates. This enabled the team to understand and control the effects of the improvements.

Control – From direct observations following implementation of improvements, there were two nights where the grout plant broke down due to not being washed out correctly which resulted in the gang only installing 10 nails in 2 days. The drilling could have been completed much quicker. The findings, once the improvements were implemented and reviewed, were an improvement from 23 nail installations per day during week one to an average of 34 installations per day in weeks 2-4. Figure 5 illustrates the gradual increase in improvement, with the maximum number achieved being 50 soil nails per day. The average was 34 per day, which meant that this programme provided a significant improvement.

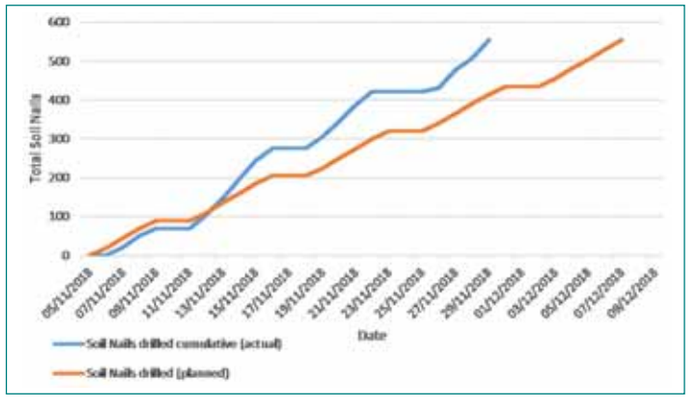

Figure 5. Soil Nailing Progress Tracker

Benefits from Lean Deployment

The deployment of Lean on the project resulted in many benefits, including improved engagement and collaboration amongst the team. This enabled smoother and more efficient working towards an aligned goal which was to beat the existing programme. The benefits from deployment of Lean included:

- There were zero incidents during this project.
- The client was delighted with the programme improvements.
- The Lean initiative contributed to winning the CIHT *Northwest Project of the Year Award* – a great achievement and recognition for the whole project team.
- GRAHAM has benefitted reputationally with this success, thus contributing to winning more work.
- The sub-contractor exceeded targets and was rewarded through financial incentives and now has a new best practice process to work towards on its next projects.

GRAHAM

COMPANY OVERVIEW

COMPANY WEBSITE
www.CField.ie

CField Construction is a Building & Civil Engineering contractor with operations in Ireland and the UK. We have extensive experience in a wide range of sectors, including Pharmaceutical, Residential, Healthcare, Leisure, and Commercial. Since our formation in 2011, the Company has experienced significant growth with turnover reaching approximately €80Million 2018. Our goal is to deliver all projects to the highest quality, in a safe, cost-effective and timely manner. We aim to form lasting relationships with clients by delivering excellence in a friendly, engaging and professional manner and see this as a key measure of the success of our business. Our team has a diverse range of skills and is committed to working closely with our clients, professional teams and supply chain to develop pragmatic, innovative and cost-effective solutions to achieve maximum value on each project.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHOR

Eolann Sheehan

In late 2017, CField Construction recognised that a new approach to how CField managed its sites was needed in order to increase productivity, reduce costs, reduce waste, and maximise profitability – and so began CField's journey into Lean Construction initiatives.

Our initial Lean initiative was based on a large-scale residential housing scheme in Cork. The project consisted of the construction of over 130 semi-detached and detached 3 & 4 bed houses, as well as all associated site civil works, including road ways, storm/foul attenuation tanks, etc. The overall project value was €31Million, on a very tight programme with multiple handover dates as the scheme progresses. Interestingly, the project team did not start off with a Lean approach and this was only introduced approximately 60% into the project timeline.

While in discussion with senior management and the site management team, the following four areas were identified that could benefit from a Lean approach:

i. Material ordering.
ii. Procurement.
iii. Storage, handling, and end use on site.
iv. Improved communications.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

In order to fully grasp the scale of the project, the site team looked at the entire process as a starting point. The team completed Lean training, which provided an overview of a Lean approach, including the 8 Wastes, Value to the Customer, impact of variability, and Lean Process Mapping.

Figure 1. Lean Training In Action

On completion of training, the process was mapped during an interactive session involving all the site management, purchasing department, accounts department, a selection of site operatives and facilitator. Visual "swim lanes" were utilised to identify each step and the decisions made during each step. The decision makers were identified as per Figure 2 (mapping the current state process from the moment material is 'out of stock' on site to the moment new material is unloaded and/or used on site).

Figure 2. Mapping the Current State Process

From mapping the process and analysing it in relation to the 8 wastes of Lean ("TIMWOODS"), it was clear that there were four key areas which would form the starting point for the Lean initiatives and improvement: i) Material Ordering; ii) Material Delivery; iii) Material Handling & Storage; and

iv) Improving Communications.

Material Ordering

Then – Traditionally the onus was on the site team to monitor stocks of each material, anticipate the requirements of various trades for the coming weeks, consider the lead times for each material, and place orders. Site management would often be notified the evening before that a particular trade was running low or out of material for tasks the following day, or that material couldn't be found in a particular location. Time was lost searching for materials before an order was placed.

Now – When ordering materials, each subcontractor is now responsible for their own ordering or notifying the site team when a material is running low in stock. This is done using a formal material order sheet which is available in the site office. Each day at 15:00 the orders are placed, and subcontractors know that there is a 5-day lead time from the date ordered. Kanban (similar to the method used in Lean Manufacturing) was utilised in the storage areas where clearly marked storage containers were manufactured to trigger an order when a certain material was running low – thus eliminating time wasted looking for materials.

From the original mapping exercise, the site team was under the impression that a 3-day turnaround time from the day the material was ordered to delivery was achievable. However, when mapped with purchasing and accounts present it became apparent that a 5-day lead time was more realistic. We have also developed a list of common materials and lead times which do not fall into the 5-day window, such as materials sourced from the manufacturer, etc. Once the order form is complete, an order requisition is generated and sent to purchasing, who in turn relay an expected delivery date to the site management team.

Material Delivery

Then – Material ordered was sent out for best price analysis, and once a price was agreed with the chosen supplier it would be dispatched to site. There were regular issues with deliveries coming in part loads, incorrect materials arriving and being unloaded, deliveries during peak times, or deliveries not arriving at all. Once on site, materials would be placed into designated areas that would often be congested due to excessive materials being ordered or lack of loadall time to keep the area in good order. Delivery dockets would be lost after delivery or not signed, leading to significant delays in accounts payable.

Now – When the material is ordered, an expected delivery date is relayed to the site team and this is then placed on a white board in the main site office for loadall drivers and subcontractors to see (Figure 3). Each morning a quick huddle with loadall drivers happens during which we review deliveries from the day before (crossing them off the whiteboard if delivered) and discuss the deliveries for the day as well as important tasks to be completed. Delivery dockets are returned each morning and a box is also available in the site office for operatives to hand in dockets. It is interesting to note that following the initiation of the Lean project, operatives suggested that all deliveries which require on site lifts be deferred until 10:30 each day thus allowing trades full access to loadalls first thing in the morning.

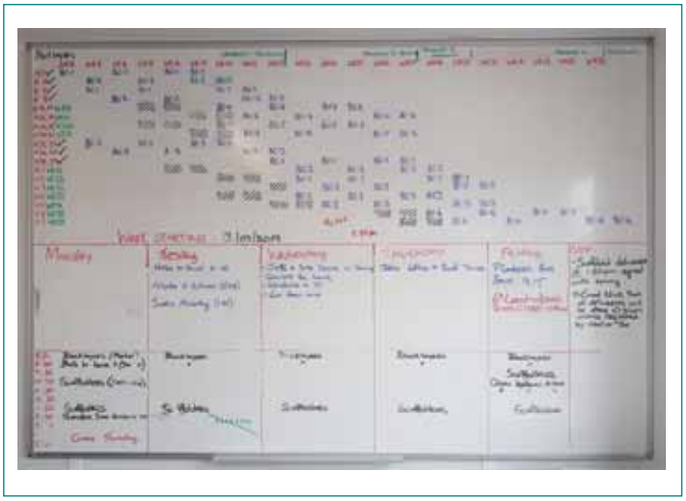

Figure 3. Daily Delivery Tracker

Material Handling & Storage

Then – Materials would arrive in large quantities (Over-Production) and be unloaded in no particular order. Materials were often taken from the set down areas in large quantities and brought to the work area, only for the majority of the material to be either returned to the set down area or left behind by trades people, leading to excessive handling and damage – all of which was creating significant cost increases and time delays for both subcontractors and the main contractor.

Now – Each element of the project has been scrutinised to eliminate waste materials as far as reasonably possible. The site team went to the place of work (Gemba) to observe how the materials were handled, how many times they were moved, etc. The site team and subcontractors are aware of exactly how much of each material is required per house and how many houses will be completed each week (using a given material) and so we are able to order just in time (JIT) materials meaning that more can be delivered to the door of the house. For example, all internal slabs (measure to minimalise waste) arrive two days before the roof is installed and are lifted in before the roof is lifted on – eliminating issues of storage, double handling, and ensuring the material is in a dry environment eliminating waste.

House kits have been developed, meaning suppliers kit materials for a specific house – a very worthwhile example is the second fix joinery. A bulk order has been placed for this material and the quantity for each house is known. When the house is ready for these materials, they are called down, arrive on site within 24 hours, and are delivered straight to the house. This has also been done for second fix mechanical and electrical materials, paint, tiles, paving, etc.

Improving Communications

Comparisons can be draw between a manufacturing facility and a residential housing scheme – for the most part each house is the same with little change to standard details. With this in mind, applying Lean techniques and solutions

is quite achievable in a residential environment. Key elements of Lean are the visualisation of the work by both the site team and the subcontractors, collaboration, and the development of your subcontractors as partners and key stakeholders in the process. Taking this into account, the site team introduced weekly meetings with all stakeholders (subcontractors) present to review the previous week's work and look ahead to the following week, and briefly touch on the month ahead (see Figure 4). This in turn greatly improved work flow, allowing materials to be ordered in a timely manner when work can be mapped out by the people doing the work.

Figure 4. Weekly Coordination Meeting in Progress

LEAN INITIATIVE IMPROVEMENTS & IMPACT

From analysing processes at the chosen residential site under the four main headings and applying Lean principles to the given situations, we have noted that significant improvements have been made not only on that particular site but on other sites that have taken onboard the learning, in addition to other departments within CField.

Some specific examples from the initial residential site analysed are illustrated in Table 1.

Table 1. Residential Site Improvements

Improvement achieved	As a result of
20% reduction in late orders being placed.	All subcontractors are now aware of the 5-day lead time. Introduction of Kanban in the material storage area.
37% reduction in time spent by Accounts Department arranging and analysing dockets.	Hold daily meeting with loadall drivers on site. We now get dockets back to site office in short time and good order
9% decrease in loadall hours on site (with associated reduction in costs).	Most material now arriving in house kits or going directly to the place of work.
Improved site presentation with 33% decrease in the set down/material storage area.	Set down area is neater and less materials delivered.
15% decrease in waste materials sent off site (excess stock, damaged goods).	Reduction of materials on site to eliminate waste where possible.
Reduced waste material ordering (over-purchasing of goods to account for waste/snags/offcuts) from 8% to 3%.	Ongoing monitoring of materials ordered per house to reduce over-ordering going forward.

Further Work – Achieving Sustainability

"Best is the enemy of Better" – a key element of Lean is the Plan, Do, Check, Act (PDCA) method. CField Construction has now taken these Lean solutions and applied them to other residential projects in our portfolio. It also has to be noted that not all of the above work for each project – it is all about finding what works for each project.

For example, another large-scale residential project (circa 150 dwellings) has adapted the Material Ordering element and developed it one step further. The project team took the time to measure as many bulk order materials as possible before the project commenced – setting up bulk orders not only for concrete, stone, blocks, etc., but also for drainage material, first fix joinery, etc., as a fixed price with a fixed supplier for 12 months. This allows the site team to deal directly with the supplier, eliminating the need for time consuming paperwork and delays in having to find the best price for each and every order.

CField Construction has also used the aforementioned project as the start point for a number of other Lean initiatives looking at eliminating rework due to snags, improving the programme and increasing stakeholder (subcontractor) engagement in the project planning process.

CField Construction Senior Management Team has completed a Lean Training workshop. As a result of the understanding of Lean concepts gained during this workshop and the practical benefits yielded to date from the initiatives listed above, the Senior Management Team has committed to have 50% of all CField Construction employees Yellow Belt trained by the end of 2019.

CField CONSTRUCTION

COMPANY OVERVIEW

COMPANY WEBSITE
www.joneseng.com

Jones Engineering has been in operation for nearly 130 years. Its core services include Mechanical, HVAC, Process Piping, Electrical, Instrumentation & Controls, and Fire Protection across all sectors. Additional services include Maintenance, Bio-Energy, Technical Support Services, Geo-Surveying, Specialist Lift Division, Fabrication Facilities and Comp-Ex Training, (competency in the selection, installation, inspection and maintenance of Ex apparatus in potentially explosive atmospheres). Working in 14 countries across Europe and the Middle East, Jones Engineering employ over 3500 people and has an annual turnover in excess of €650Million. Jones Engineering is committed to the implementation of Lean Construction thinking and practices across all elements of its operation and supply chain.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

Ray Curley

Simon Watson

Whilst Jones Engineering began from humble beginnings, it has now grown into one of the largest M&E contractors in the country with over 3500 staff. Along with this size of company comes the huge amount of plant and equipment required to carry out the large-scale projects the company undertakes. Jones Engineering currently has several million-euro worth of plant and equipment available to its project teams.

Before Jones Engineering adopted Lean Thinking, there was little or no record or control of the massive amount of plant and equipment in its arsenal – in fact, the company didn't accurately know how much plant and equipment it actually owned. Crews would carry gear from project to project or request more on an ad hoc basis. A plant management system was required to control the vast amount of equipment the company owned.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

The Group's objective is to deliver quality work through quality people. Each of the operating divisions of Jones Engineering is certified to the International Quality standard, IS EN ISO 9001:2015, and is accredited with "Safe T Certification".

With an operation this size, a massive amount of plant and equipment is required to keep each project flowing. Until recently, there was no proper record of plant throughout the Group, and an Excel file was used that had to be manually updated and was dependent on information being passed from sites. Transfers from project to project were seldom recorded. This led to a lot of errors on the manual system with several items of plant being entered more than once on the log during site audits. It was virtually impossible to put a value on the amount of plant and equipment the company owned. Crews on projects were often hoarding tools, plant, etc., in job boxes and stores waiting for the next project to start. There is an urban myth in the company that during an audit on one of the sustaining projects more than 70 individual 9" angle grinders were discovered on a site that had only 28 employees. A lot of employees had the notion that when they were given a new drill, welding plant, etc., it was theirs to keep and not to be made available to other project teams when a project was complete. Another issue that arose out of this situation was that calibration and certification dates were missed as the company was dependent on the user to inform it when these tests were due.

In 2014, Jones Engineering's Lean Department was set up. This new method of thinking and learning led to the company looking at all of its different systems of work, including Standard Operating Procedures (SOPs) and Quality System Procedures (QSPs). One of the QSPs (QSP 12) related to the control of plant. With the then current state of plant control, this was one of the first areas that needed to be addressed. The Lean Department began by looking at how Toyota became the largest and most efficient car manufacturer in the world due largely by its drive to achieve zero downtime on production. This was achieved by combining technologies with programs that focused on equipment performance combined with asset management.

Lean principles eliminate waste by reorganizing the plant into lines, or value streams, where work cells and assets perform certain tasks. This approach removes non-value-adding activities from the system, leading to more efficient processes".

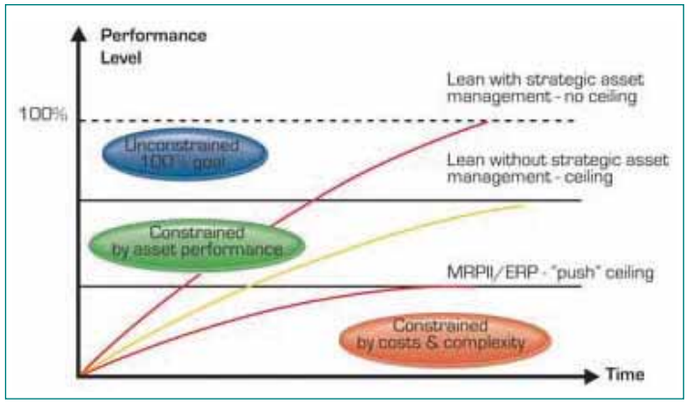

Figure 1. Strategic Asset Management Unlocks Asset Performance & Raises Achievements

Several methods of recording plant were trialled by the team over the following 12 to 18 months ranging from metal tags with barcodes on them to labels with QR codes. Problems arose with the QR codes as they wouldn't scan if damaged. There was also the problem of scanning itself. Handheld scanners were not always practical or even possible to use in the field. Working closely with their IT department, the project team investigated different systems with the goal of developing their own internal system of plant tracking. But the time delay here was a major issue.

Hilti, one of the largest manufacturers and suppliers of power tools, anchors, fasteners, etc., had recently launched its "On!Track" asset management system for the construction industry. In its promo, Hilti state that "At the touch of a screen or the click of a mouse, ON!Track tells you exactly what equipment you have, where it is and who is using it. When items need maintenance or calibration it alerts you. Our Bluetooth enabled smart tags offer a fast inventory check and tells you which equipment is nearby. When it's time to renew training or certification it tells you in advance. With this critical information at your fingertips, it's simple to keep your work on track, profitable and fully compliant". They go on to tell us how it works: "Rugged barcode tags on your equipment communicate with cloud-based asset management software that runs on mobile or desktop devices – meaning you can find your assets in an instant".

This new system seemed to fit the requirements Jones Engineering was looking for. Armed with 200 Hilti tags, trials were run on several sites around the country. The results and feedback were positive and a decision to roll this system out across the whole group was made. In June 2017, a new Group Plant Department was set up with the responsibility of controlling plant and equipment in all companies across the Jones Engineering Group. This consisted of a Plant Manager and several Plant Administrators.

Figure 2. Tools Displaying Barcode Tags

The Plant Department began systematically visiting every job site, project, and workshop/stores that Jones Engineering had a presence on. Every piece of plant and equipment had a barcode tag fitted and the following information was recorded on the database:

- Barcode Number (Scan Code).
- Alternate Number (Jones Engineering Plant Number).
- Serial Number (Manufacturers Unique Number).
- Product Template.
- Asset Group (Drills, grinders, Saw, Welding Plants, Site Vehicles, etc.).
- Status (On site or In Transit).
- State (Operational, Broken, Stolen, Retired, Lost).
- Description (Ladder-Podium, Ladder-Straight, Ladder-A-Frame, Ladder-Platform)
- Model.
- Manufacturer.
- Managed (Owned or on hire).
- Current Location.
- Default Location (Company in the Group).
- Responsible Employee (Person to whom an asset is assigned).
- Owner (Location Manager).

This proved to be a massive undertaking with over 190 live projects and 9473 pieces of plant and equipment being tagged and logged on the new plant management system. Over 300 members of staff were trained up on the use of the system and the Plant Department even travelled to the Middle East to set up the system and train the personnel out there. This new system proved an immediate success as all that was needed to use it was a smart phone. Tags could be scanned using an app and no handheld scanners were required. The Plant Department put together a short PowerPoint presentation showing users of the system how to add and transfer assets using the mobile phone app.

The new plant management system gave full visibility of what was on every project and who was responsible for it. It had the ability to set alerts for calibration and certification of plant. It also enabled the company to put an accurate value of its assets on any site at any given time by systematic audits being carried out using the app.

Current Location	Asset code/Emp ID	Manufacturer	Model	Description	Alert Type	Alert Message
Pfizer Grange Castle	21017304	J & L Lifting Eur...	Welding...	Sling Endless	Service Due	Asset service is due in 22 days
Pfizer Grange Castle	21108641	Chain & Rope S...	Welding...	Sling E&E	Service Due	Asset service is due in 22 days
Pfizer Grange Castle	20004098	CraneCare Ltd.	WBS Wa...	Sling E&E	Service Due	Asset service is due in 22 days
Pfizer Grange Castle	21017326	5t beam trolley	5.5 Ton ...	Beam Trolley	Service Due	Asset service is due in 22 days
Pfizer Grange Castle	21017364	Kratos	FA Self-r...	Self Retracting ...	Service Due	Asset service is due in 22 days
Pfizer Grange Castle	21017326	Eller	5 Ton Be...	Clamp-Beam	Service Due	Asset service is due in 22 days
Pfizer Grange Castle	21017326	Lift IQ	5ton Che...	Chain Block	Service Due	Asset service is due in 22 days
Pfizer Grange Castle	21108636	J & L Lifting Eur...	Welding...	Sling E&E	Service Due	Asset service is due in 22 days
Pfizer Grange Castle	30414669	GT	Beam Cl...	Clamp-Beam	Service Due	Asset service is due in 22 days

Figure 3. Plant Management System Showing Service Alerts Due

LEAN INITIATIVE IMPROVEMENTS & IMPACT

Following the transition onto the new plant management system and some initial teething problems, the majority of users are now fully conversant with its various functions and operations. The system has given the company improved accuracy and accountability with each plant item assigned to an individual supervisor/user. That accountability has two specific benefits:

1. Plant items are returned promptly when not in use.
2. Each item logged against an individual commands better attention and a heightened focus on security.

Complete visibility across the entire organisation is also a big plus. In the past, if a supervisor needed a piece of plant

they could check with the central plant stores to see if one was available, and failing that, they had to make a phone call to the person who managed the original plant list to see how many of those items we owned, where they were last recorded, and then start making phone calls – not an efficient process. Now, they simply open the application on their mobile phone and at a glance can see which project the items are located on. With a little knowledge of how busy each site is, an individual can track down an available piece of equipment very quickly and arrange for it to be transferred to them without delay.

Transferring a piece of plant is vastly simplified through use of the app and built-in scanner on each individual's phone to record the identifying plant number by pointing and clicking at the bar code on the tag. The simple operation of the app means the company now has a much higher compliance rate among plant users. The previous system of writing down the number, then having to enter it into an email, and forwarding it to someone else to complete the transfer was double-handling at its best.

Scanning the equipment tag avoids potential typos which used to involve frantic phone calls or emails for plant numbers to be rechecked as they did not match items on the database. The company is also seeing less downtime among the crews in the field due to locating or waiting for plant, and also less money wasted hiring or purchasing additional plant as a result of the visibility. Previously, if a supervisor could not locate a plant item easily it was safer to either hire or buy a new one as opposed to having his team held up.

Statistically, the company found that across the 13 most frequently used plant categories, there were almost 4000 assets and more than 3000 transfers in the twelve months of 2018. Based on the purchase price of new assets, if people did not have the visibility of plant locations and went ahead and bought new items instead of transfers, they would have spent in excess of €7Million. This highlights the scale of potential savings possible due to an increase in plant transfers.

Another benefit that Jones Engineering sees with the new database is that it now receives automatic notifications when equipment calibrations are due. Based on the expiry date, a reminder email is sent automatically to the plant manager and also the person the asset is assigned to. This gives them time to arrange re-calibration and removes the human element of someone having to run reports manually or constantly check the database to keep up to date.

An unintended consequence here has been the development of an internal local calibration capability for the welding equipment. The company now has a dedicated maintenance team of direct employees who have received specific calibration training and are certified as approved to carry out this work to calibrate both orbital and manual welding plant.

This may not seem like a big win, but when you consider that across all operations the company has in excess of 400 welding plants spread across more than 100 domestic projects as well as 50 sites overseas, having control of this internally gives the company more flexibility through use of in-house expertise. A small amount of initial investment was required to purchase specific test meters and load banks etc., but this has given the company the ability to be self-sufficient and minimise potential delays as they are not tied to availability of third-party calibration expertise.

Other improvements have become apparent since the process began and one of these has been with the PA Testing process.

The team noticed that this process could be improved by purchasing some new label printers where a variety of label colours were available as standard. JEG only had one label colour with its previous label printer. By using a different colour label for each three-month period, the new coloured labels now provide a good visual indicator that equipment is within its three-month calibration period even without having to check the tag for the calibration expiry date.

Again, some minor investment was required, but the company's existing printers were nearing end of life anyway as the vendor had phased out this particular model, so changing to more modern equipment was more economical and efficient.

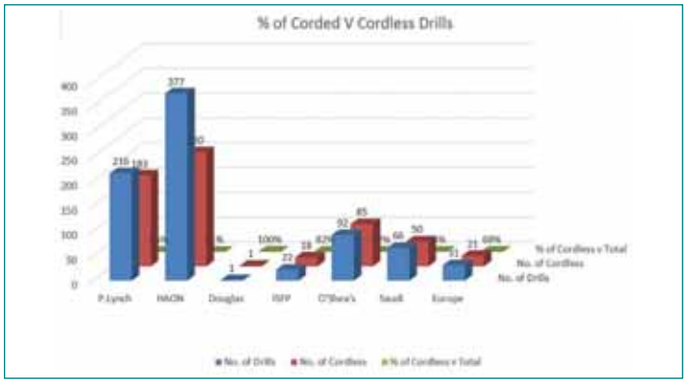

Figure 4. Percentage of Corded Versus Cordless Drills in JEG

Analysis of this data is really powerful and is giving JEG insights into other areas where efficiencies can be made. For example, Figure 4 shows the comparison between corded and cordless drills across the group. Improving cordless numbers means time savings on site, no trailing leads, reduced PA Testing, etc.

Figure 5. TIMWOODS Plant & Equipment Waste Reductions

In summary, implementation of the new plant database has improved overall efficiency in all areas where plant and equipment are used within Jones Engineering, and utilising the TIMWOODS model has reduced waste in each of the eight waste categories.

Jones Engineering

COMPANY OVERVIEW

ARDMAC
Building Better

COMPANY WEBSITE
www.ardmac.com

Ardmac is an international construction specialist delivering complex high-value workspaces and technical environments. Head-quartered in Dublin, and with offices in Manchester, Craigavon, Cork and Brussels, Ardmac employ over 300 people and provide specialist construction services to the commercial fit-out, life sciences and data centre sectors. Ardmac's vision is to be "the contractor of choice for clients and the workplace of choice for great people". Ardmac's mission is "to consistently provide the ultimate solution for high-value working environments through continuous investment in the best people, technology and processes".

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHOR

Jason Casey

Ardmac's Lean journey started in 2015 with the implementation of the Last Planner® System (LPS) on a pharma cleanroom project. From the benefits of this pilot project in the areas of on time delivery, budget, quality, and safety, leadership at Ardmac further educated themselves in the area of Lean through Yellow Belt training and conferences. This provided leadership with an understanding whereby Lean goes beyond Lean tools, and that its long-term benefits involve the integration of leadership behaviours, full enterprise alignment, and a process-based approach to manage the business.

As a result, leadership were fully committed to the deployment of Lean to deliver its 2022 Strategy Goals. Leadership engaged the organisation to develop a shared Vision and Guiding Principles. The next step involved creating a Lean Business Strategy that would align critical business processes that would support the delivery of Ardmac's strategic goals across Ireland, the UK, and Europe. Figure 1 outlines Ardmac's Lean journey to date, and this case study will focus on specific elements, including:

i. Set up of the Lean Governance Team.
ii. Leadership Development Program and Constructive Conversations.
iii. Continuous Improvement through the Do Your BIT program.
iv. Visual Management.
v. Digital Project Management Program.

Figure 1. Timeline for Lean

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Lean Strategy and Governance Team

To transition from a Lean tools-based approach to a strategic approach of Lean Deployment, Ardmac set up a Lean Governance team in early-2018. This team is composed of key sectoral leaders of the business. The purpose of the process is to:

1. Align current business strategies into one business strategy to deliver strategic goals.
2. Identify and manage key Lean programs.
3. Assign ownership of Lean programs across the business.
4. Support program leaders when they provide an overview of their programs.
5. Engage employees in Lean deployment.
6. Support Lean training requirements to support the delivery of Ardmac's strategic goals.

Figure 2 provides an overview of the alignment of key business strategies that will enable the business strategy.

Figure 2. Alignment Across the Business

The Lean Governance team meet monthly and review the status of each program. Program leaders rotate monthly and present an update of their individual program. In the event that any program requires support and/or continuous improvement, the governance team provide direction and support when required. It is also an opportunity for the Governance team to recognise the positive improvements that

project leaders contribute to the business.

Leadership Development Program
A critical element of Lean deployment centres around the consistent behaviours of leaders in the business. Alignment of consistent behaviours support the business both internally and externally. From a client perspective, and regardless of who is managing the project, the client will experience a standardised approach to managing a project. As a team member within Ardmac, consistent behaviours internally will also drive consistent behaviours within each team, thereby supporting our vision to be "the contractor of choice for clients and the workplace of choice for great people".

To ensure that Lean will be successful in the future, Ardmac has supported 17 leaders in undertaking a leadership development program at Trinity College Dublin. The program focuses on a number of areas including Operational Excellence, Strategy, Design Thinking, People Management, Integrated Project Management, and Benchmarking visits. The outcome of the program is the delivery of five strategic projects that will support the delivery of Ardmac's strategic goals. Each member of the Lean Governance team has completed this program, which provides a deeper knowledge and understanding of Ardmac's Lean journey.

Figure 3. Graduates from the Ardmac "Building Better Leaders" Program 2019

Constructive Conversations Program
To further support leaders as people managers, Ardmac has also launched a "constructive conversations" program. This program has trained leaders to perform 2-way constructive conversations with employees, thus transitioning managers from a directive to a coaching and mentoring role.

Do Your BIT Program
Lean involves a transition to all employees thinking about continuous improvement. To support this continuous improvement mindset, Ardmac has developed and deployed the "Do Your BIT" ("Building Ideas Together") program. The purpose of this program is to support employees to have a voice in continuous improvement. Employees are supported in submitting ideas for review and execution. The Do Your BIT team review ideas submitted monthly and then provide employees with feedback on their suggestions. The program considers all ideas, from a 10-minute small improvement to large-scale capital investment ideas. Ideas can be submitted electronically or can be managed via the Visual Management Boards or during Toolbox Talks. On site in particular, the daily huddle boards are a good opportunity to ensure that craft can participate in the program. This approach not only promotes continuous improvement, but also engages employees in our Lean journey and provides leadership with an opportunity to recognise an employee's innovation that they may not otherwise be exposed to in the business.

Visual Management
A key aspect to Lean deployment is the management of metrics. From 2018, Ardmac has engaged craft within projects through the application of Visual Management Boards to manage the metrics that matter daily. Each of our projects across Ireland, the UK, and Europe utilise, as part of our daily huddles, a review of key metrics including Safety, Quality, and Schedule. This Visual Management board complements the LPS to ensure that the metrics that matter are reviewed and managed daily. The review of the visual boards involves the entire team, thereby ensuring that everyone is aware and accountable to the metrics that matter. Figure 4 outlines an example of a visual management board in action, including the Daily Huddle and our Safety Program. The Visual Management process in Figure 4 is replicated across all our projects in Ireland, the UK, and Europe. The key to the success is the involvement of the right people in this short stand up review (15-minutes max) as these are the people that can constructively action the status of each metric.

Figure 4. Visual Management at Project Level

Project Management Platform
From an analysis of the workload of site management in 2018, up to 20% of site management time was absorbed around data collection and reporting. This time included activities such as printing forms, filling in by hand, scanning, and emailing results or typing results in spreadsheets. There were also large amounts of time spent walking between the site office and the work zone collecting drawings and the latest information. A project was set up to identify a solution to minimise this non-value-added (NVA) time. A number of software solutions were identified to manage documentation in a Lean manner.

In early 2019, a software solution named "Procore" was selected and implemented to streamline project process on any mobile device. A significant project plan was developed to manage the integration of Procore into the business, starting with a pilot and identifying lessons learned around the program before full deployment. To support deployment, a significant training plan was developed and executed to minimise impact of change from a paper based system to an

electronic solution. Figure 5 outlines an example from this system.

Figure 5. Procore Software Solution for Managing Documents Electronically

Integrated Project Delivery (IPD)

IPD is a project delivery system that seeks to align and integrate all project team members' interests and objectives. The team includes the client, the main contractor, and subcontractors. IPD integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimise efficiency and handover to client. Two projects were managed within Ardmac using an IPD method. For one project, Ardmac was the subcontractor. The collaborative IPD approach provided a specific focus on each contractor to utilise LPS to deliver a very aggressive schedule, with eight subcontractors working with this process throughout the lifetime of the project. Where constraints were identified, each sub-contractor realised the implications of owning and removing constraints for other subcontractors to ensure work would flow. LPS metrics were critical to the success of the project as the right metrics focused on flow and drove the right behaviours to ensure work could flow throughout the lifecycle of the project.

LEAN INITIATIVE IMPROVEMENTS & IMPACT

Ardmac has adopted a Lean strategy, going beyond the implementation of Lean Tools and adopting an integrated approach where engaged employees, supported by their Lean Leaders, continue to deliver the strategic business objectives. The Lean framework was oultined in Figure 2 and a number of elements from the Lean strategy are presented in this case study. Benefits from these examples include both qualitative and quantitative benefits. From a cultural perspective, through the development of Lean Leaders, management of the business is transitioning from a direct management approach to a leadership approach. With such an approach, leaders are enabling their teams to deliver business performance using their own initiative and the role of the leader is to provide direction and support.

Constructive conversations are resulting in positive improvements in behaviour, aligned to our guiding principles, where previously team members may not be aware of the impact of their behaviours. As a result of constructive conversations, this brings Ardmac's Guiding Principles to life.

From the various Lean initiatives undertaken as part of the Lean Strategy, which is managed by the Governance team, the following benefits were identified:

- Business Process in place to manage the Lean Strategy as a mechanism to deliver our business goals and objectives.
- Utilisation of IPD and LPS has delivered an aggressive project timeline of 1.5 years from the original estimate of 2 years.
- Engaged continuous improvement mindset across the business through the identification of 30 improvement ideas managed through the Do Your BIT program.
- Increase in collaboration, consideration of activities, highlighting residual issues, and improved communication/engagement through the Do Your BIT program.
- 25% reduction of site management NVA time.

Next Steps for Ardmac

Ardmac is fully committed to Lean and the long-term benefits that it delivers, and we will continue to manage and monitor our Lean strategy and key business metrics through the Lean Governance team.

Over the coming year, the following activities are planned as part of our Lean Strategy:

- Improving the efficiency and management of LPS metrics through the application of KPI software across the business.
- Engaging Lean in Offices through the deployment of the Lean Housekeeping Program.
- Initiate a Lean Transform with Enterprise Ireland to improve value stream performance through the further application of Lean thinking.
- Cost savings and avoidance of just under €1Million.
- Improve connectivity across the business processes.
- Engage the next iteration of leaders through the leadership development program.

ARDMAC
Building Better

COMPANY OVERVIEW

COMPANY WEBSITE
www.kirbygroup.com

Founded in 1964, Kirby is a mechanical and electrical engineering contractor. The company operates in Ireland, the UK and Northern Europe, and directly employs over 850 highly-skilled employees. Kirby provides full mechanical and electrical contracting services as well as specialist high voltage (HV) and medium voltage (MV) design and construction services to clients across a number of different sectors including Data Centres, Life Sciences, Industrial Manufacturing, Substations and Renewables, Power Generation, Petrochemical and Commercial. After 55 years in business, Kirby has earned a reputation, supported by client references, for excellence in high-value mechanical and electrical engineering contracting services. This reputation is built on early engagement, finding innovative cost-effective solutions for complex build challenges and an uncompromising approach to safety, quality and delivery. Kirby has strong capabilities in prefabrication, modularisation and digital construction, along with a Lean approach to project delivery, which ensures excellence and value for its clients.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

Martin Searson

Kevin Wall

A mindset change regarding quality can be seen since the publishing of ISO 9001:2015 standard in September 2016 and even prior to that with the Q-Mark standard applied from 2012. A duty was placed upon companies to now deliver quality from the top down to all levels of the industry. This can be particularly seen within section 5 of ISO 9001:2015 – Leadership along with Section 1.0 of Q-Mark Leadership & Commitment. It emphasised the need for senior management to demonstrate leadership and commitment with respect to the quality system by taking accountability for the effectiveness of the quality management system. It also stresses the importance of senior management demonstrating leadership and commitment with respect to customer focus and adding value to the customer needs.

With this ISO update, along with the Q-Mark standard, Kirby felt that there was an opportunity to show true leadership from the senior management as part of the company's Lean initiative. As part of Lean thinking and utilising Plan-Do-Check-Act (PDCA), the use of Gemba walks would be seen as a positive continuous improvement to Kirby work practices. This was an opportunity for the Senior Operations Team to go to the Gemba and highlight positives, reduce wastes (Muda) and promote value to the customer, where going to the Gemba meant going to the actual place where the work was being undertaken and the place where value is created (namely the construction site).

The Gemba walk, much like Management By Walking Around (MBWA), is an activity that takes management to the front lines to look for waste (Muda) and opportunities. Gemba, a term first used by Toyota, which means going to the real place where the action is. In the 1980s, 'In Search of Excellence' author Tom Peters popularised the concept when he talked about management by wandering around (MBWA). Like MBWA, Gemba walks take management to the front lines to see daily happenings. Gemba, however, is more focussed.The Gemba process was to be delivered in three phases:

- Kaizen to determine requirement and content of Gemba Form.
- October 2016 – December 2016 trial of process at 2 projects to finalise process
- Beginning January 2017 – roll-out of process and inclusion into company metrics and KPIs.

This Gemba process is now part of the Lean Construction way of thinking at Kirby and has been since January 2017 with over 45 visits taking place per year. As is it is also part of our continuous improvement process, we are now on revision 7 of the Gemba form to illustrate that once we have a behavioural change within the organisation we can emphasise the importance of something else, as continual improvements are realised.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

New quality standards and continuous improvement within the construction industry determined that senior management of companies needed to be present on projects. Progress needs to be driven from the top and senior management must be seen as promotors of innovation. Lean was the innovation moving forward for Kirby, and Gemba walks would be the tool to promote this and drive it forward.

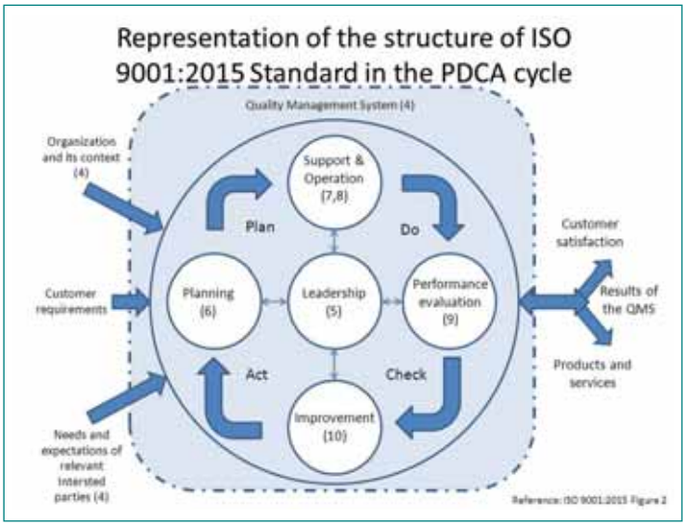

Figure 1. Structure of the ISO 9001:2015 Standard in the PDCA cycle

ISO 9001:2015 highlights the importance of the PDCA cycle in that it can be applied to all processes and to the quality management system as a whole. Kirby utilised this cycle as a way to bring its vision and values to every project it delivers. Kirby's values are Safety, Quality, Delivery, and Value. The aspect of value is where Kirby can create and share value through collaboration, innovation, and operational excellence.

Through this methodology, a Kaizen event was held with the senior management team to determine how best to deliver this value to the clients while also encapsulating the other values and vision it has moving forward. In 2016 when this was happening, Lean thinking was still being developed within Kirby, and there was a need to educate the workforce. The best way forward to deliver on the new standards, deliver value to the client, reduce wastes (Muda) in the processes, and educate Lean Construction within the company was through Gemba walks by the senior management team. A standard QEHS Senior Tour form was created to measure against aspects of TIMWOODS while also including EHS (Environment, Health & Safety) and Quality needs. Now a senior manager can go to a project, walk a site, and identify and eliminate wastes on the project. The wastes highlighted can fall under all aspects of TIMWOODS: Transportation, Inventory, Motion, Waiting, Over-Production, Over-Processing, Defects, and Skills. The site visit can result in improvements to all these aspects as they are noted. Site staff can then be educated in Lean thinking and adding value to the next customer in the cycle.

Three important elements of this Gemba walk included:

- *Go and See* – to get the senior managers to visit the sites and see the work activities.
- *Ask Why* – to explore what is adding value to the clients and what wastes can be removed.
- *Respect* – it is not a blame culture, collaborating with teams and problem solving together will enhance productivity and uptake in Lean thinking.

From a base level of 0 in 2015, to move to trial during the last quarter of 2016, and to roll-out in 2017 resulted in a large change of thought within the company strategy. A total of 48 Gemba walks were completed in 2017, and then repeated in 2018, and in quarter 1&2 of 2019 there were 42 completed – the largest number for the first two quarters.

Figure 2. QEHS Senior Manager Tours (Gemba Walks) completed – 2017 to 2019

Some of the elements that the senior management brought to these Gemba walks included:

- Promoting the use of the process approach and risk based thinking.
- Ensuring that the necessary resources needed for the tasks are available.
- Communicating the importance of effective quality management.
- Promoting continuous improvement and providing leadership support.
- Educating Lean thinking to site staff.
- Highlighting the Kirby Values of Safety, Quality, Delivery and Value (i.e. Kirby Project KPIs).

Additional Lean practices were brought to site through this new initiative. The use of 5S was key, and it makes the workplace safer and more pleasant, improves work efficiency, reduces defects and leads to better customer satisfaction and higher productivity:

- **1S – Sort:** Remove what is not needed and keep what is needed. The workplace becomes easier, quicker, and more efficient.
- **2S – Set in Order:** Arrange essential items in order for easy access. This includes identifying and labelling them and keeping surfaces and walkways clear.
- **3S – Shine:** Keep things clean and tidy. Regularly remove dirt: Damage/Defects are easier to see; safety issues are less likely to occur, and plant and tools work more efficiently.
- **4S – Standardise:** Establish standards and guidelines to maintain the first three S.
- **5S – Sustain:** Make 5S a habit. The benefits of 5S will only truly be seen if it is maintained in the long-term.

Another key Lean tool that became part of the routing of Gemba walks is Visual Management which enhances the smooth flow of information by using visual and audio signals instead of texts or other written instructions. It makes operational standards visible so that people can follow them more easily. This technique exposes waste (Muda) so that it can be prevented and eliminated. It can be used to identify or communicate easily:

- What's right, wrong, done, left to be done, delayed.
- Resources Tools & Equipment, Materials, etc.
- Norms, Methods, etc.

These became part of the Kirby Management KPIs that are now being recorded and promoted on every project within every Gemba walk. Good practices were promoted and shared, and wastes could now be eliminated.

Figure 3. Kirby Senior Management QEHS Senior Tour (Gemba Walk) Register 2017

Figure 4. Sample of a completed QEHS Senior Tour (Gemba Walk) Form

LEAN INITIATIVE IMPROVEMENTS & IMPACT

The improvements seen through the Gemba walk process are clearly shown through Kirby's continued growth within the construction industry. As part of our Q-Mark assessment in 2018, we scored 192 out of a possible 200 points for Leadership; and we continue to score highly within ISO 9001:2015 audits for Leadership. We are able to show through these project walks that Kirby Senior Management aspires to have Kirby be the most trusted provider of high-value engineering and construction services. There has been an increase in focus for adding value to clients. In a Gemba walk in Co. Kerry with an Associate Director, our client and end client were also invited to take part in the Gemba walk. They found the experience invaluable and are now promoting the practice within their own organisations. This is not an isolated case and we have found such collaboration to be a fundamental prerequisite of this practice.

From the site point of view, and collaborating with the site staff, we have found a multitude of positives, including:

- A clean/safe workplace.
- Positive, inclusive culture.
- High Employee engagement – high morale.
- Reductions in over-processing.
- Takt time improvements.
- Right first-time mentality.
- Positive Lean Thinking.

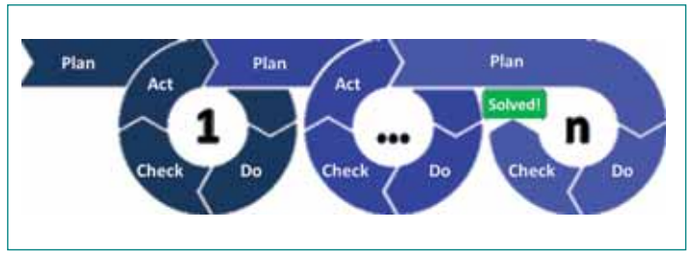

Figure 5. PDCA Cycle of Continuous Improvement

As part of our continuous improvement mind-set, though applying the Plan-Do-Check-Act approach, we are now analysing the data gathered and findings raised during these Gemba walks completed over the past two-and-a-half years, to further realise benefits from this where value is being created on our projects. We are gaining new data and a fresh perspective, in Lean thinking, as we strive towards operational excellence on our projects. Value flows horizontally across our organisation to our customers. It is these Gemba walks which help our senior managers see and reconcile the horizontal with the vertical communication and feedback loops provided so as to realise further benefits and opportunities. This helps further embed Lean Construction as a part of our values in improving our deliver and value add, for our clients and stakeholders.

kirby
engineering & construction

COMPANY OVERVIEW

COMPANY WEBSITE
www.johnsiskandson.com

John Sisk & Son Ltd. ("SISK") is an innovative international engineering and construction company employing over 1300 people across its operations in Ireland, the UK, and Europe. Sisk has the track record, scale, and capacity to successfully undertake large, complex, multi-disciplinary programmes, and is recognised by our global customers as world leaders in safe delivery. Operating since 1859, Sisk is a progressive business with long-term vision and is Ireland's No.1 ranked provider of construction services.

Sisk's strategy is to create value for customers, partners, and people through technical knowledge, ability, and experience:

- We collaborate with our customers and supply chain to provide technical and delivery solutions in an open and can-do way to meet aligned objectives.
- We offer a full range of solutions where safety, innovation, quality, efficiency, and value are integral to everything we do.
- We deliver projects and programmes in key sectors such as Data and Technology, Pharmaceutical and Life Sciences, Infrastructure, Transportation, Healthcare, Commercial, Residential, Retail, Industrial, Leisure, Education, Water, and Energy.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHOR

Cormac Fitzpatrick

This project was a large-scale leisure development in Ireland involving the design and construction of accommodation and ancillary facilities to a new Holiday Village located within mixed species woodland of approx. 400acres. The project comprised 466 accommodation units ranging from 2-bed units of 80m2 up to exclusive 4-bed detached units of 190m2 floor area. The overall programme period for the project was 68 weeks.

Figure 1. Overview of the Project Site

The project involved a fast-track schedule on an extremely large site. Due to its location within the woodland environment, the site was extremely restricted with only 4-metres of working space around each cluster of lodges. Owing to the scale of the project (if the units were constructed in a single terrace it would be over 4.2km long) there was an enormous volume of materials to manage, including:

- 300km of cladding panel.
- 600000 roof tiles.
- 4500 Doors.
- 3500 Windows.
- 160000m2 of timber frame wall panel.
- 466 Kitchens.

The following parameters were critical to the project:

- Exemplary safety record.
- Highest quality standards with zero or minimum rework.
- On or ahead of schedule.
- On or under budget.
- Visibly demonstrating respect for all involved in the project.
- Delivering job satisfaction.
- Ensuring material availability at all times to the site craft.
- Equalising outputs across all trades to ensure production continuity.
- Ensuring a common understanding of project status through accurate, visually clear, and fully shared reporting.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

It was clear from the outset that in order to ensure continuity and flow of work through the various trades, we would require a collaborative workshop-type approach to scheduling, sequencing and handoffs. "People and collaboration" rather than "systems and schedules" were going to deliver this project. The confined working environment over such an extensive area would also require a bespoke streamlined approach to logistics and materials management. Finally, the repetitive nature of much of the works demanded a Lean Programme.

From the outset, we committed with the client, design team and supply chain to collaboratively deliver the project. The following initiatives subsequently formed the basis of the Lean Programme for the project. Some were strategically

planned from the outset, and others were established or developed "opportunistically".

Understand what Value Means to Our Customer

During the procurement and pre-construction phase of the project, the Sisk team invested significant time in defining, understanding, and communicating precisely what "value" meant to our client. We carried out numerous visits to existing facilities both in operation and under construction. We also engaged with the existing client supply chain to understand exactly how the previous projects were constructed, what challenges were encountered, and what worked best. We also gained an understanding of the level of detail and expected quality of the finished lodges. We in turn were able to convey these standards to the entire supply chain so as that the entire team had full alignment when the project moved to the construction stage. This initial phase of the project proved invaluable. One of the most beneficial outcomes was the relationships that developed as we transitioned from a "client -contractor" relationship into a "single delivery team". We were very conscious during this procurement phase to ensure that we selected contractors that would buy into our vision of success and actively partake in this "one team" approach.

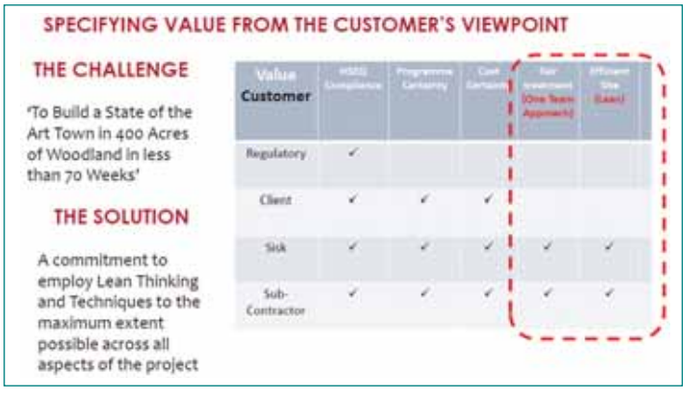

Figure 2. Customer Defined Value

Constructability Enhancement

Following the site visits to similar projects which had been delivered for the same customer, we undertook a series of workshops both internally and with our design and supply chain partners in order to streamline the actual construction process compared with previous projects. The team continually challenged and tweaked the design, detailing and construction sequence to find the optimum solution both from an installation sequence perspective and finished product quality. During this phase we worked with the supply chain to develop the best sequences both for an individual lodge and for the entire project. All parties bought into the process and were prepared to make some sacrifices for the greater good of the project – in order for the project to succeed, the team had to acknowledge that we were all dependent on each other and would either succeed or fail together. We also acknowledged that for each contractor to be efficient we needed to ensure that outputs were equalised across all trades each day. We could not have a scenario where there was a need for peaks and troughs in the labour requirement.

Figure 3. Pre-Assembled Stove

Establish Pull and Flow

We actively engaged our subcontractors to set out the optimum construction process from their point of view, and devised a work sequence and materials breakdown to minimise the extent of material handling and wastage on site. The aim of this exercise was to limit the steps in the construction process allowing us to fully define exactly what task should be carried out by each tradesperson every time they entered a work zone. This in turn allowed us to define exactly what materials were required to carry out each step. With this information, we were in a position to develop a robust construction programme that set out to equalise the outputs across all trades to ensure there was continuity of work for each trade in a production line type process. We set the required output at three lodges per day – this meant that every step in the construction process must complete three units every day, from timber frame roof trusses to silicone sealing in bathrooms, every trade must complete three per day. By adopting this approach, every trades person was guaranteed that the trade both in front and behind them were producing the same quantity and therefore they were guaranteed a productive day's work every day.

Pursuing Perfection

With the large workforce on site and the numerous customer stakeholders, we needed to develop a procedure to consistently deliver a product to the required quality standard. Rework resulting from inconsistent installation and defects was seen as a major risk to the project due to the high volume of small construction units – one unchecked mistake in every lodge would result in 450 mistakes. To mitigate against this risk, we agreed with all parties at the outset to construct 4 units to various stages in the construction process, this allowed us to agree with all stakeholders exactly what detailing and quality was required at all stages of the process, not just the finished product. Each task in the construction process was carried out by a dedicated work crew who knew exactly what standard was required of them – this also allowed us to identify and eliminate any residual defects due to damage to installed works.

Activity Sampling

As each crew was accountable for each element of the works, we had complete transparency on exactly what outputs were being achieved daily and exactly what task every person was carrying out. Activity sampling and productivity tracking enabled us to improve efficiency at every step in the construction process. We quickly identified a number of areas where we were expending excessive effort to achieve our required outputs. Obviously over the scale of a project like this, we could not afford to expend this additional effort and so we had to devise a means to identify where exactly the issues were and minimise them. We began to employ a method of activity sampling, or direct observation, to try to understand where the issues lay. This involved monitoring works ongoing for predefined periods of time over the course of a day or week. From this monitoring we

could understand where large quantities of time were being spent on non-value-add (NVA) activities, that is, where there is nothing being produced. Armed with this data we were able to target and eliminate the primary areas of waste. Examples included adjusting gang sizes, how we managed materials and accessories, and revising both construction details and even products used.

Figure 4. Work Sampling

Materials Control, Standardisation and Off-Site Fabrication
All opportunities were explored to maximise off-site fabrication from timber frame panelling and roof trusses to metal frame partitioning for chimney breasts. Materials management was identified as a key item due to the vast quantities required. The project actively set out to eliminate waste both in transport and inventory management at every opportunity. The layout and space restrictions on the site required site material storage to be minimised whilst ensuring that adequate supply was available for installation. Control of materials was achieved by various techniques including standardisation of materials required and batching of bulk materials by our suppliers for delivery to the correct locations in the correct quantity at the right time to eliminate double handling. We batched smaller and high-value items in purpose-built warehouses onsite, and M&E items, sanitary-ware, windows, doors, and patio paving were batched "per lodge".

Figure 5. Materials Control & Standardisation

LEAN INITIATIVE IMPROVEMENTS & IMPACT

This project was a success for our customer, for Sisk, and for the supply chain, as evidenced both by the metrics provided and in the outline of the various aspects of the project, safety, quality, and respect. Schedule control was delivered firstly by constructability improvements, secondly by early engagement with the client and key specialist trades, and thirdly by intensive challenge and improvement of the process. Intensive engagement at field level allowed us to hold these gains.

The intentional application of a Lean Programme was a highly significant contributor to the success of this project. We set out to strip back waste, to stop taking unnecessary steps, to spend less time in meetings, and to eliminate NVA correspondence. We also set out to do a highly efficient project by providing a shared infrastructure, logistics, a 3D model, and a common data environment for all project information. All of these achieved solid improvements.

The greatest benefit to the project accrued, however, in a manner which we did not clearly foresee – it manifested itself in the collaborative mindset that developed, the lack of conflict, the minimalist approach to correspondence of any kind, the absolute ownership of the project, and in the co-operation and camaraderie received from and amongst the client and trades who have collectively delivered first-class safety and first-class quality.

Some initiative outcomes include:

- Safety – 270000 man-hours worked accident-free.
- Schedule – 466 units delivered on schedule.
- Cost – Project delivered within budget.
- Cost – Zero claims from contractors and supply chain.
- Cost & Quality – Less than 1% rework.
- Quality – Each unit handed over snag-free.
- Efficiency – Actual labour approx. 15% below planned.
- Satisfaction and Engagement – Two of the most senior supply chain supervisors on the project summarise the impact as follows:

"At FastHouse, we are all delighted to have had the opportunity to be a part of this exceptional project. Great work was carried out by the FastHouse teams. Early client engagement and collaboration were essential in accomplishing the project within budget and schedule – and, as such, our collaborative relationship with John Sisk & Son played a key role in the overall delivery of this large-scale timber frame package." (Sean Fox, Sales Director at FastHouse)

"We at Treysta knew from an early stage with a project on the scale of Centre Parcs, that preplanning and collaboration were essential in order to streamline the sequence of each trade in the lodges. SISK's approach was very refreshing to this challenge which ensured Lean Construction targets were exceeded by having constructive design and construction workshops." (Kevin Kelly, Managing Director, Treysta)

BUILDERS SISK CONTRACTORS
Established 1859

COMPANY OVERVIEW

COMPANY WEBSITE
www.exyte.net

Exyte is a global award-winning turnkey project delivery company specialising in the engineering, design, and construction of complex facilities. Exyte is a recognised project partner for clients with challenging project requirements and Exyte operate in the following business segments:

- Advanced Technologies
- Life Sciences & Chemicals
- Food & Nutrition
- High-Tech Infrastructure
- Cleanroom Technologies & Controlled Environments

Operating since 1912, Exyte employ over 6000 people who together deliver a global turnover of over €3Billion per annum. Exyte provide clients with full turnkey project delivery of new facilities and the conversion and extension of existing facilities. Exyte has a strong, mobile, global talent pool to call upon, which is further supported by robust internal IT platforms that simplify project management and information sharing. With its scale, it offers inter-regional technology management, subject matter expertise, and consulting services.

Midlands Projects Management (MPM) Ltd. is a UK-based projects controls consultancy assisting Exyte in applying Lean Construction methodologies and enhancing its internal knowledge base. MPM specialise in project support and delivering assistance to clients and Tier 1 GC level projects on a global basis, and are currently deployed on project controls and Lean initiative projects in Europe, the USA, and the Middle East.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

Arfan Mirza

Tom Griffin

In fast-paced construction projects, it is not possible to manage the project through the conventional methods. It has been observed many times that depleting productivity in construction leads to rework and produces many wastages, including over-production, unnecessary transportation, worker displacement, unused employee creativity, loss of focus and drive. Therefore, practical ideas and techniques need to be used in construction that will help project teams to deal with waste in construction with the use of optimum resources, and this can be achieved by using Lean Construction principles and techniques.

Exyte and MPM endeavoured to improve the utilisation of project resources on two separate Data Centre projects in the Nordic region (the locations and clients are not disclosed due to the confidential nature of the projects).

Figure 1. Exyte Data Centre Project

The specific initiative sought to allow for an overlapping of lessons learned from the primary DC building, which was nearing energisation and commissioning, with the initiation of MEP installation on the second project. This challenged our ability to manage two large-scale projects set in a tough environment, with one experienced team coming to a finish and another new project requiring an immediate start.

Specifically, we were trying to change the mindset of stakeholders that if we educated the teams in Lean principles and methodologies of execution there would be a greater benefit to all. We would potentially be able to utilise the same expertise on the second project and reduce time and effort trying to on-board that skillset. The latter could therefore be phased in rather than mobilise one project and then within 12/24 weeks demobilise the previous project when the skillset and expertise required would be almost identical. We developed a better understanding of Last Planner® System (LPS) and of the impacts and variables on downstream performance.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Exyte, assisted by MPM, is already heavily involved in Lean Construction methods including utilising LPS and vPlanner, for example, on a daily basis.

One of the key concerns for any large-scale project delivery organisation would be the ability to secure long-term expertise and knowledge to ensure a level of consistency and cohesiveness is present amongst a team that has worked together on more than one project.

Exyte, whilst based at a large-scale DC project in the Nordic region, and whilst working in new territory and a relatively new business stream, managed to secure a second large-scale Data Centre project located in the same country with what seemed a perfect "dovetail scenario" of allowing Exyte and MPM, plus selected subcontractors, to move to the new site in a methodical manner.

Previous behaviours and traditional mobilisation methods

were already being actioned by regional and central offices to get teams mobilised. The focus quickly turned to a logistical concern, and one that needed to be managed by easing resources from one project to another whilst maintaining momentum on closeout for the existing project and whilst allowing the right expertise to be made available for the timely ramp-up of the new project.

A quick comparison was carried out and an agreed Lean Logistics Strategy was pencilled out in draft. Lean logistics, in the simplest terms, refers to the method of identifying and eliminating wasteful activities from the supply chain. In this case, we treated our EPCM functions as components of the project supply chain and adopted a Just In Time (JIT) approach which would enable Exyte and MPM to cut down on wasted/repeated efforts of recruiting additional or specialised project resources in a recognised and notoriously busy industry and marketplace.

Figure 2. Exyte Data Centre Server Bank

The Lean Logistics Strategy Developed & Deployed

Step 1 – Detailed list of activities to be executed in short, medium and long-term from the EPCM phases of the new project. In parallel, the impact of scope creep and executing a timely closeout on the current project was carried out.

Step 2 – Traditional methods of mobilising project resources were challenged through Kaizen cycles to see how the process could be improved. Following on from those exercises, MPM proposed to Exyte that Pull and JIT techniques should be implemented, and these became the pillars of our Demobilising/Mobilising strategy.

Pull System – The concept of a pull system is a fundamental pillar in a Lean approach. At a strategic level, pull identifies the real need to deliver the product and resources to the client along with an "absolute need date". The traditional construction process pushes the client into an often protracted development process where risk and uncertainties are prevalent. The principle of pull involves the decision-making ability to define quickly what the client needs from each phase of the project in relation to their business, and subsequently customising and delivering those needs more predictably when the client requires them.

JIT – This is classified as amongst the most developed Lean Construction tools designed to eliminate non-value-added (NVA) activities and to reduce process variability. The JIT philosophy is based on the concept that stocks/resources that do not bring added value to the customer before the time they are required (internal or external) should be considered as sources of wastes. So, the resource must be available only when it is necessary and not sooner so as to provide comfort to the client that we would be mobilising a full team at the start of the project.

Step 3 – A CPM schedule was created alongside a Last Planner Pull session for the Engineering and Procurement phases, and the program of works was driven in the short-term to the Mobilisation on site milestone.

Step 4 – Forecasting in terms of both the needs of the ongoing project as well as the new project. Detailed forecasting, derived from detailed knowledge about resources and when best to utilise them, had to mature from being merely speculative figures. A simple yet effective approach for this is was to measure our capacity (for instance, the hours our Engineers can put in) against the demand we could see based on PDCA/Kaizen cycles and Last Planner lessons learned from the current project versus the number of hours upcoming projects required. That way, we confidently calculated whether we had more people than we had a need to mobilise or vice versa.

Step 5 – Comparisons were drawn between cycle times and capacity utilisation of the specific members of the Engineering team from Exyte and MPM. We planned our resources to high levels of utilisation, and theoretically had a more efficient team and system with less wasted money on potentially unused capacity. The variables we were looking to directly reduce in this exercise were:

- Knowledge Transfer Risk
- Uncertainty for client and project teams
- Lack of impact to subcontractor performance
- Loss of integrated and harmonised workforce
- Decreased multi-tasking

LEAN INITIATIVE IMPROVEMENTS & IMPACT

In parallel to implementing these Lean initiatives, management were engaged in ongoing contractual talks, estimation completion, and prioritising equipment purchases. Then, the Project Management Team (PMT) arrived at the point of "potentially too late to implement" the JIT approach as the initial kick-off phase of the project was prolonging and gaining little momentum in a physical sense. In an assessment of the new project's estimation and engineering phase, it became apparent that stakeholders that could influence Exyte's ability to deliver to the proven Lean logistics techniques of Pull and JIT sat outside Exyte's and MPM's remit of responsibility. Thus, our focus, and one of the most significant impacts, related to collaborative engagement and onboarding of key stakeholders.

The two main outcomes Exyte and MPM were seeking to obtain were:

1) A focus on schedule certainty and an agreed strategy on how to implement an improved utilisation of project resources whilst remaining focused on client needs and project timescale.
2) Creating a smooth workflow and eliminating the waste of leaving potential key members of the new project in a role serving the current clients need for comfort and stability, but once again obtaining this whilst maintaining momentum on the existing projects close-out activities.

Having the ability to engage internal resources, controlling Exyte's Lean processes, better planning, and visualisation all gave us better predictability and better understanding among the workforce about the challenges we faced and how the process would need to be managed across all levels of the

project organisational chart. The economic impacts from Lean Construction on sustainability are mainly related to better planning and involvement – with involvement leading to better planning. The more we engaged with the relevant engineers, the ownership and appetite to participate increased. Involvement and constant interaction led to minimised use of resources and a greater focus on quality and productivity. This in turn led to less errors and changes, which directly led to lower costs, shorter lead time, and higher profitability. Not to mention that the JIT technique meant we had the right skillset lined up to transfer across at the time of needs rather than the client's time of want.

Figure 3. Exyte Lean Practitioners in Harmony

Whilst the process of skillset/resource transfer was beginning to gather momentum, and a somewhat successful outcome mobilisation costs and workflow disruption was occurring for Exyte on the new project, we did encounter an unforeseen issue which was the human factor of the team that remained at the existing project on the verge of close-out. This was overcome by a series of onsite discussions and town hall type meetings to explain the Lean strategy and reinforce to all project staff the importance of sustainable resource management rather than the need to adhere to traditional knee-jerk resource allocations. The process and techniques of the Lean strategy were explained and a simulated roll out of the JIT technique was demonstrated to the project team. Exyte and MPM then took the process further by seeking to understand how better to learn from the impacts of current project staff and ensure a reduction of the found impacts was implemented and monitored. The most frequently mentioned impacts were related to reduced stress and sick leave, increased productivity, more efficient use of resources, and improved quality.

By encouraging a harmony and understanding of a sustainable Lean resource pool, Exyte was able to benefit from increased ownership, responsibility, involvement, visualisation, and improved planning. Lean Construction has an evident impact on sustainability, but sustainability can improve Lean Construction delivery tremendously also.

COMPANY OVERVIEW

Roadbridge

COMPANY WEBSITE
www.roadbridge.ie

Roadbridge has been in operation since 1967, and is a Limerick-based global civil engineering contractor specialising in the international delivery of complete infrastructure projects across all sectors and for a broad range of clients and contract conditions. We have built our reputation on working collaboratively with our clients, offering them a quality service and product with genuine added value. Roadbridge is a fully resourced contractor. We have the experience, capability and a proven track record in delivering major projects safely, on time, and within budget. We employ over 700 people worldwide and are known as a great employer.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

Peter Byrne

Joe Gilmartin

As part of its continuous improvement programme, Roadbridge introduced the concept of Lean across the organisation through the "Our Lean Path" initiative. As part of this endeavour, we engaged with LBSPartners and several programmes were undertaken through our Limerick Head Office as a starting point.

This case study examines the analysis undertaken in our Estimating and Purchasing Departments that we felt could lead to less time wasted in the tendering and estimating process and make our entire process more efficient. It was discovered that the estimating process was being hampered by very manual processes, leading to a lot of time spent waiting for quotations to be received from suppliers. This information should be easily available through our "EVision" ERP System, which is populated by the site administration staff across our projects.

When the ERP was analysed, it was discovered that the pertinent information from orders on projects was not being entered fully, and thus information was being lost that could otherwise provide a valuable resource to the estimating team.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

In order to arrive at solutions to this problem, we decided to use the A3 Problem Solving Method for this undertaking.

Current Condition

As a starting point, we looked at the current conditions around a typical large tender being carried out at our Head Office. In conjunction with the estimators involved in the process, a round-table discussion took place, where we developed a process map of the programme. Next, that process map was converted into a form of value stream map so that it could be determined where the delays were coming into each tender. Then, from the value stream map of the process, we found that on a typical 88-day large tender process up to 23 days (i.e. 26% of the time) were spent waiting on information to be received from our supply chain in order to correctly price the project. This result came as a surprise to all involved, even the personnel closest to the process, as it highlighted just how much time was wasted. This result helped to develop a sense of urgency within the team to make a change.

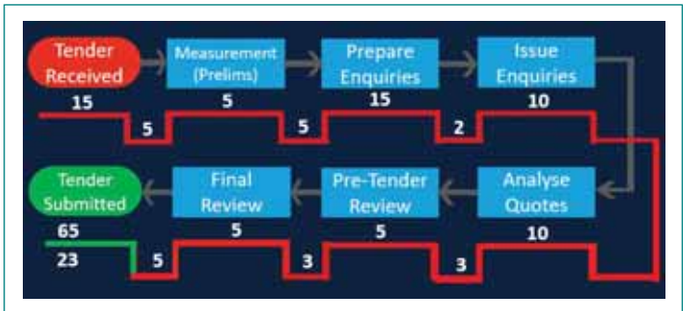

Figure 1. Large Tender High-Level Process Map

When investigating why the estimating team had not been using the ERP to source this information from our live projects, particularly for repetitive standard construction materials, it was discovered that the estimators were having issues logging onto the system initially, which led to the practice of using manual excel spreadsheets in isolation rather than a collective system. Those who were using the ERP complained that the information was neither accurate nor detailed enough, and thus they got into the habit of not using the system. At all times throughout this process, it was stressed to those involved that this analysis was going to be carried out in a blameless and collaborative fashion, which encouraged open and frank discourse. This was an interesting part of the process, as it was a major paradigm shift from our more traditional siloed approach to working.

An analysis of the information being inputted was carried out so as to determine the extent of the issue within the ERP. During 2018, we conducted a Pareto Analysis on the numbers of order entries by item type. The item type is a pre-populated items library for the user to utilise to enter information in a standardised format. Once we had created the Pareto, we then determined the 80/20 rule to see where the largest numbers of orders were arising.

Figure 2. Pareto Analysis of Order Entries by Item Type

The Pareto showed us that there were four types of order entries making up the top 80% of orders during 2018.

ENTRY %	ITEM TYPE	ITEM DESCRIPTION
29.39%	CRFM00007	C16/20 Concrete (20N strength concrete)
25.65%	CRBS00023	Clause 6F2 Stone
12.19%	MATR00001	Materials
9.12%	CRFM00019	C35/45 Concrete (45N strength concrete)

Table 1. Findings from the Pareto Analysis of Order Entries by Item Type

The entries for concrete and stone make perfect sense as they are a prime constituent of any civil engineering project, but the MATR00001 entries warranted further analysis, particularly as it accounted for 12.19% of entries. It was then discovered that this item type had begun to be used as a miscellaneous item, and, rather than entering the correct detail for purchase orders line-by-line, the information was being added in one line, as MATR00001, which told the person looking at the order nothing unless they could see the attached invoice from the supplier. The accounts team at Head Office would only add the invoice later, and so it was not always available.

A further Pareto Analysis was conducted on the projects where the 'MATR00001' item type was being used the most, to see which projects were the worst offenders and where our efforts to provide a solution would need to be focused. This Pareto highlighted that there were six projects that contributed to 80% of the orders being incorrectly added to the system.

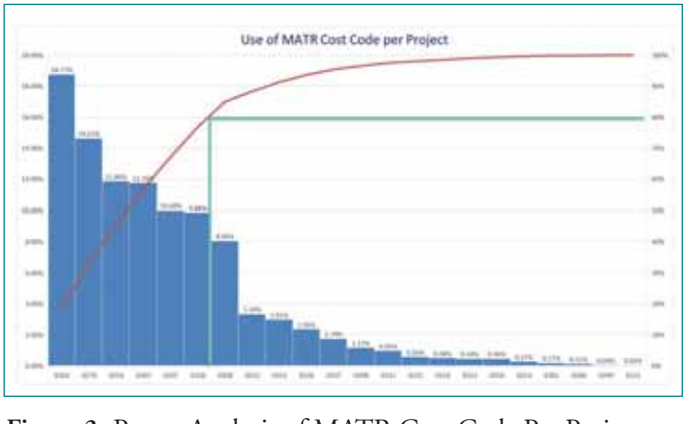

Figure 3. Pareto Analysis of MATR Cost Code Per Project

Goals/Targets

Once the extent of the issue was established, it allowed the team to develop a Gantt Chart for the implementation of a solution and for the setting of targets. The targets that were set for the programme were as follows:

- To reduce wasted estimating time over an 88-day tender by 15 days.
- To reduce the use of the MATR00001 item type code to 5% from 12.19% by February 2019.
- To increase confidence in the data being produced by the ERP and utilise this information in a tender submission.

Root Cause Analysis

In consultation with the estimators at Head Office and with several site administrators, a Root Cause Analysis and a Cause & Effect Analysis were undertaken. This was carried out as a team event at Head Office, and again it was stressed that all views could be discussed openly and honestly in a blameless environment.

Figure 4 highlights the results of the Five Whys Root Cause Analysis, showing that the root cause in this case was insufficient site administration staff in place on these busy projects.

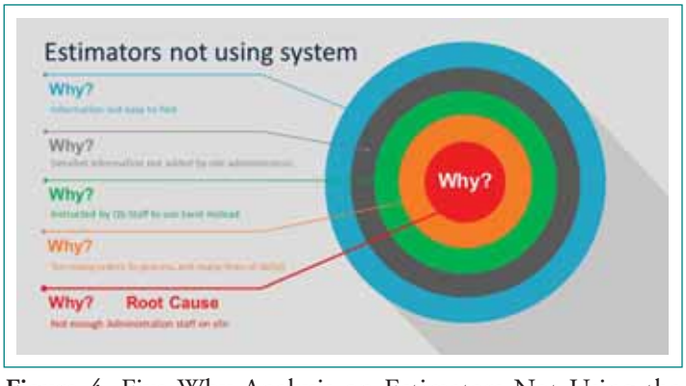

Figure 4. Five Why Analysis on Estimators Not Using the System

Cause & Effect Analysis

As an added exercise, and to determine if the same root cause would surface, the group also carried out a Cause & Effect Analysis, followed by Cause Screening, and this analysis flagged the same issues.

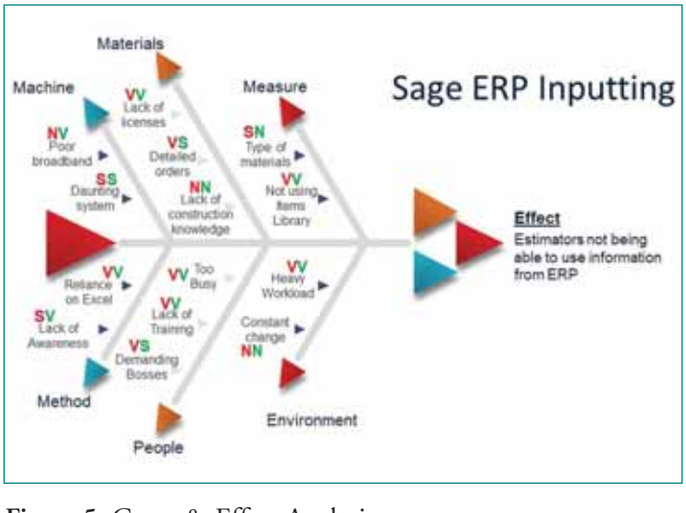

Figure 5. Cause & Effect Analysis

Countermeasures

With several key issues identified, we could make plans for implementation of action plans to solve the problems. The team, in consultation with the estimators and site administrators, developed a countermeasure sheet and assigned actions and action dates. Some of the suggested actions were ultimately rejected as ideal solutions; however, the process of opening communication was a valuable exercise in and of itself.

One of the first actions was to generate a live report from the ERP in an excel format that the estimators could use, rather than navigating the system. This meant that they could do an initial analysis of the costs within the system for particular materials quickly and see if they had sufficient information to proceed. The estimators favourably received this solution. The team then met every two weeks to ensure that action occurred in line with the programme and that progress occurred towards achievement of the aims of the exercise.

By bringing together the site administrators, head office accounts team, and estimators, we could follow through the entire process of raising orders at site level and demonstrate how that information flowed through to provide important information for the estimators. It gave all parties involved a better overview of how their actions became a vital part of the data chain and a better understanding of one another's roles. Several even commented on the fact that they had worked for years in the same office with others in the team, yet they had little or no appreciation for the actual roles played by their colleagues.

LEAN INITIATIVE IMPROVEMENTS & IMPACT

Some of the quick wins and achievements included:

- The countermeasure sheet highlighted a deficiency in the number of available licences for the system, so personnel were getting frustrated at not being able to login. This led to an automatic log-out of a user if they were idle for a period.
- To ensure that the numbers of concurrent users was not an issue, the ERP system licencing was split into UK and Ireland licences.
- The Head Office Finance team provided additional training on the use of the items library to all site administrators.
- System user training manuals were developed and made available through use of a cloud-based system.
- Extra administration staff are now hired for new projects as the initial mobilisation is one of the busiest periods for creation of purchase orders.

However, the biggest improvements were noted during a follow-up analysis of a value stream map for a tender. By being able to utilise the system effectively, the target of reducing estimating time by 15-days was well and truly beaten as it was discovered that up to 33-days could now be saved as a result.

Using this information, we calculated that this could lead to a saving in associated cost of €11,000 per estimator over a tender. There are four estimators at Head Office and three more in our regional offices, meaning a potential saving of €231,000 per year in time if each estimator were engaged in three large tenders per year. Ultimately, this also means that the team can tender for more work as they have extra time available, potentially leading to extra projects won in a typical year. This more than covers the cost of hiring one to two new site administrators who ultimately end up adding value to the system themselves. The site administration staff are now aware of the part they play in the wider organisation and how the information they input can flow through to assist in the winning of future work.

During 2018, a decision was made by the Board to move to a new ERP system during 2019, and, by highlighting the incorrect usage of the system during 2018, it means that inefficient information will not be transferred over to that new system.

Overall, this continuous improvement process has highlighted to us the need to challenge our actions and the habits we fall into constantly. It was a great exercise to undertake and showed how data can be analysed effectively to reduce waste and increase efficiency. It also highlighted the need to include those working at the actual Gemba of the particular process being examined, and that priority has to be given to making the process improvement meaningful for them.

Roadbridge

COMPANY OVERVIEW

COMPANY WEBSITE
www.collen.com

Established in 1810, and trading as "Collen Bros" until 1984, Collen Construction is one of the leading construction firms in Ireland, and we are extremely proud of our history and reputation for building quality and excellence. The company offers a full range of construction services, including management contracting, design and build, joint venture/partnering, and turnkey contracts. We have experience in a variety of project types, including residential, commercial, educational, retail, leisure, health, pharmaceutical, industrial, and conservation, and ranging in value from under €1Million to in excess of €300Million. We have longstanding relationships with numerous Clients and Consultants built up over the years, ensuring the company has remained at the forefront of Irish construction for two centuries. Our Client list is testament to the excellent service the company provides on every project.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHOR

Rebecca Reilly

Collen Construction has in the past trialled Lean on a small scale but has since moved strategically to a fully integrated Lean approach on all projects from design stage through to practical completion. This case project focused on pull planning with early collaboration between our Client, Design Team, and Subcontractors. The overall outcome was extremely successful with critical issues being identified and rectified prior to them becoming an issue for our operations team.

Collen had previously adopted the Last Planner® System (LPS) on a pharmaceutical project and observed positive outcomes. Collen engaged with a new client on a fast-track data centre in a design and built capacity, and viewed it as the perfect opportunity to fully embrace the pull planning process and engage with key stakeholders at design stage to gain the best possible outcome at operations stage.

The project chosen was a €160Million fast-track data centre project with Collen appointed as Main Contractor responsible for design and build. Initially we started with the master programme with the Key and Tag Milestone dates for each major element of works plus the equipment installation. Micro Schedules from the Vendors with key activities and requirements for their supplying Equipment were integrated into the master programme.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Once Collen made the commitment to embrace a Lean way of thinking, there was one clear objective at the forefront, namely to create greater value for the consumer while using fewer resources. Collen adopted Lean principles to eliminate waste through all processes and increase operational efficiency.

Collen found the Lean concept to be an excellent fit with our company that encourages planning, change and innovation in an ever-changing sector. In 2014, we engaged a Lean Specialist to come into the company and train our senior managers, both onsite and in the office, on LPS, with 20 members of staff receiving full 5-day training on LPS. The training was very successful as it encompassed all the elements that are standard practice to Collen and formalised these elements into a usable template.

Collen's greatest strength is one that has been forged over decades "To foster a collaborative one team approach and build lasting relationships with loyalty at the core". With this already well embedded in the company, the shift to Lean and Pull Planning at project level was well received.

Figure 1. LPS Planning at Collen Construction

Common Data Environment

The first element reviewed was information flow. Historically in the construction sector, the greatest barrier is the flow and

approval of information at early stages. With lead-in times onsite being reduced, there is not always time to put the necessary controls in place to ensure information is correct by the time it gets to the construction phase. This was an element Collen were keen to get right from the start.

The Collen team are very familiar with cloud-based platforms for integrated document control and transmission. The software Collen employ is "Viewpoint" (formerly "4Projects") which is similar to several other software systems on the market in recent years. This platform facilitated full and coherent collaboration with all key stakeholders in the process. It encouraged transparency towards critical project deliverables for all stakeholders, and, as a highly configurable platform, was amended to meet specific project demands, requirements, and constraints. The platform promoted efficiency with correct information retrieval, succession, and validation. It also drove consistency in quality protocols and standards. Ultimately, Viewpoint removed duplication and created transparency right through the project from feasibility through to commissioning and validation.

The most difficult barrier was to onboard all key stakeholders to trust the system and share information through it rather than reverting to traditional outlook emails for sharing of information. Our Design Manager on the project, along with the entire Collen team, consistently encouraged the use of Viewpoint and assisted any stakeholder who was unsure of how to use the system.

Figure 2. Collaboration Makes the Difference at Collen Construction

Full training was carried out with each stakeholder by our Document Controller on the file structure, namely, how to retrieve, upload, and amend information on the platform. As the majority of our subcontractors work across all projects, this training proved invaluable and increased usage of Viewpoint was witnessed across all projects.

Once we had all stakeholders on board, the natural progression was to integrate our Pre-Construction Services with the Lean approach in mind and examine how we could maximise value whilst minimising waste.

Communication

Communication is key to the success of Lean Construction. From the design stage, Collen ensured open lines of communication between all stakeholders, ensuring issues were mitigated prior to them arising onsite. Weekly Lean/Design Team meetings were held onsite, and, once the design was developed enough, our first LPS session was held onsite. This involved all key stakeholders and was one of the most beneficial meetings on our project schedule. Key milestones were set which allowed Collen and all other stakeholders to clearly identify critical times onsite and mitigate and plan for any issues that may arise. The session also gave ownership to all stakeholders of their key dates and commitments.

BIM

As part of the Lean initiative, Collen has fully embraced the BIM process and embedded it into every aspect of our daily activities. At a pre-planning/design stage, we have found BIM to be the last word from a visualisation perspective to clash detection. It is imperative that subcontractors are engaged from an early stage to ensure they are fully BIM-compliant and understand the importance of the process. Our trusted list of BIM-compliant subcontractors is paramount to the success of full BIM implementation on any project.

Figure 3. BIM at the Gemba Coalface

Housekeeping & 5S

Collen Construction prides itself on its strong approach to housekeeping onsite, and all materials must be stored correctly. This in turn avoids incidents, materials being damaged, and loss of control of materials onsite. It has also assisted Collen in reducing slips, trip, and falls onsite, and improved Safety across all projects. The 5S approach has brought housekeeping to the next level onsite and assisted our operations team greatly with the standardised approach it offers.

Preplanning/Forecasting

Weekly design team meetings were held to allow all stakeholders to review current works onsite and compile 4, 8, and 12 week lookahead to identify and mitigate against any issues and solve them before they affected the programme. A monthly pull planning session was held to review previous lookahead and plan for the next 4, 8 and 12 weeks. This system proved invaluable as subcontractors felt there was more transparency and ownership of the project than under the traditional siloed approach.

Eliminate Waste

The key objective was to eliminate waste in processes, materials, and time from pre-construction through to practical completion. All stages of construction were fully designed in BIM prior to the build commencing onsite. All models were coordinated and federated by the inhouse Collen BIM team. Weekly BIM coordination/design meetings were held onsite where all parties would interrogate the models to ensure they were advanced. The Logistics Manager attended all meetings to ensure the logistics schedule aligned with the 4, 8 and 12 week lookahead. Lookahead lead-in items were highlighted early, and progress updates were reported monthly at the pull planning meetings.

LEAN INITIATIVE IMPROVEMENTS & IMPACT

The overall implementation of a Lean approach to our Data Centre Project proved to be critical as we moved towards practical completion. The most notable improvement was through the utilisation of our Common Data Environment. To have a single source for all information from pre-construction through to practical completion was invaluable when it came to carrying out due diligence on our Handover/Safety File.

The compilation of the handover file documentation proved seamless through the Lean approach to doing it right first time (RFT). Traditionally, information given at Design stage through design team specifications, and requested at Tender stage from the Quantity Surveyors, was requested again at Submittals stage through our operations team onsite, and again at Practical Completion stage by our Digital Safety Provider. Using Lean techniques, we were able to direct our digital safety file provider straight to Viewpoint where they could retrieve approved information for each element of the project. This information had been previously approved by the design team through the submittals and verified through the Quality Assurance system onsite. This one change alone eliminated hours of rechecking documentation that had already been verified by Collen, the Design Team, and Subcontractors.

Figure 4. Collen Construction Factory Witness Testing

Another major benefit of the collaborative Lean approach was the increased participation and communication between our design team and subcontractors. Collen witnessed much greater collaboration and ownership from subcontractors through the utilisation of the pull planning method. Traditionally, dates slip and milestones are not met, but through the monthly pull planning lookaheads subcontractors felt more accountable to other trades as they had a greater understanding of how their delays impacted other trades. Through working together towards a common objective, stakeholders did not just focus on their own objectives but rather on the project objectives as a whole. When issues were identified, all stakeholders came together to find a solution rather than all stakeholders working in silo with minimal effect. Alone we can do so little, but together we can achieve so much.

The final most measurable impact of the Lean approach was the full utilisation of BIM, and BIM collaboration seamlessly occurred across all disciplines within the project. Our inhouse BIM coordinator federated all models to ensure clashes were identified early and mitigation measures put in place. Cloud access also allowed project teams to take the office to the field, with access to a live 3D model onsite.

By using BIM, our design team could plan and visualise the entire project during preconstruction and before a shovel hit the ground. These visualisations also allowed clients to experience what the space would look like, offering the ability to make changes before construction started. By having a greater overview from the beginning, it minimised expensive and time-consuming changes in the construction stage of the project.

Elimination of waste was realised through improved communication and the integration of standard operating procedures (SOPs). By challenging the traditional approach through the integration of new technology into SOPs, wastage in the processes were identified and removed. Closer collaboration with contractors led to fewer overall variations and fewer opportunities for claims as information was correct going out to tender packages. Improved overview of the project before commencing onsite allowed for increased time for prefabrication and reduced waste on unused materials onsite.

Modular prefabricated elements were utilised to their full potential on this project, and they greatly improved the quality of the finished project and safety onsite as they were fabricated in a factory environment rather than the traditional construction site environment. BIM data greatly assisted in the modularisation process, and it was used to instantly generate production drawings for manufacturing purposes, allowing for increased use of prefabrication and modular construction technology. By designing, detailing, and building offsite in a controlled environment, waste was diminished, efficiency increased, and labour and material costs reduced.

In the same way that many of these benefits save money, they saved time by reducing the time of project cycles and eliminating construction schedule setbacks. BIM allowed design and documentation to be done at the same time, and for documentation to be easily changed to adapt to new information such as site conditions. Schedules were planned more accurately and communicated exactly, and the improved coordination assisted the project by completing on time or early.

Overall, we could not recommend the Lean approach highly enough. Whilst some of our team were sceptical to start with, and they viewed Lean as a manufacturing-based tool, they soon realised it was a vital tool required for the ever-changing world of construction.

Figure 5. Collen Construction Lean Practitioners

collen 200
building excellence since 1810

COMPANY OVERVIEW

COMPANY WEBSITE
www.sheahancollinsconstruction.com

Sheahan & Collins Construction (S&C) is a young construction company offering Main Contracting, Fit-out/Refurbishment, Pre-Construction, and Project Supervisor Construction Stage (PSCS) services operating in the broader commercial sector, including hotels, nursing homes, multi-unit accommodation developments, and office buildings. S&C is driven to offer innovative, solutions-based methods to its projects in the safest possible manner. Motivated by 'building better through collaboration' S&C place emphasis on an inclusive non-silo approach to project delivery and is dedicated to applying Lean Construction principles and methods in-house and across its supply chain.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

Eoin Curham

Conan Doyle

The initiative for Lean was two-fold. Firstly, as a young company, the opportunity presented itself to 'start as we intend to go on' and commence the company's Lean journey during the company's infancy, building systems with Lean Construction in mind and incorporating Lean methods into our management systems. Secondly, during the early stages of the Dublin City project which is the focus of this case study, the need to apply a different approach to project delivery was recognised in order to successfully hand over the project to the client ahead of the new academic year in September 2018.

This was based on the obvious challenges such a project presented, plus experience – the same approach to project delivery typically led to similar outcomes, thereby highlighting the need for a different approach to effect the required outcome. The project consisted of a Design & Build (D&B) purpose-built student accommodation (PBSA) development in Dublin City comprising a 6-storey over-basement building delivering 128 bed spaces and ancillary spaces in a very compact site and with much of the layouts governed by existing planning permission. The development also utilised the entire footprint of the site, which only left public spaces remaining for staging construction works. Apart from the normal logistical challenges of such an inner-city site, including being on a main thoroughfare adjacent to a large school plus a significantly larger construction site next door, the building's four separate blocks and cores added to the significant challenge of making everything fit.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

The building design and internal floor layouts went through a number of iterations to optimise the cluster apartment arrangements so as to ensure rooms were adequately sized with efficient layouts, and also to address the limited floor-to-ceiling height for services routes and installations (the site was acquired with planning and thus increasing the building or floor-to-ceiling heights was not an option).

It was recognised early in the process that the project would therefore present certain challenges from both design and construction perspectives as noted above, as well as dealing with day-to-day construction operations and activities. S&C identified the opportunity to implement certain Lean Construction processes and tools to address or assist with the above. While some members of the project team were aware of or had prior experience in Lean, the majority of the team, including key trade partners, were not familiar with or experienced in Lean. The project commenced in 2017 and S&C quickly followed with the procurement of key trade partners (structure, envelope works, M&E services installations, lifts, interior fit-out), and with these appointments the Lean initiative commenced in earnest.

The main tools and techniques implemented were:

1. Early engagement of key trade partners.
2. Structured M&E design coordination meetings (design consulting engineers, specialist contractors, and main contractor in attendance to negate working in silos).
3. Implementation of Last Planner® System (LPS) for schedule management.

Early Engagement of Key Trade Partners

This led to overall improvement of project team performance over the course of the project. It also fostered a real culture of a project team which was evident to newcomers to the team. As trades joined the Project, evidence of an integrated approach rather than a siloed or segregated approach was confirmed.

The main parties were aligned to the client and project goals from the outset, leading to a more united effort in achieving this. Key players – the parties who ultimately influence the outcome of the project and hold responsibility for its delivery – understanding the project goals and client's critical success factors earlier than normal enhanced the likelihood of those success factors being achieved.

There was expert input into design of critical items at the

beginning of the design process, which led to improved design through enhanced coordination. Adopting the approach of 'the answer is in the room', all parties played their part in developing a workable design at the early stages of the project.

There was better coordination of design, leading to improved construction (safety, time, budget), reduced re-work, and less waste. Buildability and coordination challenges were dealt with via optioneering on exploring budgets, current technologies, materials and systems, service routes, and so on. All of this led to safer construction, improved productivity, and less waste.

It helped establish a more collaborative environment for the project with less confrontation and a greater willingness to address the issues via collective effort. This helped foster the team environment where there was genuine interest and understanding of each other's work and scope. The impact of each on the other became clearer with improved effort to make it all work.

It enabled key trade partners to engage with their respective supply chains earlier and in focusing on procurement, material, and equipment options, thus resulting in better value for the project.

Structured M&E Design Coordination Meetings

While detailed M&E services coordination meetings are a standard process on construction projects, S&C and the team identified this as an area that required particular attention. Given the aforementioned challenges presented by the building structure (floor-to-floor height, block and core arrangement), the sizing and routing of M&E services throughout the floors and in the main plant rooms located in the basement required significant effort from all parties to make the M&E systems work.

The architects and structural engineers used BIM for the building design, and this model was then shared with the M&E consultants and contractors for their systems to be inputted. This allowed sizing and routing of key services to be determined accurately, as well as locating key equipment in limited spaces. Front-end design and construction planning meetings were held by the project team where M&E services designs were worked through the project BIM model, with issues and clash detection worked through to avoid issues on site during the build.

When the M&E contractors commenced on site, weekly team meetings were held on site to maintain the collective effort though design development and to also facilitate Gemba Walks to review and address any design, spatial, or buildability issues that presented. Whilst not unique in having these meetings on site, the starting of the process as early as possible, and continuing on throughout the project, created and fostered the integrated approach with shared responsibility for addressing any issues and finding workable solutions promptly.

Implementation of Last Planner System® (LPS) for Schedule Management

S&C engaged a Lean Construction Ireland (LCi) commended consultant for introductory training on Lean Construction and LPS with the key trade partners on site. This was aimed at firstly giving background to Lean Construction to help the project team get an understanding of Lean thinking and processes, and secondly to put in place a structure and process to assist in the management of schedule and project delivery.

Figure 1. Project Team Trained on Lean Construction and LPS

The focus on LPS came from a combination of research on its implementation, traction within the local sector on its use and reported success, and a clear understanding by S&C that traditional Critical Path Method (CPM) scheduling methods are limited due to the following:

- Inadequate of input or buy-in by trade supervisors.
- Lack of understanding of the project plan as presented on Gantt charts, etc.
- Absence of clear tracking of progress on day-to-day or week-to-week as work is detached from the CPM schedule.

S&C understood and implemented the following five elements of LPS:

1. Master scheduling – setting milestones and identification of long lead items (what *should* be done).
2. Pull Planning – specifies work handoffs and identifies conflicts that will impact work (what *can* be done).
3. Make Work Ready Planning – utilising lookahead planning to confirm work is ready for installation (what *will* be done).
4. Weekly Work Plan (WWP) – team makes commitments to perform defined work in a specific manner (what the team will *do*).
5. Learning – measuring percent plan complete (PPC) and conducting root cause analysis of failure, and conducting lessons learned for future improvements.

Figure 2. Pull Plan for Mock-Up Suite

With considerable effort over the course of the project, the team realised the benefit of LPS with the process providing

ongoing opportunity for rich learning. The commitments made in WWPs as a result of a collaborative process became more honest and meaningful, with genuine efforts to identify/remove constraints, and a keenness to have honest conversations when planned tasks were not completed for learning opportunities.

LEAN INITIATIVE IMPROVEMENTS & IMPACT

The project was completed on time and within budget, with Practical Completion achieved July 2018 in advance of the start of the new academic year, thereby allowing the client requisite time to hire and train key staff ahead of a busy opening period.

Schedule Improvements
Practical Completion was achieved in 42 weeks from completion of the ground floor slab (completion of 6-storey structure, envelope, internal fit-out of 128 bedrooms, ancillary spaces) and this could not have been achieved in that timeframe if LPS had not been used. LPS negated earlier project delays on site and facilitated project completion through primarily normal working hours, without significantly increasing crew sizes.

Lessons Learned
A Lessons Learned session held with key members of the project team (client, design consultants, key trade partners, main contractor) yielded some valuable findings along with overwhelming endorsement of the Lean initiative undertaken. The highlights regarding improvements and impact were the improved quality and safety, collaborative approach to teamwork, the use of LPS, the resultant change in people's mindset, and an improved project team feeling overall.

Last Planner® System
With LPS, the Villego® simulation training was a seminal moment in people realising the positive impact of effective communication and working together. This contributed significantly to the change in mindset on the project, and it had optimal impact as it occurred at the outset of the Lean journey.

Figure 3. Villego® Training with Key Trade Partners

Also, the introduction of Pull Planning led to improved and consistent flow of work, enabling confidence to grow amongst the trades with regard to schedule commitments being made. Trades were also able to maintain smaller crew sizes as a result of the improved flow.

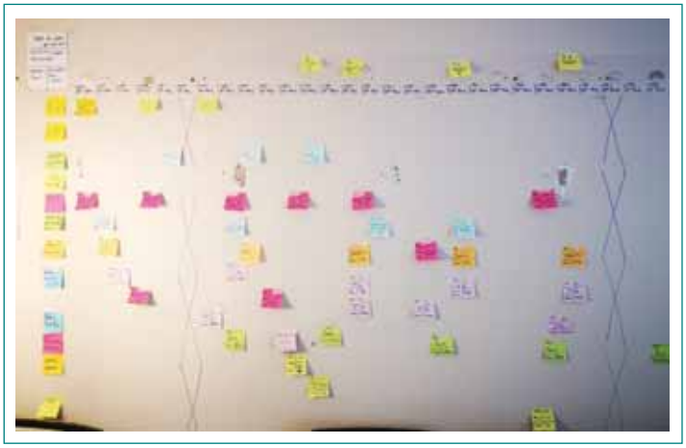

Figure 4. Pull Plan for Part of the Works

Safety and Quality Improvements
The benefit of improved flow area-to-area and floor-to-floor resulted in work being carried out much more safely. While pressure remained to deliver, it was in a controlled fashion due to reliable commitments on productivity being made and achieved. This also improved quality with a 'right first time' approach being encouraged throughout and achieved for the most part. Re-work rates were reduced, again improving flow and also reducing costs and waste throughout.

Early Engagement Benefits
As noted above, the goals of early engagement of the project team were evidenced in the integrated and collaborative approach. Improved daily and weekly communication was as significant as it was simple – people talked and trades supervisors engaged effectively on a daily basis. Morning huddles were anticipated and attended consistently in large numbers as their benefit quickly became apparent to all. Questions were asked of each other to gain an understanding of what the other needed and how they could be assisted in their work.

Integrated/Non-Silo Working
The electrical contractor's project manager noted it was the first project he worked on in a non-silo environment. As a result, he now approaches work with a different mindset. This was echoed by the mechanical contractor, who remarked it was the best project he had experienced from a site communication perspective. This is not to say there were not problems, delays or site issues, but rather that the difference on this project was the approach to dealing with each of these issues as and when they arose. People offered help, expertise, solutions, support, ideas – a problem became a team problem and a solution came from the team for the team.

Long-Lasting Impact and the Future of Lean at S&C

The impact of the Lean initiative was immediate on the project with enthusiasm and buy-in evident from the initial training. It should be noted that to maintain the initial impetus, a significant and concerted effort by the project team was required. Again, it should be noted that this was not without challenge and periodic 'recalibration' of the effort was required – stock taken, opinions and ideas given, processes tweaked, and so on.

Long-term impact has materialised in the form of S&C now deploying Lean as one of its core management systems. It has recently been successfully deployed on a hotel refurbishment project with some of the same project team members, and is becoming embedded within the group and some of our key trade partners. Also, a culture of organisational continuous improvement has evolved on the back of the Lean initiative, with everyone in the group encouraged to contribute to the enhancement of the processes. The target future state is that S&C is recognised for Lean project delivery with a solid core set of processes deployed on each project, and we become a contractor of choice for our clients based on track record, and for key trade partners based on an integrated and collaborative team approach to project delivery.

Key Benefits and Outcomes

Some key benefits and outcomes arising from the Lean initiative are:

- Understanding and appreciation of the what Lean is and how it can be applied to have positive impact on a construction project.
- Positive change in mindset of project participants – integrated, non-silo approach, while having an awareness of waste.
- Active participation in collaborative planning and problem solving.
- Buy-in to daily collaboration (morning huddles) and weekly LPS meetings based on evidential benefits to the management of the project.
- Key trade partners have embraced the learning and the tools used on the project, and are implementing on new projects.
- Key trade partners are adopting Lean principles within their own organisations as a result of their experience on the project.

S&C

Sheahan & Collins Construction

COMPANY OVERVIEW

CLANCY
Built on Partnership

COMPANY WEBSITE
https://clancy.ie/

Founded by Mr. John Clancy in 1947, Clancy is an indigenous Irish company that enjoys three generations of continual development. Today the company has developed into a strong and innovative organisation, with vast experience in all sectors of the construction industry throughout Ireland. Safety is paramount to all work we engage in and we are proud to be Safe T Certified. Investment and implementation in areas such as BIM and Lean Construction have propelled Clancy forward, and have given the company the platform to become one of the leading contractors in the country.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

Aidan Maher

Aidan Clancy

Clancy has been in the construction business since 1947 and has constantly evolved over the years. Lean thinking, tools and techniques have been introduced to the Clancy team since 2014. This transformation happened gradually at first and it has now expanded to the point where it is generating its own momentum. Lean Construction is now a core part of how we approach each project.

Part of our mission is to continuously improve and adapt to the newest industry standards and technologies available to the construction industry. This is driven by the young and energetic team within the company and guided by the excellent resources provided by Lean Construction Ireland.

Change can be hard to implement successfully and at Clancy the change management focusses on three key elements: People, Process, and Technology (PPT). We recognise that focus needs to be put on these three areas in order to continuously improve our processes.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Over the past number of years, Clancy has been looking for ways to reduce waste across all its construction sites to improve overall project outcomes. Recent Lean initiatives include:

People
- Creation of the Continuous Improvement Committee
- Introduction of BIM, Lean and Last Planner Champions throughout the company

Process
- Overhaul of the Content Management System
- Improved internal auditing of processes, improved "lessons learned" procedures
- Improved visual communication

Technology
- Rollout of new software systems, including: "BIM 360", "Conquest", "Bluebeam" Hilti "On!Track"
- Additional hardware including robotic total stations, and mobile devices.

All of these initiatives are designed to improve collaboration and minimise waste, thus allowing us to deliver projects better, faster, together.

The Current Issue

While many improvements have been made in recent years, internal research from the Continuous Improvement Committee showed that programme over-runs remained a significant contributory factor to poor project performance. In particular, the committee zoned in on some key performance indicators (KPIs) across the projects, namely:
- Project Type
- Project Value
- Project Planned PC date
- Project Actual PC date
- Requests for Further Information (RFIs) generated per project quartile
- Number of defects identified by the project architect

The committee analysed these KPIs, wastes, and the various root causes across multiple projects and concluded that the existing forward planning techniques were no longer sufficient to meet performance targets.

Traditionally, projects had been managed using a top-do hierarchical approach to resource allocation and planning. The project manager on each site would create a fortnightly look-ahead programme outlining what each subcontractor was to deliver in a given period. This meant that resources weren't always allocated appropriately, and milestones weren't always met on time. If a subcontractor didn't achieve their targets it often led to waiting and rework waste.

The traditional template used did not encourage the planner to review the resources required or to confirm what percentage of the overall task was to be complete at any given time. The template also failed to prompt the question for "Make Ready Needs" which is fundamental to any planned task being completed. While this is a simple question, it is one that may be overlooked amidst the many tasks that a

project manager must carry out on any given day. The template also lacked an adequate review function, where a project manager must "look back" and assess if planned works were completed on time.

Another area identified for improvement was the timely issuing of RFIs to the design team. The traditional project management techniques generated waiting waste and poor workflow.

The Proposal

This analysis, combined with recent successful trials of the Last Planner System (LPS), lead to the committee recommending the roll out of LPS on all sites. LPS is an alternative to the traditional method of project planning. Traditional methods of construction were driven on productivity versus time where critical path tasks were monitored closely and stakeholders working on the project worked in silos.

LPS takes a holistic approach to a project where stakeholders are asked to work in collaboration to ensure workflow and better transitions between each trade. Words such as Plan, Do, Check, and Act are used to describe a process within the LPS system where these actions are required on a continuous basis during the project duration.

Planning refers to a review of the master programme, a six week look-ahead programme, pull planning sessions, and finally the fortnightly programme. Once these are in place, the requirement to complete the works as planned can take place and agreed milestones can be met. It is critical to review the plan to ensure compliance and close out any incomplete works.

Constant review of future works allows project teams look ahead and identify potential stumbling blocks in time to address them. By issuing RFIs early in the project cycle, waiting and reworking can be minimised. When this review process is in place it allows design teams and clients to keep ahead of the construction works. It also fosters a better working relationship between the design team and contractor, which in turn allows a project run smoother.

Implementation

The LPS system has now been rolled out across all Clancy sites. LPS training was completed by several senior managers who now act as champions within the company. A standard wish list to implement the Clancy LPS system was created to simplify the set-up stage for each project. New templates such as the fortnightly programme and daily white board meetings were created, and site teams have been trained to use these successfully.

The LPS system has been backed by Clancy senior management and its significance for the overall functioning of the company has been highlighted during company management meetings. This has been another effective element for the implementation process.

LEAN INITIATIVE IMPROVEMENTS & IMPACT

Following the company wide rollout of LPS, research was undertaken to quantify the impacts on project outcomes and the specific impact on programme and defect performance. The research covers data from the 15 most recent projects completed.

These projects vary in scope, size, and location, but when aggregated, allow us to assess the impact of LPS under a number of headings. Each construction project has its own unique challenges but by controlling for project value we can make meaningful comparisons across different projects. Four of these were completed using LPS and the remainder were completed using traditional project management techniques.

The analysis shows that LPS contributed to:

- 27% reduction in programme over runs; and
- 32% reduction in defects.

RFIs

One of the benefits of LPS is that all stakeholders are involved. This allows the right people to raise queries at the earliest possible time. To assess the impact of this, we divided each project into quartiles. This allowed us to understand what stages queries were generated on site and if LPS was leading to earlier answers. The results are shown in Figure 1.

Analysis of the data shows that the actual quantum of RFIs generated has increased on the four LPS projects. The critical finding here though is not the volume of RFIs, but the timing of them. There is a clear shift towards submitting more RFIs and submitting them earlier in the project cycle.

This graph is evidence of a clear shift in the mindset of the construction teams. By increasing the forward planning in the earlier stages of a project, more resources are freed up to focus on programme and quality as the project reaches conclusion. This is also very positive for design teams and clients as they receive queries ahead of time for the most part, so it allows them time to get answers or make decisions.

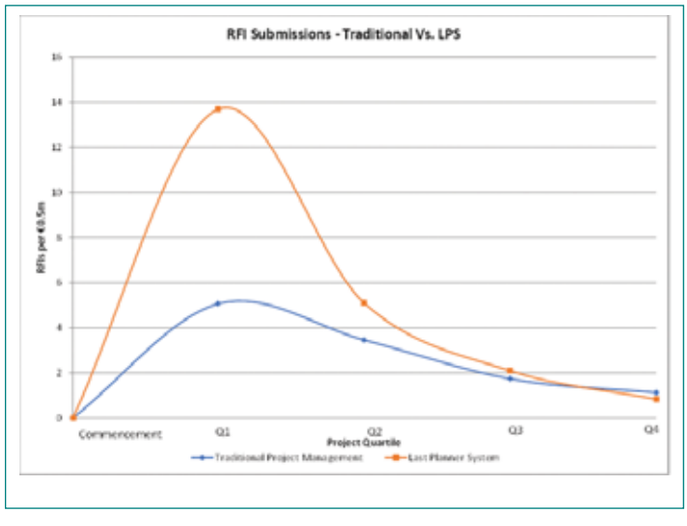

Figure 1. Impact of LPS on RFI Timing

This directly contributes to a reduction in waiting, rework and over-processing. The impact of this is further seen in the following results.

Programme

Programme was analysed by comparing the planned Practical Completion (PC) date to the actual PC date. Figure 2 shows that the introduction of LPS contributed to a 27% reduction in programme delays across all projects.

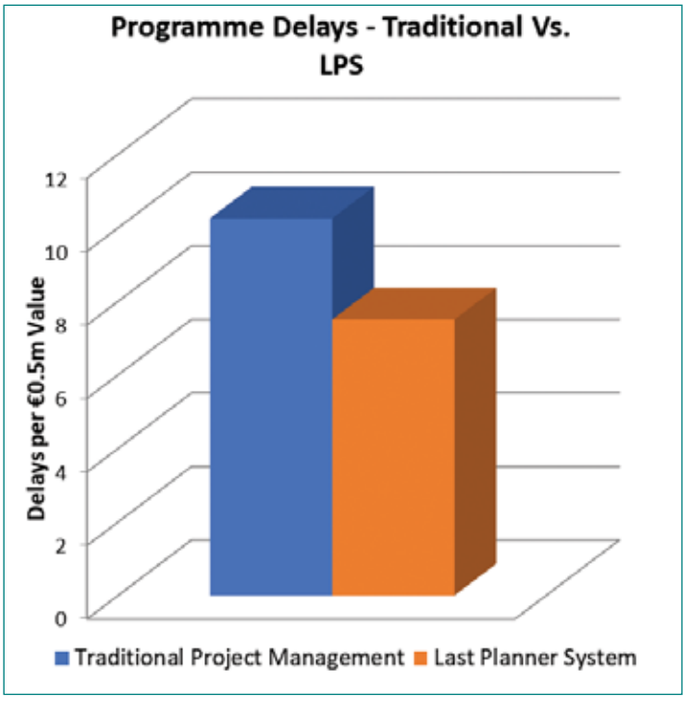

Figure 2. Impact of LPS on Programme

While there are still delays, it is clear that there has been a significant improvement within the projects using LPS. It should also be stated that no continuous improvement project occurs in isolation, so one would expect that this improvement is also generated in part by improved procedures and systems generally, particularly increased use of BIM360 by project teams.

Defects

The final metric examined was the number of defects, in the form of snags, identified by the lead architect. This is a wide-ranging metric that helps us understand how well a project was managed throughout. Commitment to getting a task done right first time (RFT) is a key element in minimising waste in any project.

Figure 3 demonstrates a 32% reduction in defects across all projects. As with the programme impact, this cannot be said to be solely due to LPS, however, it is undoubtedly a significant contributory factor. BIM360 has been used on all LPS projects and this also helps to more efficiently identify actions and close-out on quality issues as early as possible. This, in conjunction with the fortnightly programme, has had a huge impact on defects. Site teams must report on percentage complete and make ready needs which ensures that ongoing works are only removed from the programme when they are 100% complete. These reports are reviewed by senior managers within the company to track each site's progress.

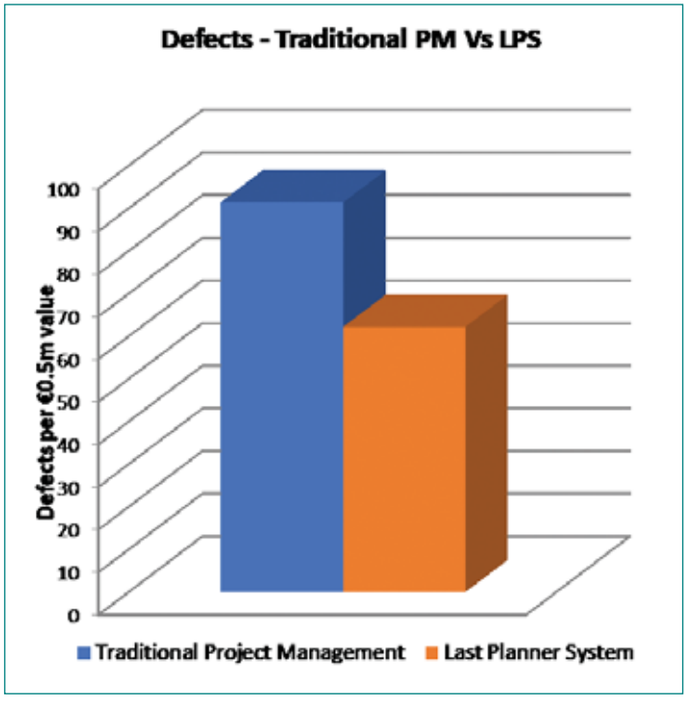

Figure 3. Impact of LPS on Defects

Conclusion

The metrics and outcomes presented show a clear justification for the continued use of LPS within the company. As more contractors embrace the system, and as more subcontractors become familiar with it, there is scope for ongoing gains for all stakeholders.

CLANCY
Built on Partnership

COMPANY OVERVIEW

COMPANY WEBSITE
www.alucraftgroup.com

Alucraft has a longstanding history of delivering exceptional architectural glazed façades in both Ireland and the UK. We work in tandem with visionaries in architecture and construction from the conception stage through to project handover, providing cost plans, design, engineering, manufacturing, installation and maintenance of our façade systems to meet the aspirations of our client's design intent and quality finish. Operating since 1975, and with a turnover of circa €44Million in 2018, we currently employ over 180 across Ireland, the UK, Poland and the Philippines. Our systems include Unitised and Stick Curtain Walling, Roof-Glazing, Point-Fixed and Structural Glazing, Windows, Doors, and Cladding Solutions.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

Áine Hargadon

Susan Clancy

This case study outlines the Lean journey within Alucraft Ireland. Alucraft's vision is "to be the specialist façade contractor and employer of choice in Ireland and the United Kingdom". Having experienced a huge growth spurt in the last two years, it was imperative that we reviewed the foundations on which our company's success is founded. We therefore decided to apply Lean thinking as we recognised areas within our business that would benefit from its implementation along with the value-add to our clients.

Our Lean journey commenced when we engaged with BPI Services to focus management on their aspirations for Alucraft. This involved revaluating the Mission, Vision and Values, and from there strategic goals were developed. We focused on three key areas which are paramount to our vision; People, Growth, and Delivery. We identified key projects, and from there a Master Continuous Improvement (CI) Plan was set out for 2018/2019. We applied the DMAIC methodology across all the identified projects: Define, Measure, Analyse, Improve, Control.

Projects implemented and achieved in 2018 include:

- Skills Matrix Development
- Streamlining Flow of Information and Processes from Design Stage to Manufacturing
- Implementing a Graduate Programme
- Investment in 3D Software
- Review of Annual Leave
- Standardised Estimating Practices
- Review of Residential Market Opportunities
- Alucraft CWCT Tested Rainscreen System

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Skills Matrix Development

As the headcount in Alucraft has almost doubled in the last 2-3 years, it had become harder to keep track of the required skills, existing skills, and skill gaps in our company. At the beginning of 2018 we had no standardised method for analysing skills, and this left us with the possibility of employee skills being under-utilised and a number of departments with skill gaps. Our goal for this project was to develop a process to identify the gaps and to develop a visual skills matrix graphic. An internal team was set up with members from an initial three departments which were to trial the matrix: Production, Design, and Site. Our Production Manager commenced mapping his team with role specific skills and populated a matrix. From there the project moved to our Design team with the same skills matrix template utilised under new headings, and finally our Site department was reviewed. The project ran smoothly until we reviewed sub-contractor skills – feedback was populated for a number of sites but was difficult when the sub-contracted employees on a site changed frequently. As such, it was decided to modify the scope of the project and remove sub-contractors, focusing solely on direct site employees. The project resulted in a visual aid where gaps are easily identified, it is easy to assess what level an employee is currently at, and it highlights areas where further training and education are needed. This paved the way for a personal training development plan to be implemented for each employee.

Streamlining Flow of Information and Processes from Design Stage to Manufacturing

This project involved a cross-functional group from Production and Design working together to, firstly, gain an understanding of the unitised project they were embarking upon. Secondly, this team needed to develop a suitable way to track the progress of information and process from the start to project completion. This team used a unique "Post-it" planning process to assist this, hosting weekly meetings on the unitised project to gain a status. This mechanism allowed

Figure 1. Master CIP Tracker

the team to work really well collaboratively, and like many other teams they went through the stages of team development, Forming, Storming, Norming to reach an incredible Performing stage. This visual tracking system not only allowed the team to communicate more, understand each other's roles and support one another, but it also allowed the team to meet, and in some cases, exceed their delivery timeframes and meet their invoice target each month. The team have adopted this approach so much that they decided to extend this methodology to all their projects going forward.

Figure 2. Streamlining Flow of Information and Processes CI Team

Implementing a Graduate Programme

As a specialist sub-contractor, we face challenges in attracting young emerging talent to our company with stiff competition from main contractors and leading consulting firms. Due to the recession, many potential employees emigrated or left construction related careers. This left a void and affected our ability to recruit new and emerging talent, in particular for our Design Office. To tackle this problem, we initially set up a team to brainstorm how we would attract graduates to our company. From our brainstorm we developed an action plan.

The project involved relationship building with specific colleges in Ireland where prospective employees are currently in education. We reached out to specific departments and organised presentations with second- and third-year students with the aim of recruiting two summer interns for 2018 and two graduates for September 2019. We also attended career days and graduate fairs to expand the recruitment net and to build brand recognition within the third level sphere. A key measure of success was the number of applicants we received which grew from 9 for our 2018 Summer Internship to 90 for our 2019 Graduate Programme, an increase of 900%.

Figure 3. Alucraft Stand at Grad Ireland 2018

Investment in 3D Software

We commenced this project when we recognised the potential value-add for our clients. In this ever-evolving market, our clients were focusing more and more on 3D modelling and visualisation, and we wanted to deliver a seamless mechanism to bring our clients through our façade design. The project commenced with a design capabilities analysis where our current software was reviewed, and a cost and capabilities comparison was carried out for potential 3D software. We had to determine if the 3D software could be integrated across the three design stages within the department – Design for Architecture (DFA), Design for Production (DFP), and Design for Pressings (DFPP) – and therefore trialled it on complex parts of the façade on a project. We ran this trial in conjunction with the lead architects on a specific project, and on the back of its success we rolled out our 3D modelling to other ongoing projects. The project had dual benefits:

- internally it meant we invested heavily in our employees; and
- externally we are meeting and exceeding the expectations of our clients.

We now have over 50% of our design office fully operational on BIM 3D software. Our strategy is to have a 'cradle to grave' suite of 3D software that will satisfy the needs of our clients.

Review of Annual Leave

Historically, all Alucraft employees followed the holiday schedule set out by the Construction Industry Federation (CIF) which meant that the company shut down for the two set weeks during summer. Listening to the voices of our employees, a request was submitted to review this practice and a CI committee was set up. The committee comprised of individuals from each department across the

company and they were tasked with the objective of developing an annual leave policy which met the needs of the individual and the business. As part of the analysis and benchmarking activity, the CIF and other companies of similar size within the industry were contacted to get an understanding of annual leave practices elsewhere. A cost comparison analysis was then carried out and a mock annual leave schedule was set up for a specific department to show the feasibility of flexibility of annual leave. The proposal was created and presented to management for approval incorporating a number of guidelines for the change of policy. Management agreed to a year trial for 2019.

Standardised Estimating Practices

While carrying out a Gemba walk of a project lifecycle, we identified the handover process from the estimating department as being an area where significant value could be added. The current handover system did not cover all the requirements of the individual departments that relied on this process to fully set out their scope of works. There was also a need to reduce post-handover queries.

The project commenced with a review of each department's requirements. Brainstorming sessions were held and requirements were defined and prioritised. The tendering procedure was also reviewed in order to streamline information for the handover document. When the various feedback was collated, the resulting new handover document was trailed on a medium-sized project. Further tweaks were made to the layout and information, and a final handover document was rolled out for a large-scale project. Feedback from the brainstorming team has been very positive and post-handover queries have significantly reduced by 70%.

Review of Residential Market Opportunities

We identified this project as being business critical during the CI process as we recognised the need to have a more balanced business portfolio of residential and commercial projects. The following steps were carried out:

1. The project commenced with a review of the market growth and also required a better understanding of both the Irish and UK market, suppliers and their offering.
2. We defined a specific number of screens that would be most likely used on high-end to mid-range residential and industrial projects.
3. From there we chose several system suppliers who we requested to complete a questionnaire based on a performance matrix. The evaluation criteria included both technical and commercial criteria along with the accompanied support provision from the suppliers.

On analysing the residential market, we identified:

- the differentials associated with this sector compared with commercial projects; and
- site requirements, installation timeline, contract management, approval processes and legislation differences between Ireland and the UK.

We are now in a position where we know the exact type of project we want to tender for in the residential market and our preferred supplier network.

Alucraft CWTC (Centre for Window and Cladding Technology) Tested Rainscreen System

While process mapping the manufacturing stage of a project's lifecycle, we identified the outsourcing of rainscreen cladding to be disadvantageous to our business in terms of cost, control, and the time it consumed in terms of procurement and contract management. We therefore began the process of designing and completing our own tested rainscreen system which would meet all CWCT, relevant standards, and performance specifications. This involved the design and engineering of prelim calculations and detailed drawings of the system which was then manufactured in our facility and sent to Building Envelope Technologies (BET) for testing. The rainscreen system successfully passed testing and we are currently working on increasing the range.

LEAN INITIATIVE IMPROVEMENTS & IMPACT

This programme brought the entire leadership of the Alucraft Group through a programme that has been truly transformational. It helped them understand how to analyse and improve their system performance. It gave them the aids to be in a position to behave as Lean Leaders in providing direction, driving performance and developing people.

Throughout the workshops, the Senior Leadership Team experienced a diverse number of Strategy, Lean, and Change Management tools, and in the latter workshops facilitated a number of breakouts with the extended leadership team using some of those tools. The programme challenged their current thinking and delivered a clear leadership accountability to deliver CI initiatives and a cascaded set of metrics and targets that tells them whether they are winning or losing.

The CI process brought together representatives from each of the departments around the company who identified the roadblocks in the way of delivering on our key pillars: People, Growth, and Delivery. This collaborative method meant that Lean thinking was implemented into each department in a holistic manner. The tactical improvement plan which grew from this meeting of minds aligned to our business strategy and ensured that we were focused on the correct projects.

The onboarding of Lean thinking within Alucraft began in 2017 and the following outcomes were delivered:

- Vision Statement that generates excitement and aligns the organisation around a common future state was reviewed and confirmed.
- A 2-year Strategy Roadmap was developed with the input of the organisation so that there is a common understanding of the critical issues facing the organisation and what needs to be done about them.
- Tangible Tactical Plan that translates strategy into measurable and meaningful projects that can be delivered on the ground.
- Prioritisation and sequencing of improvement projects that ensure the organisation does not become overwhelmed by the pace of change
- Clear leadership accountability to deliver improvement initiatives.

Figure 4. Senior Management Team Vision and Mission Brainstorm Output

Benefits of CI Programme

- As part of our CI programme, the senior management team reviewed and updated the Vision and Mission Statements for the company. This was an important step for our team in defining, both internally and externally, what Alucraft do and to set a long-term goal for the future. We wanted to take the next step which involved setting new Guiding Principles (GP) for the Alucraft Group and defining what those values will mean to all individuals within our organisation. These GP will form the backbone of our organisation and, when implemented and demonstrated by each individual, will underpin the success of our vision for the future.
- Brainstorming and the use of Post-its have become a regular exercise in meetings throughout the company outside of the CI identified projects as Lean thinking and its benefits has been adopted and embedded throughout the company.
- While the primary objective of implementing Lean into our business is to see benefits to the bottom line, we noticed a massive culture shift within the company. The CI programme breathed a collaborative life into the business. Departments work together in greater harmony than they have done previously. Projects have had a knock-on effect as they have highlighted areas that need attention and have been added to the programme for 2019/2020.
- We currently have 10 people within the company undergoing Green Belt training who will become part-time Lean Six Sigma programme members able to lead a cross-functional project team using a range of Lean Six Sigma project management, problem solving, and statistical analysis tools.
- We have a CI board in the main thoroughfare of the building which houses information on completed, live, and upcoming projects. The board also houses the live projects' A3s where the status of the project is easily identifiable with the use of visual aids. The visual aid selected was a simple traffic light system to indicate the current status against pre-set milestone dates. Regular CI briefings happen where project sponsors are accountable for updating board information and reporting the status of ongoing projects. These weekly briefings hold the team accountable and ensure that completion dates are met and that programmes are kept on track.

Future of Lean in Alucraft

The future of Lean looks bright in the Alucraft organisation:

- We continuously engage more staff in the programme.
- We are developing a number of Green Belts to carry the torch for Lean thinking in their departments and cross-functionally across the company.
- Our UK office has set up its own CI programme and taken learnings from the Dublin office.
- Our sister company, Williaam Cox, has also set up a CI programme, with many projects currently live and one of which is aimed at making the company paperless by September 2019.

Figure 5. Williaam Cox CI Team

ALUCRAFT
REFLECTING EXCELLENCE

COMPANY OVERVIEW

COMPANY WEBSITE
www.dpsgroupglobal.com

DPS Engineering is a global Project Management and Engineering company providing project and programme management, procurement, design, construction management, health and safety management, commissioning, qualification and start-up. Our sector expertise spans many markets including Biotechnology, Pharmaceutical, Medical Technologies, Oil and Gas, Advanced Technology, Food & Beverage, Energy, Science & Education. DPS has more than 1600 employees globally, with 14 offices located in Europe, Middle East, Asia, and the USA.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHOR

Richard Casey

This case study examines how Lean principles and tools can be utilised to improve construction projects schedules and costs via the identification and mitigation of delays. The goals of this project were to determine how Last Planner® System (LPS) constraint data could be utilised to identify activities to complete a Lean intervention on one of DPS's ongoing construction projects, and if an improvement roadmap could be generated. To establish a baseline for comparison, DPS completed a literature review of construction delays on international projects. DPS then used delay data generated by the LPS of schedule management from a project in flight to identify opportunities for improvement in a Kaizen event. Lean tools and processes were then utilised during the Kaizen to identify solutions and implement the improvements.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

The project was completed in three phases:

i. Phase 1 – DPS determined common causes of delays on construction projects by developing a ranking table of construction delays for comparison with existing DPS construction projects.
ii. Phase 2 – DPS then determined the most common causes on delays on construction projects currently being managed by DPS ATG by researching six weeks of data from LPS variance information; collating and analysing the variances into a Pareto of opportunities; using Pareto data to identify activities for investigation; and utilising direct observation to determine the current status of labour productivity and the main causes of delays on construction projects.
iii. Phase 3 – DPS made targeted improvements on an ongoing construction project by facilitating a Kaizen event and utilising Lean tools to identify and make improvements.

Implementation

A project steering team was formed consisting of five project managers from DPS ATG. Four of the project managers were directly responsible for the construction management activities on the projects, and the fifth manager was utilised as an independent observer for the data gathering and progress of the team. The agreed goal was "to determine if Lean tools could be utilised to identify projects that could reduce the overall construction execution schedule by >10% and corresponding costs by >10% by the reduction of delays identified by analysis of LPS information". The case study was completed in four stages.

Stage 1 – Data Gathering

Level 1 data analysis – LPS variance. The team gathered 6 weeks of variance (delay) date from the LPS constraint data and collated and characterised into a Pareto.

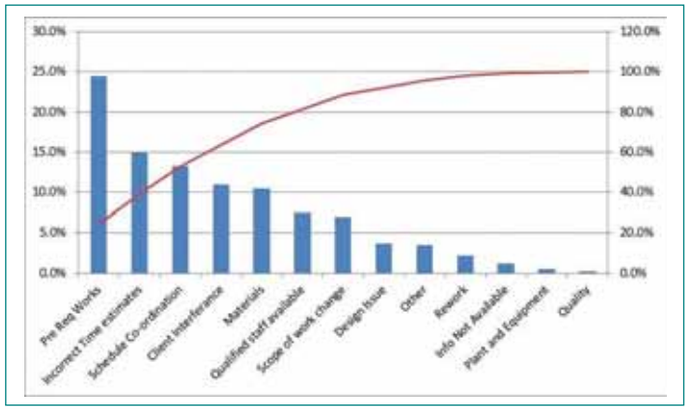

Figure 1. Most Common Delays in Construction Execution on DPS ATG Projects

On review of the findings with the project steering team, it was agreed to focus on determining the causes of prerequisite works and incorrect time estimates. The agreed goal was restated as being "to determine if Lean tools could be utilised to identify projects that could reduce the overall construction execution schedule by >10% and corresponding costs by >10% via the reduction of delays during prerequisite works and improving incorrect time estimates".

Level 2 data analysis – LPS Percentage Plan Complete (PPC). DPS completed a deeper analysis of the PPC performance to identify what project activities caused the most prerequisite and incorrect time estimate delays. The following activities were identified as low PPC performing (avg. <70%):

- Containment Installation

- Pipe-fitting and Welding
- Raised Ceiling Installation

To facilitate an additional level of detail, and to identify the specific areas of investigation, a direct observation exercise was completed on each activity.

Level 3 data analysis – Gemba and Direct Observation. In a manufacturing environment, Overall Equipment Effectiveness (OEE) provides a mechanism to identify untapped capacity by identifying and eliminating impacts to equipment availability, speed, and quality. In a construction environment where the trade resource is the equivalent of equipment, the use of direct observation utilising OEE principles can be utilised to determine the main causes of impacts to Trade Labour Productivity. The DPS Productivity Manager completed a direct observation exercise with the crews completing the top three identified activities over a five-day period to establish the average productivity of the trades during that period, as well as the main causes for non-value-added (NVA) activities. The impact to the trades' productivity was categorised into twelve impact areas (excluding safety).

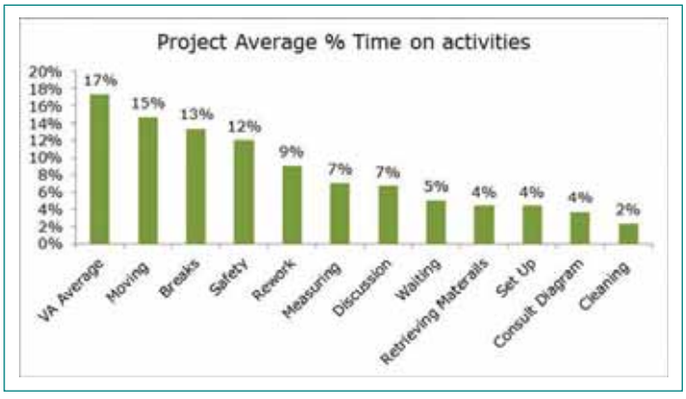

Figure 2. Construction Labour Productivity pre-Kaizen

Project Implementation

The average trade productivity was measured at 17% for the project. This indicated that 83% of a trade's day was spent on activities other than what they were being paid to do. At this stage, DPS deemed that enough data had been gathered to move to the Kaizen phase of the project.

Stage 2 – Kaizen Preparation

DPS presented the data to the onsite construction management team and outlined the reasons why the Kaizen was to focus on prerequisite works delays and incorrect time estimates. The timeframe for the Kaizen was agreed as one week, but the continuous improvement duration was agreed as five weeks incorporating one week for the Kaizen event; three weeks to implement findings; and one week to complete a recheck to see if the desired improvements were made. As the concept of Lean was new to the construction team, it was agreed that tactile and demonstrable tools would be used that could be replicated by the trade companies on other projects and sites.

Stage 3 – Kaizen Event

DPS facilitated training on the basics of Lean, including Lean principles, the 8 wastes, the infinity matrix process, the concepts of value-add (VA), necessary non-value-add (NNVA), and NVA, and the direct observation process. The research data was then presented to the Kaizen team members, and the Kaizen team agreed to focus on four major activities during the Kaizen:

i. Waste walks post-training to identify sources of waste.
ii. Brainstorm session using an Infinity Matrix to identify Just Do It (JDI) improvements on any delays.
iii. Targeted reductions in Motion during ceiling tile installation using direct observation.
iv. Targeted improvements in Materials Management onsite using a 5S exercise.

The Kaizen goals were agreed as a >10% reduction in delay causing activities and a >10% reduction in project costs due to the reduction of NVA activities.

Brainstorm Session – Infinity Matrix – A brainstorming session was completed to identify a list of JDI improvements which were changes to be made that were within the control of the project team and required negligible cost and effort. An Infinity Matrix was used so as to help the construction team determine what activities could be improved.

Table 1. Infinity Matrix post-Brainstorm Session

Current state	Just Do It	Moving	Rework	Meas.	Disc.	Wait	Set Up	Consult
One schematic drawing per team	Individual drawing for each Crew within a team	Y			Y			Y
Sharing Hand tools	Purchase Hand tools per Crew					Y		
Single cutting bench	Install Cutting benches around site	Y				Y	Y	
Single Vise on cutting benches	Install Vise on both ends		Y			Y	Y	
Broken Band saw	Repair band saw	Y		Y	Y	Y	Y	
No pre walks of area's	Implement Weekly walk of area to identify physical roadblocks		Y		Y	Y	Y	

Motion Improvement – There were multiple observations of excessive moving but the Kaizen team decided to focus on the movement associated with installing ceiling tiles. A direct observation was completed, and the use of the Spaghetti diagram showed the crew how the practice of placing the pallet of ceiling tiles in one location increased their walking distance as the day went on. The proposal from the team was to put the material pallet on wheels and move the pallet with the team as they moved across the construction area.

5S Improvement – For retrieving materials, the team identified two areas for improvement: walking distance to the material shed; and materials not stored correctly. As a JDI improvement, it was proposed to move the material shed closer to the work place and a 5S activity was planned for the Materials storage areas. One shed was audited and a full 5S was completed to reorder all materials. Bins were to install bins to sort parts into their required positions. A reorder Kanban system and set minimum stock levels for re-ordering. Finally, cable rolls were installed to ease identification and cutting of cable lengths. The team agreed to proliferate the 5S activity to the other materials sheds onsite.

Report-out – The Kaizen team had identified 12 specific improvements to implement over the remainder of the project which was appreciated by the client and was agreed to be implemented over the following 30 days.

Identified Potential Schedule Savings – Schedule savings were calculated based on full elimination of the NVA activity. While it was recognised that this would not be achievable, the Kaizen team wished to proceed with that target. To this point, a 16% reduction in schedule impacts was proposed by the Kaizen team.

Table 2. Schedule Reduction Duration Calculation

Activity	Team Size	Hrs per week	Duration Weeks	Total Project
Containment	3	360	11	3960
Piping	3	360	13	4680
Ceiling	4	480	18	8640

Project Hours	17280
Target Saving	2733
% Savings	16%

Identified Potential Cost Savings – Cost savings were calculated based on an average cost per hour rate of €32.50 for each hour saved due to full elimination of the NVA activity. To this point, a potential cost saving of €88,822 was proposed by the Kaizen team as being achievable via productivity improvements from a reduction in delays.

Stage 4: Implementation Plan

The improvements identified were broken into three phases (per Table 3), and the 30-day roadmap was published to the onsite construction team with agreement that a 4-week check-in would be completed.

Table 3. Three-Phase Improvements

Phase1	Phase2	Phase3
2 weeks	2-4 weeks	4 weeks
Just Do it	Purchasing required	Process change
Vices to be installed on all work benches	Spur Audits completed	Pre walks of area's
Mobile band saw to be installed	Material Pallets on Wheels	Horizontal Welding
Individual drawings to be provided to each team	Material Bins installed in Materials shed	Pre Marking of Area's
	Power Tools	

LEAN INITIATIVE IMPROVEMENTS & IMPACT

The project was closed out at the start of March 2018 with a review of the project results with the team. The project was deemed successful as a total of twelve improvement projects were identified with a targeted increase in labour productivity of 63%, a targeted reduction in schedule of 16%, and a target of €88,822 in cost savings.

Result 1 – Labour Productivity Increase

Average labour productivity for the three main activities measured was shown to have increased by 64%. The improvement was driven primarily by a reduction in moving, rework, measuring, and retrieving materials which was all driven by the implementation of the Kaizen improvement activities.

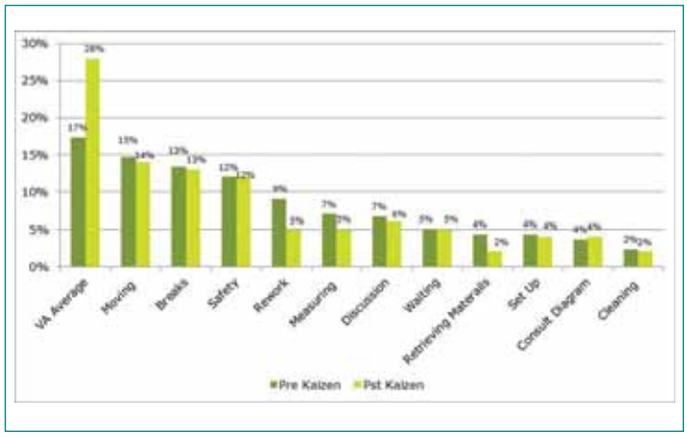

Figure 3. Construction Labour Productivity Improvement post-Kaizen Project Implementation

Result 2 – Kaizen Measured Cost Reduction

Overall cost reduction on the project was calculated at €41,190 versus a goal of €88,822 which equated to a 46% achievement of the goal set by the Kaizen event. While still a great achievement the loss of €46,642 in savings was attributed to the late implementation of improvements.

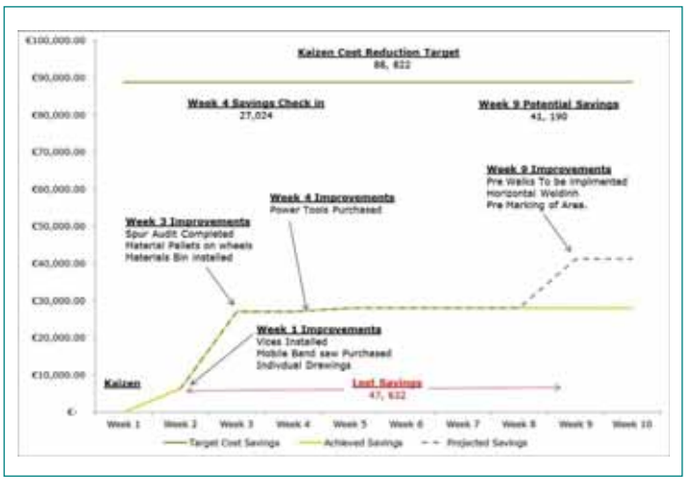

Figure 4. Construction Cost Improvement post-Kaizen Project

Result 3 – Kaizen Measured Schedule Reduction

Overall schedule reduction on the project was calculated at 905 hours versus a goal of 2733 hours, which equated to a 33% achievement of the goal set by the Kaizen event. While still a great achievement, the loss of 1827 hours in savings was again attributed to the late

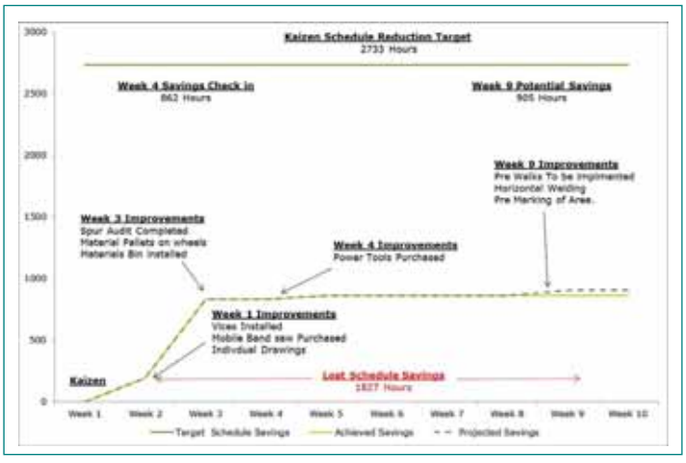

Figure 5. Construction Schedule Improvement post-Kaizen Project

implementation of improvements.

Improvement Summary

The implementation of the project proved that Lean tools and principles could be applied to the construction industry and that delays in construction can be measured, quantified and improved. While Lean principles could be used, as construction is a tangible industry it was necessary to use tools that could be quickly applied to the construction activities and the tools had to be thoughtfully selected for the construction audience. The use of the 8 wastes, the infinity matrix, direct observation and the 5S provided tangible and observable improvements for the trades. This helped significantly to encourage their participation.

COMPANY OVERVIEW

COMPANY WEBSITE
www.suireng.ie

Established in Ireland in 1984, Suir Engineering is a Mechanical & Electrical services provider and part of EDF Energy Services group of companies. Suir Engineering has offices in Dublin, Waterford, Denmark, London and across the UK. Suir Engineering has 1000 directly employed staff.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHOR

Andrew Norris

Since 2015, Suir Engineering has continuously increased its investment in its strategic and company-wide improvement initiative entitled "Suir Way" (see Figure 1). In 2015, Suir partnered with Lean Construction Ireland (LCi) to sponsor and organise an LCi Community Event entitled "Lean as Ideology & The Ability to Change". In 2016, a number of employees were supported on higher education programmes to Black Belt level competency in Lean management. Between 2017 and early 2018, Suir secured approval to undertake a "Lean Transform" project supported by Enterprise Ireland. Since April 2018, Suir has been rolling out a new process for managing the entire organisation. This has necessitated a significant amount of both off-site and on-site training, and the company is now seeing some large step-change improvements on how we manage our projects. This case study presents an overview of this new management system and some of the benefits realised as a result.

Figure 1. Suir Engineering's Lean Journey to date

The construction sector has significant productivity issues, with several reports identifying substantial non-value-add (NVA) or "waste" in its processes. Suir Engineering, along with the wider construction sector, is currently facing the challenge of delivering projects on ever-tighter schedules and budgets. Clients, who themselves are increasingly familiar with Lean thinking and practices, are demanding that their contractors follow suit in the pursuit of waste reduction. Whilst concerns about the levels of waste in construction are nothing new, the destructive impact of the recent prolonged recession has made it clear that, even as the economy recovers and construction activity increases, business as usual can no longer be accepted in construction. Lean Construction offers opportunities that allow companies to thrive in any economic conditions, and Suir Engineering has made a strategic commitment to the adoption and implementation of Lean thinking and practices internally and on its capital projects.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Build-up to Rollout of the Suir Way

In 2017, Suir Engineering Senior Management recognised that our way of working needed to be improved in order for the company to grow. We realised the need for change and to enhance the company performance. Direct Labour accounts for 42% of our cost base and we needed to improve on and become more efficient with this cost. Quality resources across the sector were difficult to find and thus we needed to change our methods, optimise our internal expertise, and grow from within through learning across the business. Where Lean tools were adopted on other projects, outcomes were quantifiably improved. The Suir Way would ensure the company had more robust systems, aligned processes, and personnel equipped with the right tools and skills to deliver future growth. If we didn't change, we would fall behind our competitors. This case study broadly details the main elements of our initiative to create and roll out the Suir Way.

Lean Management System

- Visual controls – daily measurement boards, at all levels of the organisation.
- Standard accountability – built into our visual boards.
- Leader Standard Work – including senior management conducting Gemba Walks to monitor the health of the management system.

Lean Tools

- 5S.
- KPIs.
- Mapping – processes and value streams.
- Standard Work.
- PDCA.
- A3 Reports.
- Pull Planning using Last Planner® System.

Lean Behaviours

We identified the following as our ideal behaviours: Authenticity; Curiosity; Respect; Patience; Perfectionism; and Humility.

Our case entry in the 2018 LCi Book of Cases detailed the substantial quantitative improvements made on one of our construction projects using Lean tools. However, a Lean ecosystem needs more than just the use of tools. As was evidenced in our main learning takeaways of this case study, it is very difficult to sustain focus on improvement activity without changing our management system. At the time, we knew that we needed to invest a lot more resources into education, Lean training, and the development of a Lean culture and systems to ensure that our level of improvements wouldn't plateau or regress. We knew that our strategy was lacking and that if we didn't change something we would never achieve a sustainable and "True-Lean" trajectory (see Figure 2).

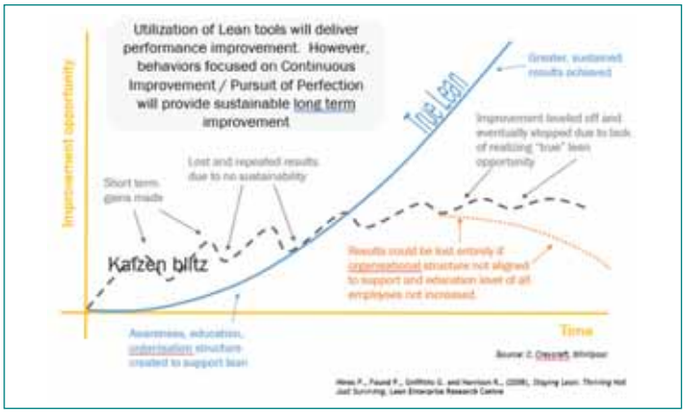

Figure 2. "Kaizen Blitz" Approach Versus "True Lean" Approach

In the subsequent months, we engaged with external consultants who completed an extensive "Lean Maturity Assessment". As part of that assessment, external experts interviewed in excess of 40 Suir employees, one-to-one, getting a cross-section from across the entire organisation. The positions of those interviewed included departmental managers, support staff, project management teams, tradesmen, general operatives, and all the company's directors. This "deep dive" into Suir's internal business processes informed the consultants and company as to where investment of resources would be most fruitful – namely on the three core elements of a Lean Management System (LMS) (see Figure 3):

i. Visual controls – daily measurement boards, at all levels of the organisation.
ii. Standard accountability – built into our visual boards.
iii. Leader Standard Work – including senior management conducting Gemba Walks to monitor the health of the management system.

A team was created to design visual control boards which would subsequently be trialled on a number of our project sites (see Figure 3). The theory behind using measurements and visual control boards is that we keep our finger on the pulse with regards to our performance. This enables us to quickly identify a drop in performance and other problems. It can be equated to the scoreboard and statistics in a match. Are we winning or losing? Did our actual results equal what was expected? Are our processes healthy or breaking down and laden with waste? And if our processes are compromised, what do we need to do about it?

Once we decide that we are doing something, the next element of the LMS ensures that we act in a timely manner. We want to eliminate conditions that enable the paying of lip-service over a drawn-out period of time, eventually fading away without

Figure 3. The Suir Way Lean Management System in Operation

meaningful improvement. Every relevant problem, opportunity, or action needs to be logged (with specifics) and assigned to an individual with a corresponding date of completion. This ensures that it will be followed up on. It is essential that these boards are appropriate for their particular area and meaningful for the people using them. Figure 4 shows the structure of the Tiered system, some of whose principles include:

- The Tier system is designed to involve everyone and get them engaged in the success of the business.
- Clear and aligned goals at every level of the business, tying into the overall organisational strategy.
- Everyone understands their personal contribution to site goals and expected behaviours.
- Any problems or issues can be managed locally or escalated to the next tier for support.
- There is a standard work approach to all tier meetings across the site.
- There is clear escalation and feedback pathways between tiers.

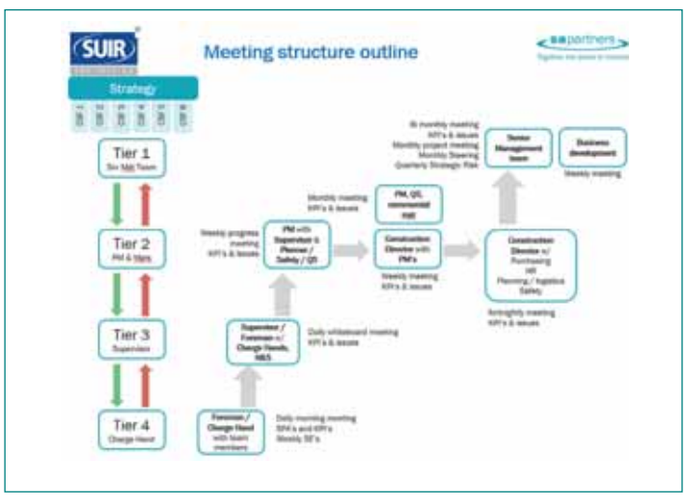

Figure 4. The Suir Way's Lean Management System Structure

As stated previously, for a large-scale improvement initiative to be sustained, education of the workforce is critically important. Therefore, in addition to creating and trialling the visual control boards, we also conducted extensive amounts of training of our staff. We recognised that, apart from a few isolated instances, there were very low levels of Lean competencies in the business. We therefore needed to deliver a number of training courses that would improve the knowledge, skills, and attitudes of our workforce. Some of our training courses included Lean awareness, Problem solving, Workplace organisation (5S), LMS Tiered Management System, A3 problem solving report writing, and Behavioural and Gemba training for senior management.

Figure 5. Lean Training for Suir Engineering's MD, Michael Kennedy, and Senior Managers

At the time of writing, we are rolling out the training and management system to 18 of our project teams at different locations throughout Ireland with another 9 already picked out for later in 2019. The rollout typically starts with several off-site classroom-style training days, followed by a Suir Lean Champion visiting and supporting the site team to help embed the new processes, systems, attitudes, behaviours and audits. Integral to this is training not only on the Lean tools, but the concepts behind the tools – the "How-To" knowledge of tool deployment. Additionally, there is particular focus placed on the criticality of teamwork:

- teams with divergent knowledge and expertise can outperform homogeneous teams – when they share and integrate their knowledge.
- divergent goals can broaden the scope of a team's accomplishments – if value-claiming behaviour doesn't crowd out value-creating behaviour.

LEAN INITIATIVE IMPROVEMENTS & IMPACT

The benefits of the LMS are that it enables us to:

- Align everyone in the organisation through our tiered management process.
- Identify issues, roadblocks, and impact for our business and people.
- Give everyone a voice.
- Improve communication at all levels of the business.
- Deliver on our critical success factors (CSF).
- Enhance company performance, efficiency, and profitability.
- Have a safer and more engaged workforce.
- Build brand profile.
- Continuously improve and learn.
- Improve on client engagement.

Our 5S system helps us create standard working methods whereby we set up the workplace in a more organised manner. Bringing material and equipment closer to the workface, using higher quality and standardised tools, and putting controls in place to ensure they are maintained result in the elimination of many of the 8 Wastes. This practice allows workers to be more efficient with less trips to stores for materials, and makes up-to-date information and drawings available locally.

One of the major changes is in our data collection methods. We would have always collected data from our sites in term of productivity, but now we also track and record waste and DOWNTIME. Tracking of the productivity and wastes allows us to have a clearer picture of where we need to focus our improvement efforts. We mapped and improved many of our processes as a direct result of investing in improvement activity, with many of our improvement projects delivering monetary savings ranging from ?5k to ?20k. A 20-year Construction Manager put the improvement as simply as this: "The way I've seen it help me the most… I used to get about 40 phone calls during the day from our guys, now it is only 20. The guys all know what's going on".

Broad Accomplishments

- Improved planning of works by supervision.
- Over 400 trained in Lean Awareness to date – remainder being trained in 2019.
- Reduced reworks on site which improves customer satisfaction and productivity.
- Minimised site material shortages and improved workplace organisation.
- Improved workforce engagement.
- DOWNTIME quantified and addressed at source.
- 5 Lean Champions actively trying to make change happen.
- Reduced requisitions to procurement resulting in increased buying power and maximising supply chain performance.
- We completed the first paperless handover of a capital project in Ireland through our EIDA System which ensures we are at the forefront of new ways of working through technology.
- Lean Office roll-out training commenced March 2019.
- 23 sites rolled-out up to April 2019.

Lessons Learned

- Change is hard – the education route is slower and expensive, but it is critical.
- Group Think – a diversity of perspectives and resources is needed for a finely-tuned Lean system to run smoothly and recover from interruptions.
- Psychological Safety:
  - o Fear in the industry – What vs Who – Troublemaker (subtle fear of ridicule).
  - o Empower your team – Lead by example – Leadership theory.
- People being defensive when hearing about a problem in their area – feeling that they need to have the answer.
- PDCA – universal to everything we do – use your 5-step check.
- Measure what you want to improve:
  - o Removes a lot of waste and problems from our processes.
  - o Helps us plan better.
  - o Enables better communications.
- More knowledge sharing.
- Important to leverage from experts – can save you time and from going down the wrong rabbit holes.

COMPANY OVERVIEW

COMPANY WEBSITE
www.mercuryeng.com

Mercury is an Irish-based European contractor. We build and manage complex engineering projects that reimagine how people work and live in the built environment. We believe that real innovation happens if you're willing to be brave. Our determination and sharp focus enable us to deliver leading-edge construction solutions across a range of key sectors including Data Centres, Healthcare, Life Sciences & Technology, Fire Protection, Building Services, and Technical Support Services, taking our clients to new territories they never thought possible. Mercury employs 2000 employees across Ireland, the UK and Europe and had an annual turnover of €770Million in 2018.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

Shay Lacey

Jason Toomey

Mercury has long been an advocate of Lean and has been implementing its principles into work practices for many years. Lean has always been something we strive for and our default position is if there's an activity or a task that we're going to perform for our client, safely, we're always trying to make it happen better, faster, or smarter. We have a Lean programme at Mercury called "Leaders in Lean" where once a week a great idea from a construction site is shared across all our staff which comprises 2000 people spread out over 10 countries. Additionally, we've recently re-commenced our Yellow Belt programme and are currently in the process of implementing a Green Belt programme as part of our drive towards Kaizen or continuous improvement of our employees so as to ensure the maximum value is added within each and every one of our projects. Approximately one third of our people have been trained to date to either Yellow or Green Belt level.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Value-added (VA) is the key phrase in this case study. We are aware that every day our objective is to complete our work with as much VA time as possible. For our trade operatives work crews, our goal is to add the maximum value to each project every day. Construction crews require a wide variety of different resources such as tools, machinery, etc., on a daily basis to execute works. If these resources can be identified and made available to trades at the start of each day, the likelihood is that non-value-added (NVA) time in the first hour of the working day can be greatly reduced. It has been measured within the industry that the first hour of the working day is by far the most likely to contain the greatest amount of NVA time.

The objective of this case study was to create a company-wide Standard Operating Procedure (SOP) that would help supervisors and foremen to plan the crews' works and the required resources ahead of time to ensure that Mercury would achieve more VA works within the first 15-minutes of every working day. This SOP aimed to result in an additional 4% of VA time to the working day. An additional 4% of VA time simply converts to an additional 4% profit on direct labour projects which naturally reinforces the business case for implementing this new process Group-wide across Mercury. Poor planning leads to poor performance, and naturally it is assumed that better planning will result in a better performance in terms of safety and quality, but also contribute to increased VA time across projects.

Running an efficient project should always make use of Lean Construction to reduce waste. Using the mnemonic "TIMWOOD" helps to identify waste. Identifying waste allows us to reduce our costs, increase profits, improve lead times and boost customer satisfaction. The easiest way to remember the seven wastes is to ask every day on site "Who is TIMWOOD?".

TIMWOOD:

- Transport: It was discovered that trades were spending too much time everyday walking to retrieve materials.
- Inventory: Pipe storage racks were loaded with materials that trades did not require on a given day, wasting valuable space.
- Motion: As per transport, there was too much time spent walking from work areas to retrieve information or drawings.
- Over-Production: Our off-site facility was delivering excess materials to what we needed for a given period.
- Over-Processing: Employees were spending too much time on getting information required from drawings – we required more clear and concise information for trades.
- Defects: Staff were having to re-work elements of works due to them not being done right first time (this can be attributed to the lack of required information mentioned previously in Over-Processing).

Using TIMWOOD, our team was able to identify the waste and inefficiencies that we needed to address to increase VA time. In addition to using TIMWOOD to identify waste, Mercury has implemented a variety of Lean project management tools in order to increase efficiency and improve VA time across projects, including DMAIC, PDCA, LPS, and 5S.

The PDCA Cycle (Plan, Do, Check, Act)

This PDCA cycle gave our supervisors the appropriate

structure to address the issues noted from their direct observations:

- Plan: Day 1 – Supervisor spends one hour each evening planning the works for their crew.
- Do: Day 2 – Supervisor utilises their general operatives to obtain the resources required by trades to complete their daily tasks.
- Check: Day 2 – Supervisor completes 'Daily Huddle' to inform crew of planned works for next day and check that all the required information and resources are available.
- Act: Day 3 – Crew complete works with VA time within 15-minutes of start.

Last Planner® System (LPS)

The foreman and supervisor complete a 10-minute huddle at the end of each working day to discuss:

- What their team needs to plan to complete tomorrow.
- Establish what resources are pre-planned and available.
- What was completed that day.

5S

The foremen worked with their general operatives to properly sort the pipe spools that were required for trades to install the planned works on the next day. Pipe racks were labelled with shelf numbers, for example Pipe X is now stored on Pipe Rack Shelf No.1. All waste pipe or materials (if any) were removed from the pipe rack and work area. This process became standardised within the work crew and was then subsequently shared with other crews. The process became a habit and now continues to be utilised on a daily basis. The process was initially piloted with one supervisor/foreman, with the supervisor then educating their team on the process and keeping them updating on its ongoing benefits. Trades staff noted the benefits to supervisors at daily huddles as they found it easier to execute their works. The process was then rolled out to the other supervisors/foreman in the group who again took their trades through the learning process and benefits. As the new processes were introduced to other groups, more supervisors/foremen and trades become involved.

The team involved in this case study who planned, refined, and implemented the project comprised the:

- Project Manager.
- Site Supervisor.
- Site Foremen.
- Site Trades.

Define, Measure, Analyse, Improve, Control (DMAIC)

This project identified that every trade on the construction site could be losing 30-minutes of VA time at the start of each working day (at a conservative estimate). Due to the daily start up nature of the works, it had never previously been considered that the entire time could be recovered. With VA within the first 15-minutes being the target, and in making allowances for the time spent by foremen and general operatives' pre-planning works, the target set an additional 4% VA time per day per crew member.

The existing process was measured using data from the ongoing Direct Observations (DO). Figure 1 shows a typical example of a measured activity. The VA time across the day was extremely low with a total 9% VA time (equalling only about 5.4-minutes of actual productivity within the first hour). Upon further investigation, we discovered that retrieval of materials, set-up, consulting diagrams, and moving totalled 43% of the time and as such were particularly applicable with regard to the first hour of daily activity.

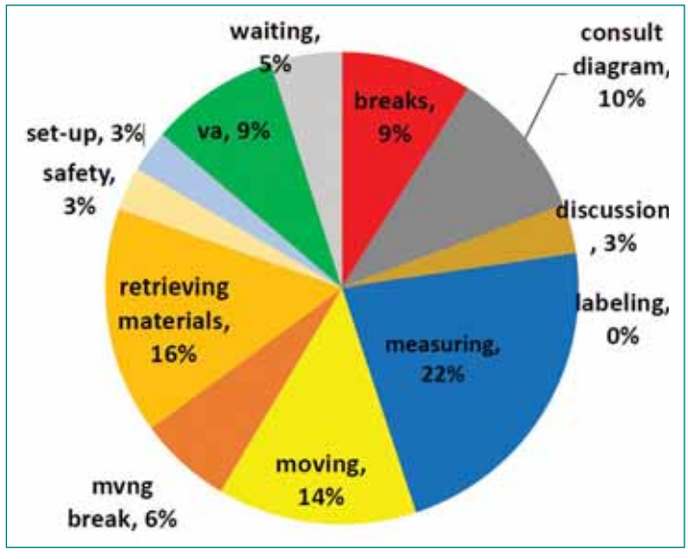

Figure 1. Direct Observations A

LEAN INITIATIVE IMPROVEMENTS & IMPACT

The process was piloted in one group ("Group 1") which consisted of approximately one third of the overall project. The process was developed and refined with one specific supervisor who had bought-in to the process from the outset. The supervisor added to the process by implementing 5S principles with regard to the sorting and labelling of resources (in this case Pipe Racks) to enable trades to become more efficient. With some work and weekly reviewing of direct observation data to emphasise wins, we implemented the process with the other supervision members in Group 1. Supervisors bought into the process, and with this we had achieved our first major win.

The Project Director noted the results that were achieved from the process and focused on the DO results. After reviewing the DO results for Group 2 (see the key observations below), the Project Director insisted that the process now be implemented for Group 2.

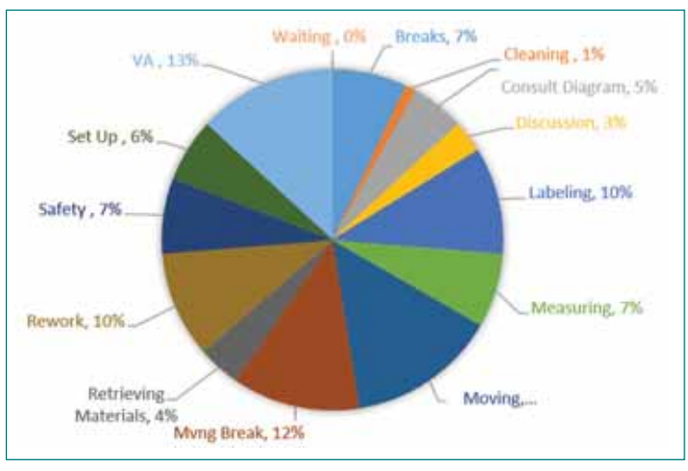

Figure 2. Direct Observations B

Group 2's Key Observations of the Working Day

- 14% of the time (2-hours 26-minutes) was spent moving at the start of shifts, breaks and mid-shifts between the sub-work area and the main work area to rework the maintenance panel, retrieve labels, and fabricate a spool in the sub-work area (1-hour 50-minutes). Moving around the spool in the work area under the floor and in the adjoining chase to measure/assess (22-minutes). Remainder of moving due to moving with tools, moving to stores, and BIM.
- 10% of the time (1-hour 43-minutes) was spent reworking to remove the gauges and conduct fitting from the maintenance panel and refitting of the same incorrect order as well as the drilling two holes in the maintenance panel. This time also includes leaving the main work area to complete this in the other level.
- 10% of the time was spent labelling the spools under the floor in the work area. Again, this factors in leaving the work area in order to retrieve labels and writing the specific lines from LSP to ID labels upon return to the work area.
- 7% of the time (1-hour 8-minutes) was spent measuring. This time was spent checking and verifying HP pipes for the exact location and alignment, checking and verifying the work was completed and also measuring for the installation of the maintenance panel.
- 8% of the time (45-minutes) was spent retrieving materials. This consisted of retrieving spools and ID selection from the rack (14-minutes). The remainder of time retravel materials was due to retrieving fittings, cushie clamps, clutters and facing tools.
- 6% set up (1-hour) due to assisting the welder to set up purge lines from workplace level (47-minutes). The remainder was due to removing tape from spools (10-minutes).
- VA time (13%) – HP SS Pipe installed & maintenance panel on the pillar.

Recommendations

- 10% rework on bought in items – need to investigate why gauges and fittings need to be altered on this and if all tool requirements are different.
- Moving between different levels for labels and reworks – consider if the labels could be kitted for the crew and left in the pass-through to avoid having to leave the work area.

The DO in Figure 2 illustrates a poor VA at 13%, and highlights the areas that were addressed throughout this case study. Group 2 will implement the process over the next period, and despite some early scepticism there is overall confidence that the process will result in a performance improvement. We are now intending to move the process to Group 3, and we intend to move the process to a new project that has just began using direct labour trades. It is imperative that Senior Management buy into the process before this happens and for it to be documented as a Supervision SOP. Once written formally as an SOP, it will make the process much easier to implement on future projects.

The team involved learned and demonstrated their learnings from the project initiation to completion. We soon learned that if a productivity problem exists, it cannot be fixed by simply brainstorming and implementing the fix via "who shouts the loudest". The DMAIC process proved to be effective in systematically working through any processes to improve the current situation. We also now have the learning of a kaizen approach and how we can implement this process with regard to any future challenges we may face.

In the construction industry generally, and particularly during this case study, we have found that if we can remove the obstacles and waste to allow trades to have good cellular flow (trades often speak about having a "good run at the work"), productivity will see significant improvements. The fact that supervisors along with much of our trades had been introduced to Lean Construction through a Yellow Belt process was beneficial as they gained an understanding of what VA or NVA work actually was and why there was a need for Mercury to address it.

Moving forward, we need to continue to utilise the tools and processes we have learned. The smaller and relatively simpler elements such as the 5S process is now embedded into our company-wide site procedures and will be of major benefit in the long-term. From a management point of view, we now have a process for evaluating, diagnosing, and improving those project productivity items that have a commercial impact on project success.

MERCURY

COMPANY OVERVIEW

COMPANY WEBSITE
www.kirbygroup.com

Founded in 1964, Kirby is a mechanical and electrical engineering contractor. The company operates in Ireland, the UK and Northern Europe, and directly employs over 850 highly-skilled employees. Kirby provides full mechanical and electrical contracting services as well as specialist high voltage (HV) and medium voltage (MV) design and construction services to clients across a number of different sectors including Data Centres, Life Sciences, Industrial Manufacturing, Substations and Renewables, Power Generation, Petrochemical and Commercial. After 55 years in business, Kirby has earned a reputation, supported by client references, for excellence in high-value mechanical and electrical engineering contracting services. This reputation is built on early engagement, finding innovative cost-effective solutions for complex build challenges and an uncompromising approach to safety, quality and delivery. Kirby has strong capabilities in prefabrication, modularisation and digital construction, along with a Lean approach to project delivery, which ensures excellence and value for its clients.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHORS

Martin Searson

Kevin Wall

Kirby's strong capability in prefabrication, modularisation and digital construction, along with a Lean approach to project delivery, ensures excellence and value for our clients. As early as 2012, Kirby started following an EFQM (European Foundation for Quality Management) framework approach to quality which included a philosophy of continuous improvement. Lean and value became more and more prevalent to our strategy moving forward.

As the construction industry's value moved more towards Lean, including standardisation and consistency of outputs, the requirement for this is being realised ever more on projects through Quality Assurance (QA) Benchmarking, First of Kinds (FOKs) and/or sample Mock-Ups. These methodologies help establish a consistency and standard work approach, by ensuring a right first time (RFT) approach to the first installation of a service, equipment or system from a Mechanical and Electrical (M&E) perspective or from a Civil, Structural & Architectural (CSA) perspective for designed and/or construction building elements or building fabric finishes. This was a major change to the industry and Kirby had to move with the industry or fall behind the standards being set and expected by clients.

This process is still being rolled out throughout the industry and certain clients have not requested Benchmarking, FOKs or Mock-Ups, as yet. Where it is requested, Kirby has established a process flow to follow to ensure completion and archiving is standard. A new form (MF6.27 – QA Benchmarking Inspection) was created for completion and to be signed off and stored electronically, including photos, as standardised work.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

A philosophy of continuous improvement within the construction industry determined that standard work would become the norm, where possible, to add value to customers and meet legal regulations. This resulted in the development of Quality and Lean tools including Benchmarking, FOKs, and Mock-Ups. Construction contractors could either utilise these tools or get left behind. In addition, this provides a standardised reference standard for trades and professional personnel to benchmark the installation requirements versus the project specifications, i.e. design criteria, for consistency and replication, site wide. Previous to this, there was waste through defects, rework, rectification, change management, over-production, over-processing, and underutilised skills. This impacted the bottom line of any project, and also had an impact on schedule and reputation. Designing and getting approval of FOKs aimed to reduce all these wastes, and, as each component would be still used as the first installation, it removed these wastes from arising.

Mock-Ups and First of Kinds (FOKs)

Typically, the specialist installation company provide a schedule of Mock-Ups and FOKs of Capital Equipment and Field installation works within the first two to six weeks of starting a contract. The specialist installer and their qualified

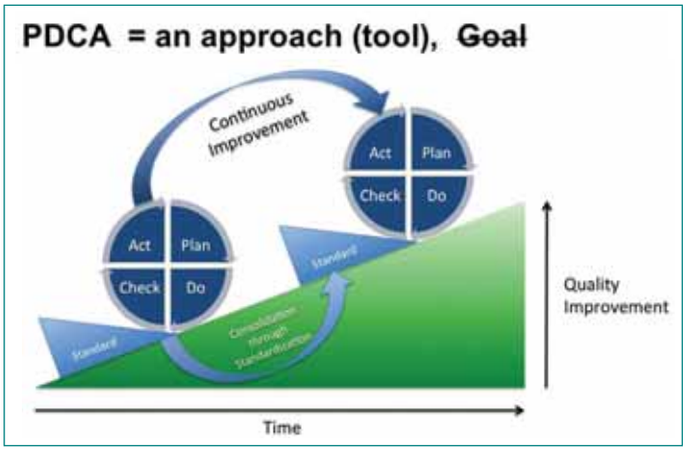

Figure 1. PDCA (Plan-Do-Check-Act) Approach

trades personnel will construct Mock-Ups (or FOKs in situ on site) as required to demonstrate the quality of finished work, for approval. The Construction Management Team (CMT) and the Client then perform inspections of these Mock-Ups and provide feedback, review comments on any deficiencies, engineering updates or changes required versus the project specifications and standards and/or regulatory requirements to set the benchmark standard. Once the Mock-Up (or FOK) has been agreed as meeting the requirements and specifications by both CMT and Client, it is then recorded using photographs where necessary and logged through the submittal process accompanied by the relevant QA Benchmark or FOK form, as a receipt/acceptance of the specialist installer's FOK/Mock-Ups.

This then serves as a benchmark agreed between the parties for quality of materials and workmanship for the full scope, as contracted. Future work will be compared to the benchmark in order to establish whether it meets the requirements and project specifications, i.e. engineering matching. Mock-Ups must not be removed or covered over without the prior permission of the CMT. Where agreed with the CMT, the specialist installer may utilise the first sample or portion (FOKs) of the permanent works as the benchmark or Mock-Up. The CMT will examine the first 5% to 10% of the permanent works in stages, where appropriate, in accordance with the project approved Inspection & Test Plan (ITP) and provide feedback to the specialist installer on the quality of the works and workmanship, provided thereafter, in accordance with the contract and customer requirements. The matrix in Table 1 summarises the provision and use of samples across the various construction disciplines.

Discipline	Mock-Ups	FOKs	Photographs (incl. As Verifying Documents)
Civil/Structural	-	Yes	Yes
Architectural	Yes	Yes	Yes
Roofing, Cladding, Glazing	Yes	Yes	Yes
Clean Rooms	Yes	Yes	Yes
Mechanical & Piping	Yes	Yes	Yes
Building Services (incl. HVAC)	-	Yes	Yes
Electrical & Instrumentation	-	Yes	Yes

Table 1. Discipline Field Installation Sample Matrix

Submittals, samples, Mock-Ups, and FOKs would in the first instance be presented or submitted to the CMT who then refer to the Design Engineer, Client, End User's Operational team and others as appropriate for comment/approval before responding to the specialist installer. No work would be undertaken prior to obtaining and incorporating as required the comments of CMT, Client, and nominated others. Typically, the following status codes would be used by the CMT when returning comments on drawings, calculations, method statements, submittals or any other submitted documents, i.e. QA Benchmarks or FOKs. The standard quality assurance forms used by Kirby Group Engineering are:

- MF6.26 QA Benchmark Register template R0
- MF6.27 QA Benchmark Inspection form R0

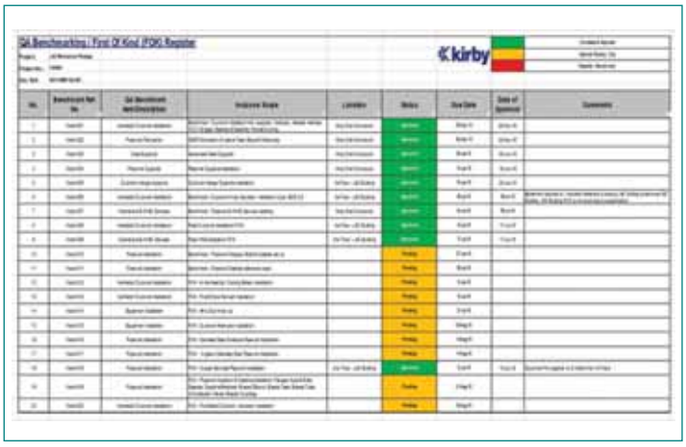

Figure 2. MF6.26 QA Benchmark Register Sample

Figure 3. MF6.27 QA Benchmark Inspection form R0

This results in a standardised work approach on sites. The benefits of standardised work includes documentation of the current process for all changes made, shifts, reductions in variability, easier training of new operators, reductions in injuries and strain, and a baseline for improvement activities. This standard work approach can be considered an RFT approach bringing quality to the source.

Advantages of the RFT approach include:

- Reduction in waste (material, time, manpower, rework).
- Improvement in productivity.
- Better understanding of the production issues and process variation.
- Empowerment of employees in achieving the desired quality.
- Awareness of the importance of the quality throughout the organisation.

Through the creation and approval of a standard, it can be considered mistake proofing (known as "poka-yoke"). A poka-yoke is any mechanism in any process that helps a construction worker to avoid ("yokeru") mistakes ("poka"). Its purpose is to eliminate product and material defects by preventing, correcting, or drawing attention to human errors as they occur. It is a case of taking over repetitive tasks or actions that depend on vigilance or memory, and it can free workers' time and minds to pursue more value-added activities. In addition, it reduces variability in processes and installation methods, as employed, during to varying trade crews working on site and across the project.

Figure 4. Site First of Kind (FOK) Example (signed off)

LEAN INITIATIVE IMPROVEMENTS & IMPACT

The improvements seen since 2012 with the introduction of QA Benchmarking, FOKs, and Mock-Ups are highlighted by the growth of Kirby Group within the construction industry. It has resulted in a much more competitive service with a high reputation of delivering quality and on time. Thus adding value for our clients and stakeholders, though consistency and standardised work.

This new process was initially rolled out on a number of high priority projects, but has now become more and more client driven as they have seen the value in this process. Kirby management have also increased the scale of this process to now reach as many new projects as possible within the M&E scope of works.

Defect (snag) elimination has become a major focus within Kirby operations and our approach to quality management (as shown in the previous Kirby Case Study in 2018). Through the application of QA Benchmarking/FOK/Mock-Ups, this complements additional defect reduction (or effective elimination) on a construction project, though a systematic approach to minimising rework activities arising. Thus given further time and cost savings back to the client, to the elimination of duplicate activities or rectification.

The concept of implementing an improved and automated defect management, i.e. 'snagging', process was proven through the following tangible benefits:

- A cost saving of 45.16% was made per processing of one snag.
- The number of snags per €1Million project value was significantly reduced, predominantly due to removal of duplication.
- Improved snag categorisation – proper allocation of categories that allowed effective action, with "Other" category snags decreasing from 33% to 9%. (This proves the concept that the improved and automated Snagging Process brings significant savings to the business, as well as competitive advantage.)

Figure 5. Site First of Kind (FOK) Visual Management Board In Use

Visual management boards were created within the site office to highlight this new process and where the team could go to check the QA Benchmarks. All new site staff were instructed to these new processes as part of their induction. This helped, and, continues to help, bring about a further behavioural change with site staff on the benefits of Lean and their future involvement in additional Lean improvements as part of our continuous improvement strategy.

Benefits of visual management:

- It gives a chance to an operator (trades person/engineer) to see and correct a mistake before it becomes a big problem.
- It gives a chance to an individual to see and correct standards if there is any deviation from set standards or

specifications.

- It is set of 6S tools that enables a working environment where everyone feels safe and facilitated.
- It helps avoid workplace injuries.
- It gives a chance to see non-compliance of any set standards immediately.
- It helps operators to see how we are performing and allow them to improve their score in case the low output from set standards and/or any negative variance present.

*Why visual management is so imp*ortant?

- One of the most important reasons to implement the visual management system is to place/introduce a problem-solving culture, adopt an improvement-driven approach/mindset, eliminate response time, and prepare teams to continuously work on eliminating waste and improving quality issues highlighted through visuals.
- They are a tool that provide a lot of information at a glance with just visuals and limited text.
- It helps to improve communication within a team.

As part of the continuous improvement mentality within Kirby that includes Plan-Do-Check-Act (PDCA), we are constantly trying to have positive behavioural changes for site staff. By educating to Lean Thinking, it is no longer the norm to ask the same questions all the time. Hence, we have also revised the register and QA benchmark form a number of times, and we will continue to review it as clients continue to engage with us.

It is now a case where Lean Construction has become part of the values of Kirby and staff are now engaged within all regions where Kirby operates. It is clear that there is now a greater focus on high standards, adding value to the clients, and reducing and removing wastes. This will allow us to continue to grow and aspire to be the most trusted provider of high-value engineering and construction services. Kirby consistently wins national and international awards in areas of Quality and Environment, Health and Safety (QEHS), reflected in our 10th consecutive RoSPA and 7th consecutive National Quality Award nominations. We credit this to our strong performance culture, our outstanding Kirby team, and our reputation for quality and service delivery.

kirby
engineering & construction

COMPANY OVERVIEW

COMPANY WEBSITE
www.pmgroup-global.com

PM Group is an international project delivery company operating across Europe, the USA and Asia. We have a 45-year track record in project management, process design, facility design and construction management for leading multinational companies. We are world leaders in the Pharmaceutical, Food, Mission Critical, Medtech, Advanced Manufacturing and Energy sectors. Our reputation is built on great people with a flexible "can-do" attitude who consistently deliver successful projects safely for our clients. We pride ourselves on our technical expertise and work closely with our clients to develop innovative solutions for complex projects. We have over 2600 highly skilled employees worldwide. While headquartered in Ireland, we have offices based in 17 countries worldwide.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHOR

Conor Sych

This case study details the Last Planner® System (LPS) processes applied to the fast track delivery of the construction of a biopharmaceutical facility in Dublin, Ireland. LPS was adopted to help implement lean practices and enable high level project-wide coordination. The owner was converting an existing facility in Swords, North County, Dublin to a high-tech biopharmaceutical manufacturing facility. PM Group was retained by the owner to partake in the design and construction management of the Biotech Project. The author is a project engineer employed by PM Group, and is coordinating the implementation of LPS on the Biotech Project.

Construction and turnover is scheduled to be completed by July 2020 and, to support delivery of this ambitious fast track timeframe, detailed design had to be completed by July 2019. In order to achieve this schedule on time, systems turnover began when the project was about 35% construction complete. Conventionally, system turnover usually begins somewhere between 55-65% construction complete. This earlier turnover start drives a much greater overlap between construction and detailed design phases, which forces greater emphasis on coordination in the field.

The project comprises 5 buildings with 11 manufacturing suites and a high level of GMP finishes and fit-out on a constrained site in a suburban setting.

Biotech Buildings

1. Bulk Drug Substance Building (BDS)
2. Warehouse
3. CUB
4. QC & MS&T Labs
5. Offices & Other

Figure 1. Site Layout Plan

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

This case study focuses on the construction of the Bulk Manufacturing Building (BDS). Interfaces can range from physical connection boundaries between building components to contractual work package scopes. Interface management is a key project delivery risk. There are numerous common and constantly changing interfaces between 15 trade contractors. By limiting and clearly defining interfaces, communicative action can take place which will resolve a lot of the issues in construction. Updating IT application to interface management, and using it extensively, can reduce project CAPEX costs by 2% and delivery duration. Instead of the traditional approach of contractors and EPCM firms relying on 14-30-90 day schedules, and placing heavy emphasis on them by pressurising crews to meet deadlines, LPS addresses these issues by recognising interfaces and tackles them by engaging all stakeholders to the level of contractor foremen and supervisors to create a micro-schedule. These micro-schedules look one week and six weeks ahead, breaking down

activities daily and weekly. Inherently, now the people in the field are actively driving the schedule, and they are making an honest commitment to deliver within the team. This changes the traditional culture and enables the foremen to think in a Lean way.

Creating a "people first" collaborative environment is key to achieving high levels of construction progress. LPS promotes a non-blame culture. LPS meetings take place once a week to discuss the next week's work plan and constraints. These meetings are chaired by the BDS LPS lead and attended by the BDS Construction Manager and other members of the BDS Construction Management (CM) team. In addition, they are attended by at least one design project manager and designated contractor representatives, typically a CM or supervisor. The weekly lookahead is broken down and focused on process zones and rooms. The Weekly Work Plan (WWP) is the output from the weekly LPS meeting and includes:

i. Work breakdown by Process Zone and Room.
ii. Colour coding of responsible organization/contractor.
iii. Resources planned.
iv. Percent Planned Complete (PPC).

Each week when the plan for the next week's lookahead is discussed, the team highlights constraints that are to be removed. Constraints vary and include lack of materials, labour, predecessor works, design, field clashes, weather, etc. These items are then logged and dated. The team will then identify a person who will answer or resolve the constraint. For example, to install a process pipe run, the contractor may need a bracket redesigned. They will flag this in the meeting, and a designer at the meeting will undertake to resolve the constraint; promising a date for the redesign to be done. This approach differs from the traditional means of going through a request for information (RFI) process, and improves on it. LPS enables the constraint to be identified to the team and made clear to the party responsible to remove the constraint. In this case, the designer on the spot now knows where the bracket is and that it is on the critical path. Eliminating the interface of an RFI and getting a designer who normally wouldn't interact with a foreman to be aware of the construction process, helps ensure the workflow will be completed on time. Separate streams of meetings are also arranged to resolve constraints such as design delivery, clashes, and sequencing. These are taken "off-line" for resolution by the key parties outside of the LPS meeting.

In addition to identifying future potential constraints, those constraints that have arisen previously are recorded and analysed, and trends are identified so that measures can be put into place to reduce risk of recurrence. Figure 2 illustrates a sample of some of the constraints that have arisen on this BDS Project.

After the weekly meeting, the LPS plan is printed and posted on a wall in the LPS meeting room to be checked off daily by the contributing contractor foremen. The contractors will check "yes" or "no" based upon the activity having been completed, and, if not, the reason it

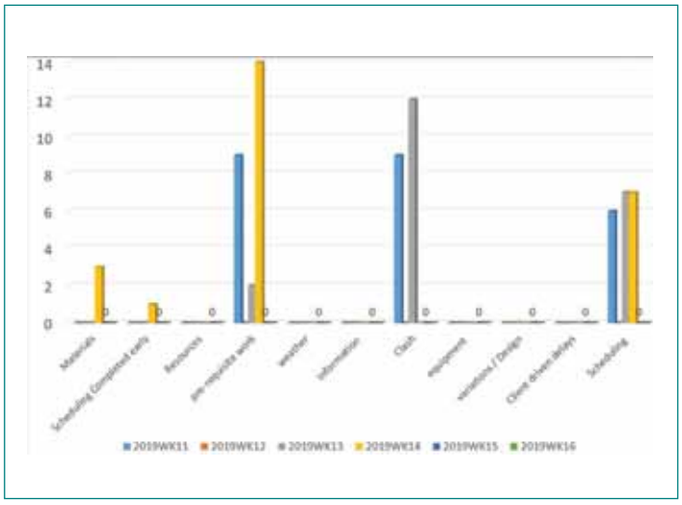

Figure 2. Extract from BDS Constraints Log

wasn't completed.

The data collected from the contractors' status update on the weekly LPS plan is used to create the PPC. The PPC metric is a measure of the activities actually completed within the weekly plans. The PPC is then displayed and this shows how well the weekly plans that are put together each week are working. PPC is linked with constraints and identifies what constraints are hindering construction progress. For instance, if the redesigned bracket did not come as promised, this will prevent the particular activity being completed and so reduce the PPC metric for the week. Over time, PPC data will compound and show what variances are slowing the progress down. In summary, the LPS process makes clear the effect of a break in the delivery chain by any member. This fosters a culture of delivery within the team over a short period of time.

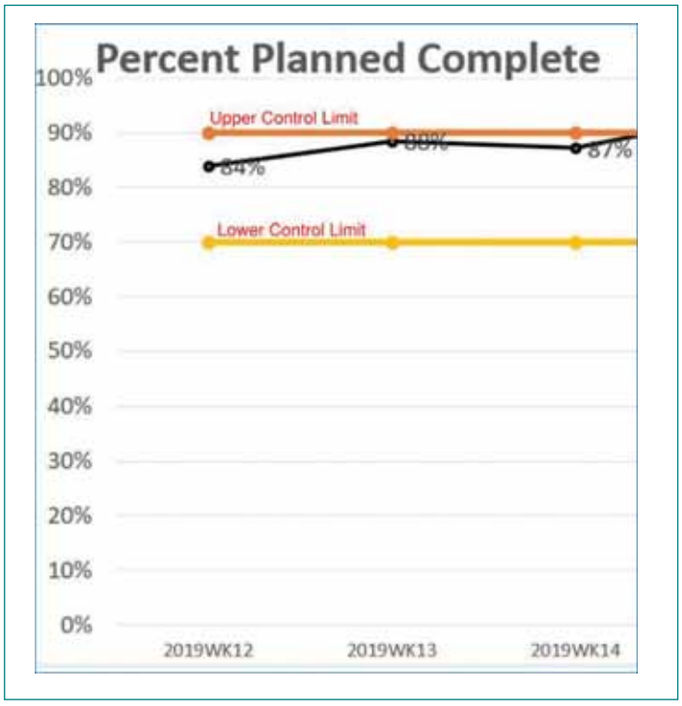

Figure 3. Percent Planned Complete (PPC) Curve

PPC is tracked weekly and measures how

well the team is performing tasks planned versus tasks completed. An extract from the BDS PPC curve is shown in Figure 3, with the yellow line representing the lower control limit and the orange the upper control target.

A key element of LPS is pull planning. By focusing on the end milestone and developing a six-week schedule, the constraints, the interfaces to be managed, and the activities to be completed to meet the milestone are clear to the team. For instance, issued for construction drawings (IFC) were constantly a constraint, and particularly in the earlier stage of the project given the significant overlap between design completion and construction. To overcome this, pull plans gave the design team clear visibility of priorities. For example, focusing early on freezing the architectural package for walls enabled the timely release and install of the associated mechanical and electrical services with minimal rework.

The project has its own dedicated LPS meetings which create a strong sense of team and partnership for all parties involved in the BDS Project. The scale of the BDS Project requires a large dedicated room to facilitate these meetings which is beneficial in adding value to the team. The room allows for the CM team to present not only the key project milestones, but also weekly project data, design constraints, quality information, etc., in a consistent group environment. Over time, the BDS LPS team has become familiar and responsive to each other's needs in the best overall interests of successful project delivery, namely the common goal of the team. Mechanical contractors learned where and what electrical contractors were struggling with or succeeding with and vice versa. By identifying these issues, plans have become more accurate and collaborative in nature. Dual projection screens allow for general layout drawings and aerial photos to be displayed enabling better understanding of works discussed. Frequently team members walk up to the drawing or use a laser pointer to highlight the works or plans under discussion. The meeting is on site so team members are able to walk to see and address any potential challenges immediately after the meeting."

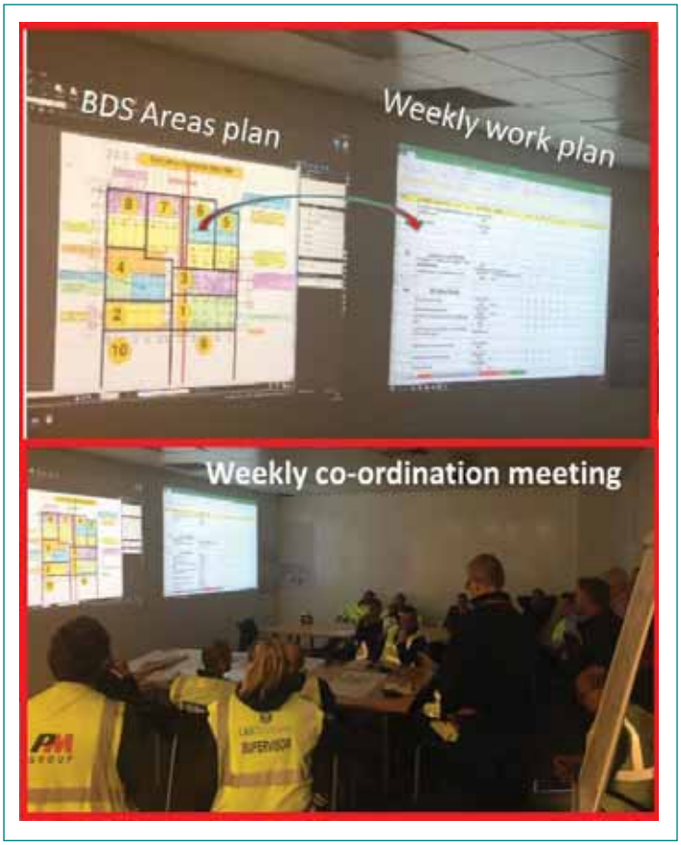

Figure 4. LPS Weekly Meeting

LEAN INITIATIVE IMPROVEMENTS & IMPACT

LPS was challenging to implement on the BDS Project due to the scale, fast track schedule, and the large number of contractors and interfaces in close quarters. In the beginning, it required a significant culture change for many team members used to more traditional approaches of construction delivery. Contractor supervisors are now also focused on schedule development, and the majority of planning decisions are made as a team. Initially, the CM team had to constantly work to overcome negative attitudes, traditional methods, and getting contractor management to buy into the system. However, the impact and improvements are very visible on site and from the data PPC averaged around 35-45% from weeks 1-20, and by week 35 forward PPC was averaging within the 70-90% range. This meant the team was making dates, milestones, and was working smartly. Constraints went from an average of 10 per week to approx. 5 per week – a near 50% reduction. This can be attributed to design being more substantially complete, but also to the construction team "thinking ahead" identifying problems and collaboratively solving them in advance and achieving critical milestone dates.

The strengthened relationships developed from the LPS process, and founded on collaboration and integrity, have shown great benefits on schedule and project cost delivery. The BDS Project has seen similar benefits through increased collaboration and trust in coordination and action of plans. Contractors from different trades are interacting amongst themselves independent of the CM team's direction in terms of coordinating, completing, and handing over work areas. Frequently, an electrical contractor will raise constraints claiming they can't commence work due to mechanical works taking place adjacent or overhead. Now the mechanical contractor, due to LPS is enabled as a scheduler to point out where they could start work as another area might be free. On a fast-track project, traditional 'parade of trades' approach is not fast enough. Work needs to be constantly flowing, and LPS has given the team predictable workflow. Predictable workflow leads to

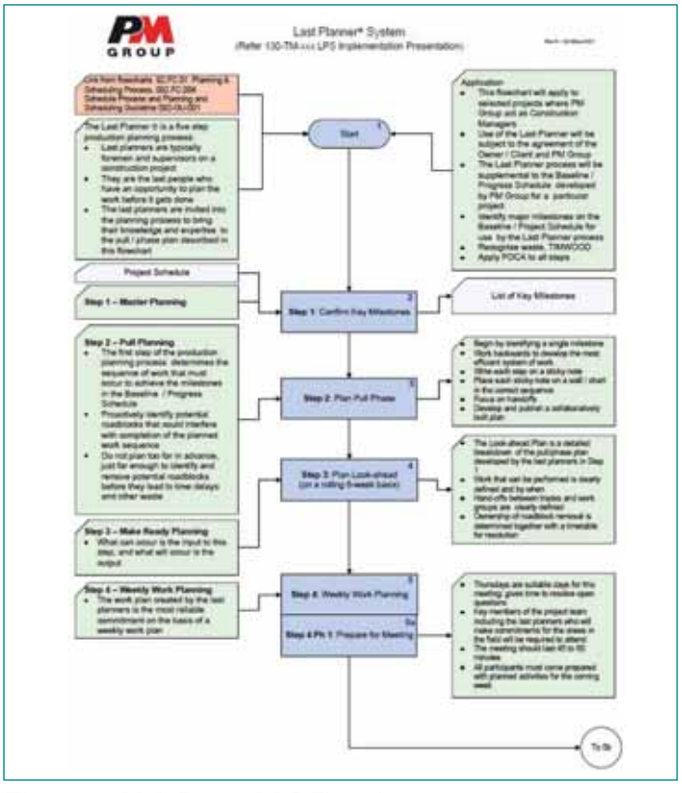

Figure 5. PM Group LPS Flowchart

higher productivity. The BDS team set a goal of snag free construction and this has been realised with a number of the first systems having been successfully walked down snag free. Credit can be given to the team for sequencing works from a top-down approach to allow for quality installs.

In conclusion, the intangible outcomes that LPS brings to the project team is where the real benefit lies for the BDS Project. The biggest challenges are developing and maintaining strong collaborative relationships and overcoming adversarial "turf battles" by dealing pro-actively with interfaces through working together effectively. A construction manager and management team can strive only so much to create a "team environment" with respective contractors, but complete commitment is needed at every level of the team to generate and achieve the highest level of safety, progress, and quality. It has been the experience on the project that the LPS approach as summarised in this case study assists greatly in achieving this outcome.

COMPANY OVERVIEW

COMPANY WEBSITE
www.bamcontractors.ie

Operating successfully for over 60 years, the bedrock of BAM's success has always been an understanding of our clients' needs and a willingness to deliver innovative solutions that ensure cost savings and surpass environmental expectations. BAM Ireland is the top Civil Engineering company in Ireland, and in the top 2 of the country's largest construction businesses. Operating across all construction sectors and throughout the complete project lifecycle, our principal activities are building contracting and civil engineering in the public, private, and PPP sectors. Other activities include facilities management, property development, and rail infrastructure.

It is BAM's mission to build sustainable environments that enhance people's lives by enabling the right people to capitalise on state-of-the-art knowledge, resources, and digital technologies, whilst also providing solutions across the total construction lifecycle for BAM's clients and generating maximum value for its stakeholders. We are a member operating company (OpCo) of Royal BAM Group of the Netherlands, a stock market listed PLC answerable for performance, which has a turnover of €8Billion and employs approx. 23000 people worldwide. At BAM we are building the present while creating a sustainable future for all.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHOR

Simon Tritschler

This case study explores how Artificial Intelligence (AI) deploys Lean culture to the construction environment. BAM Ireland recognises the value of innovation and that continuous innovation and improvement through technology is the path to our success in the future. Three years ago, BAM Ireland was selected as part of the pilot for a new software from Autodesk on their then fledgling "B360 Next Generation" platform. During this pilot, BAM Ireland's Digital Construction Team worked closely with Autodesk's developers on the application that has now been released as "B360 Construction IQ", Autodesk's application of AI for the construction industry.

AI is becoming more commonplace in our everyday lives, and it is behind many of the technologies like predictive text that we may now take for granted. Construction IQ utilises "Machine Learning" and "Natural Language Processing" across the BIM 360 platform to identify high-risk issues that impact cost, schedule, quality, and safety, as well as to identify patterns across the project portfolio. Identification of patterns within our projects has enabled us to more readily identify some of the sources of waste in our existing processes and to then act as a tool to monitor any implemented improvements.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Lean Thinking

Lean thinking at BAM Group is being applied in the more traditional context of Lean manufacturing. For example, BAM Nuttall in the UK operate a road sign manufacturing division that runs the full range of Lean tools for their daily operations, including, for example, 5S, Value Stream Mapping, Morning meetings, and Kanban. Additionally, there are several internal Six-Sigma experts, Lean handbooks and working groups. Yet despite our best efforts, the adoption of Lean within the construction industry is still playing catch-up with manufacturing in the adoption of Lean culture.

There is a growing trend toward Design For Manufacture and Assembly (DFMA) – also known as "Offsite Manufacture" – where the construction industry is moving from traditional onsite construction to factory construction, logistics, and onsite assembly, along with all the benefits this will bring. We already utilise offsite manufacture for modular construction, for example in bathroom pods, and companies such as Ikea and Katerra are currently offering complete finished structures as modular solutions.

But we are not there just yet – until we have taken that journey, the majority of our projects are still traditionally built and this means that not all of the Lean tools developed for manufacturing are directly applicable to construction. The Lean fundamentals of removing waste and increasing value are, however, completely applicable, and we must start from these fundamentals to ensure that the tools we implement develop in line with our needs and the needs of our customers.

Tools

In our entry to this publication in 2018, we went through the application of BIM as a means to introduce Lean thinking "indirectly" into the construction workplace.

Through BAM's 2020 Digital Vision for the implementation of a digitally enabled workplace, we have been able to realise the key tenants of Lean thinking to:

- increase the flow of work and information;
- reduce the waste of our traditional practices; and
- continuously improve our processes and the skillsets of our staff and wider supply chain.

In this case study, we focus on how BAM Ireland is using cutting-edge AI technology to build on our current digital experience, to reinforce the lessons we have learnt to date, and to share these learnings across BAM Group.

Construction IQ – AI Pilot

Construction IQ is a web-based application with an accessible graphical interface that displays project information in the form of graphs and prioritised lists. Transitioning from a traditional paper-based system to a digital system reduces much of the waste of transporting, processing, and communicating the information. Where paper checklists for quality and safety were once stored locally on shelves or boxes, or construction issues were kept in a someone's head or notebook, all this information is now instantly accessible and available to the relevant parties online and in the cloud.

One of the often-neglected consequences of such improvements in the reduction of paper is the massively increased volume of digitized data and information that is now captured and available to use. Where information was previously lost through the cracks of the process, it is now captured, and this creates a new problem for the user – what information in this vast sea of information is most relevant to me right now.

This is where AI is the right tool to assist in not only filtering through the data to "Sort" and "Set in Order", but also to look for patterns to "Standardise" how the information is displayed. While the 5S work very well within manufacturing, the S of sort, shine, and standardise are the most appropriate for construction from our pilot.

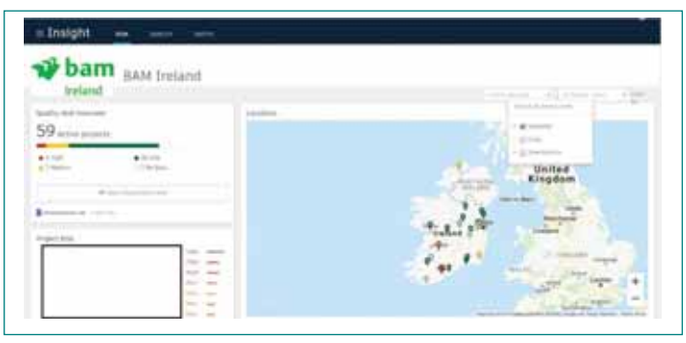

Figure 1. Project Address Issue Data Example

Project Address

Straight "out of the box" Construction IQ highlighted that we had not implemented a standard approach when setting up our projects in the B360 environment. We had not been diligent in entering the address details (they did not seem relevant at the time), the IQ map locations were incorrect, and the projects were incorrectly categorised by 'internal BAM department' or 'project type'. This became our first opportunity to shine our data model by backfilling all this basic information across our projects.

Issues – Impediments to Project Delivery

During a construction project there can be thousands of issues that can affect the delivery of the project, and on a daily basis the management team must prioritise these issues for resolution and to put in place the best resolutions.

"Setting in order" this sea of data is achieved through the dark magic of the AI algorithm. Using Natural Language Processing, the algorithm looks through the text that has been entered by the project team. Where the AI sees words that relate to a high-risk issue such as "leak" or "damp", it associates this as a water-related risk with the potential of water-related damage. It then uses its data model to automatically "weight" the severity of what it finds using the context of the surrounding issue text as a reference and the status of the issue with reference to its due date.

In addition to the automated assignment of the risk, the user can fine-tune the response of the AI utilising their own experience and professional judgment, and from this the AI is trained by their input and updates the data model for future reference to a similar event. This training of the AI – a form of continual improvement – builds a risk profile for BAM within the data model. Over time, this risk profile "standardises" BAM's response to similar issues as they arise and shares the learnings across all of the BAM users of the platform.

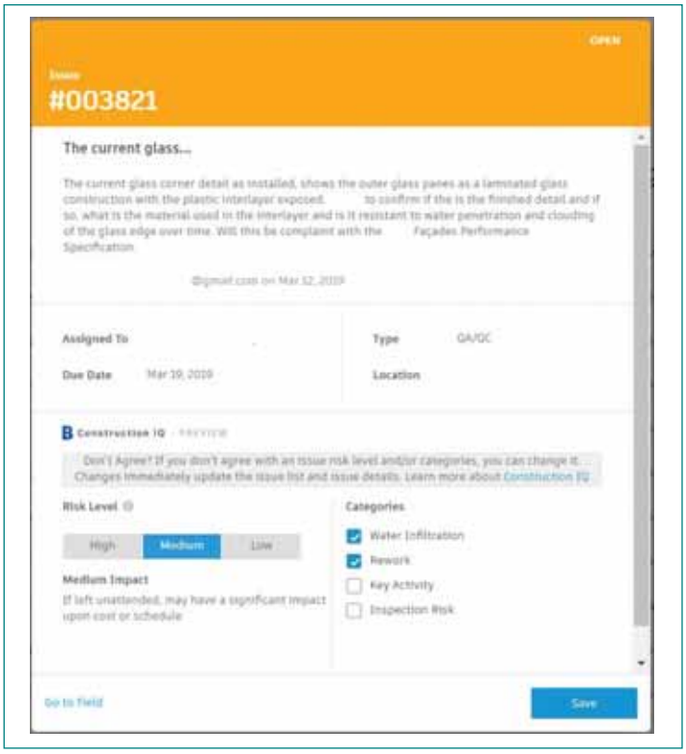

Figure 2. Open Issue Data Example

LEAN INITIATIVE IMPROVEMENTS & IMPACT

Key to the successful delivery of every project is the resolution of issues in an efficient manner. Following the initial basic housekeeping improvement within the project set-up, Construction IQ quickly identified that we, BAM, were the greatest risk to our own success. When we looked at these projects, the number of unresolved issues was uncomfortably high and represented the key to the high-risk factor to BAM.

Further investigation showed that our site teams were dutifully observing and logging the issues as they occurred within the B360 Field site management application.

Unfortunately, this is where our internal process started to fall down and our existing resolution process had become overwhelmed by the sheer volume of the issues being raised. We were recording the issues and then compounding the problems by not resolving them in a timely manner. This in turn created a waste cycle where the over-production of these problems was taking from our resources to focus on addressing the most relevant issues.

Figure 3. Quality Risk Factors Improved

Armed with the Construction IQ overview, we were able to refocus the project teams on closing out the issues, and, as the issues had been sorted, we were able to prioritise clearing the highest impact issues and bulk closing issues that had been closed on site.

Construction IQ Impacts

- AI has greatly reduced time spent analysing site data, leading to more time on site – we have seen a 20% improvement in both quality and safety issue resolution).
- Removing BAM as the main risk to their own projects by understanding the sources of the risk on each project.
- Increasing utilisation of mobile site data capture due to benefits now visible to site teams.
- Increased likelihood of BAM staff identifying serious issues that would adversely impact project delivery.
- Enabling BAM staff to better support the supply chain via focused issue resolution processes and better understanding by the various subcontractors of the risks to the project.
- Better understanding of risks to the project from poor process execution.
- Direct feedback of improvements made to existing process through reduced risk profile.
- Cross-project analysis to ensure that standard processes are being employed.

Figure 4. Subcontractor Risk Improved

Real Waste Reduction

- Reduced over-production of information.
  - o Reinforcing the correct process through additional training to the site teams has reduced the numbers of issues that BAM is responsible for resolving.
- Reducing Inventory & Transport by default.
- Reduced defects.
  - o By improving the resolution cycle of issues and closing them out promptly, the compounding of issues has been greatly reduced or removed.
- Reducing Inventory & Transport by default.
- Reduced waiting time as a result of automated reporting.
  - o High risk issues are automatically flagged directly to the user dashboard.
- Reduced non-utilisation of talent.
  - o Talent is no longer wasted sorting through a sea of information looking for the key issues.
- Reduced motion.
  - o Issues are no longer resolved by the wrong party.

Figure 5. AI Enabling Our Future Now

Future Positive Impacts

BAM Group is currently following on from its 2020 Digital Vision with a program entitled the "Universal Project Approach" (UPA). Under UPA, BAM is looking to standardise how we approach the entire construction lifecycle from design to O&M. Construction IQ, through the Autodesk B360 platform, will allow BAM to continuously assess and improve this approach across all of its operations globally by:

- Re-inventing the way BAM capture information, i.e. reducing the over-production of data captured.
- Exponential growth of effective Machine Learning data model via scaling of Autodesk Forge Platform for the construction lifecycle.
- Introduction of a proactive quality and safety culture.
- Removing unnecessary and time-consuming 'after the fact' reporting.
- Upskilling of BAM staff to better understand benefits and impacts of advanced analytic methodologies.
- Upskilling of BAM staff to better evaluate future technologies and their benefits.

bam Ireland

COMPANY OVERVIEW

JACOBS

COMPANY WEBSITE
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Jacobs leads the global professional services sector, providing solutions for a more connected, sustainable world. Headquartered in Dallas, Texas, with approximately US$12Billion in revenue and a talent force of more than 50000, Jacobs provides a full spectrum of services including scientific, technical, professional, construction and program management for business, industrial, commercial, government and infrastructure sectors. Marking 45 years in Ireland, Jacobs established its first international office in Ireland in 1974. Today, the company employs more than 1100 people across Dublin, Cork, and Belfast and is one of Ireland's largest firms.

OVERVIEW & BACKGROUND TO THE LEAN INITIATIVE

AUTHOR

Karl Page

The Charter

Jacobs' offices span several continents, time zones, and different lines of business (LOB). Traditionally, this meant that each office and LOB operated to their own standards using a variety of software systems. However, as this presented challenges to multi-office execution, Jacobs invested a significant amount of time and resources into standardising these software systems.

This investment required significant upskilling to implement new software systems. As with any standardisation initiative, a program that initially presented challenges has since afforded the broader group opportunities to mobilise resources from several offices to support large-scale project delivery.

The standardisation of software systems has allowed each office and LOB to also standardise elements of design that were traditionally specific to them such as "Revit" families, e.g. pipes, lights and equipment, with master cloud-based libraries used by each LOB. It is on the back of this strategic improvement across the operation that Jacobs have been afforded opportunities to dramatically change and improve how we design projects.

As a centre of excellence, the Irish operation over the past number of years has been given a charter to 'pave the way towards a leaner digitised solution for project delivery'. A disruptive mindset across the Irish operation has enabled this charter, and this approach has been encouraged and supported by Chair and CEO Steve Demetriou and his senior management team, including Ireland's management at local level. Without this support and the drive for innovation, the ask may have been too great.

In parallel to project delivery, over the past number of years the Irish operation has also focused on this charter by enabling a Digitised Solutions Group (DSG) to focus on areas across our project delivery which could be optimised by digitisation and automation. This case study is a summary of the areas where we have optimised our execution strategy and project delivery.

LEAN INITIATIVE UNDERTAKEN – LEAN THINKING, TOOLS, TECHNIQUES

Revit

As the new standardised software across the LOBs, Revit afforded the DSG a platform upon which to build a digitised delivery foundation. In comparison to its predecessor "AutoCad", Revit is a much more advanced system based on a 3D environment. As a 3D design tool in its basic form, Revit allows engineers to co-ordinate and gain an appreciation for the scale and complexity of the projects that we deliver.

However, this is just one element of the benefits of using this Autodesk product. The DSG focused on other capabilities available and discerned that a much greater focus was needed on the data entry into the model. It is based on this data entry that the Autodesk suite is a truly powerful project delivery tool. Through other software add-ons to Revit, the data can be managed, mined, controlled and used as a lean delivery tool, providing quality assurance as a biproduct.

Single Source of Truth

To get an appreciation of the potential to digitise elements of design, the DSG initially focused on data entries and areas of duplication. Across all the disciplines, we found that Jacobs had a vast amount of data which was duplicated in some format. Different forms of data were recorded on decentralised storage locations and on a multitude of different software programmes.

This meant that the data had no reference point and was open to inconsistent entries, leading to potential errors across the data. A further deep dive into the documentation presented single points of failure across the discipline design co-ordination, presenting the potential for errors to occur. To mitigate this potential issue, Jacobs developed robust quality procedures. However, as project schedules become more aggressive and the complexity and scale of the projects increase, these procedures would be stressed tested. Quality assurance

became a focal point, and the DSG set about establishing a Single Source of Truth (SSOT) to mitigate these potential concerns.

An SSOT, as the name suggests, is where all supporting data in a design is referencing a master document or database for information. Inputting design data is done once, at source, and duplication is removed. This is relatively straightforward for an individual discipline to manage, however in a multi-discipline sphere, changes made by one discipline can have a compounding impact on others.

The SSOT focus, therefore, had to be based on leading factors such as the equipment lists for process and mechanical, and that data being referenced by other disciplines. In its ideal state, the SSOT system has a multitude of layers of truth which need to co-ordinate across the layers. This means that the data entry inputted can be manipulated by the other layers or discipline data. For example, changes to room size have an impact on air conditioning, which impacts electrical, which impacts plant rooms sizes. Once an SSOT had been developed, the DSG looked to areas where digitisation could improve design efficiencies.

Figure 1. Single Source of Truth

Digitised Design

Without an SSOT, it would not be possible to automate elements of design as multiple sources, and potentially conflicting data, could exist. Once in place, and in conjunction with Revit and associated add-ons, the DSG were able to write programming code and scripts to automate design functions such as locating electrical services within the model with the click of a button.

Elements of design that would have previously taken weeks to design are now being produced within much shorter timeframes. Documents that would have previously been developed manually with limited functionality, have now in-built scripts to mine data from the model to extract reports, such as Material Take-Offs. The data inputted and extracted from the model is being managed in a much more efficient manner.

Separate to Revit, smart functionality has been programmed into a multitude of other deliverables, all referencing back to the model and the SSOT. This means that when changes are made to the SSOT a full suite of updates takes place across the design, which leads to programmed updates taking place. For the example used previously, when a room changes in size and the air conditioning changes – which leads to an automated update to the air flow diagrams – then the equipment lists would automatically be updated. This in turn automatically updates the electrical load list, which updates the single line diagrams and cable sizes.

Figure 2. Digitised Design

LEAN INITIATIVE IMPROVEMENTS & IMPACT

Quality Assurance

The introduction of the SSOT and Revit has afforded Jacobs the ability to programme in quality assurance measures such as error checking and design functions that are in compliance with regulatory standards. The programming of all the scripts and code has the engineering element built in to automate the design in compliance with the regulatory standards and specifications that we operate to.

A pertinent example of this would be our automation of the fire alarm design for the building: code has been written to locate fire alarm devices in compliance with IS3218 and EN54, with variable elements inbuilt. This means that if a heat detector is used as opposed to a smoke detector, the design accommodates to suit inputting said detectors in an unlimited amount of rooms at the click of a button.

This is but one example of how digitised engineering can provide quality assurance while also reducing the time to check a design. Traditionally, quality procedures require all drawings to be checked and updated, but our robust programming functions are providing the opportunity for Jacobs to check the code written and trust in the quality of deliverable. With the removal of multiple entries, the engineering teams have been afforded more time to focus on the engineering side of the project.

Figure 3. Quality Assurance

Big Data

As Peter Drucker said, "If you can't measure it, you can't manage it", and the DSG are focused on data mining the models and information from past projects to ensure that Jacobs are understanding the metric data. This data is essential not only to winning future projects, but also to bench-mark project delivery against the key performance indictors which we are judged upon. Programs have been written that automate the extraction of data from the model in a consistent manner. This makes the overall review of the project data easy and less time-consuming. Material take-offs, Builders work opes, data sheets and schedules are easily extracted from the model where traditionally this data would have been hugely time-consuming to generate.

Figure 4. Data Mining

Looking to the Future

Jacobs DSG are constantly looking at opportunities to innovate and improve the systems utilised in the design, with a focus on the future of engineering. Artificial Intelligence (AI), Machine Learning, and Neural Networks are all providing these opportunities. It means that this is a truly exciting time to be involved in engineering.

Figure 5. What's next?

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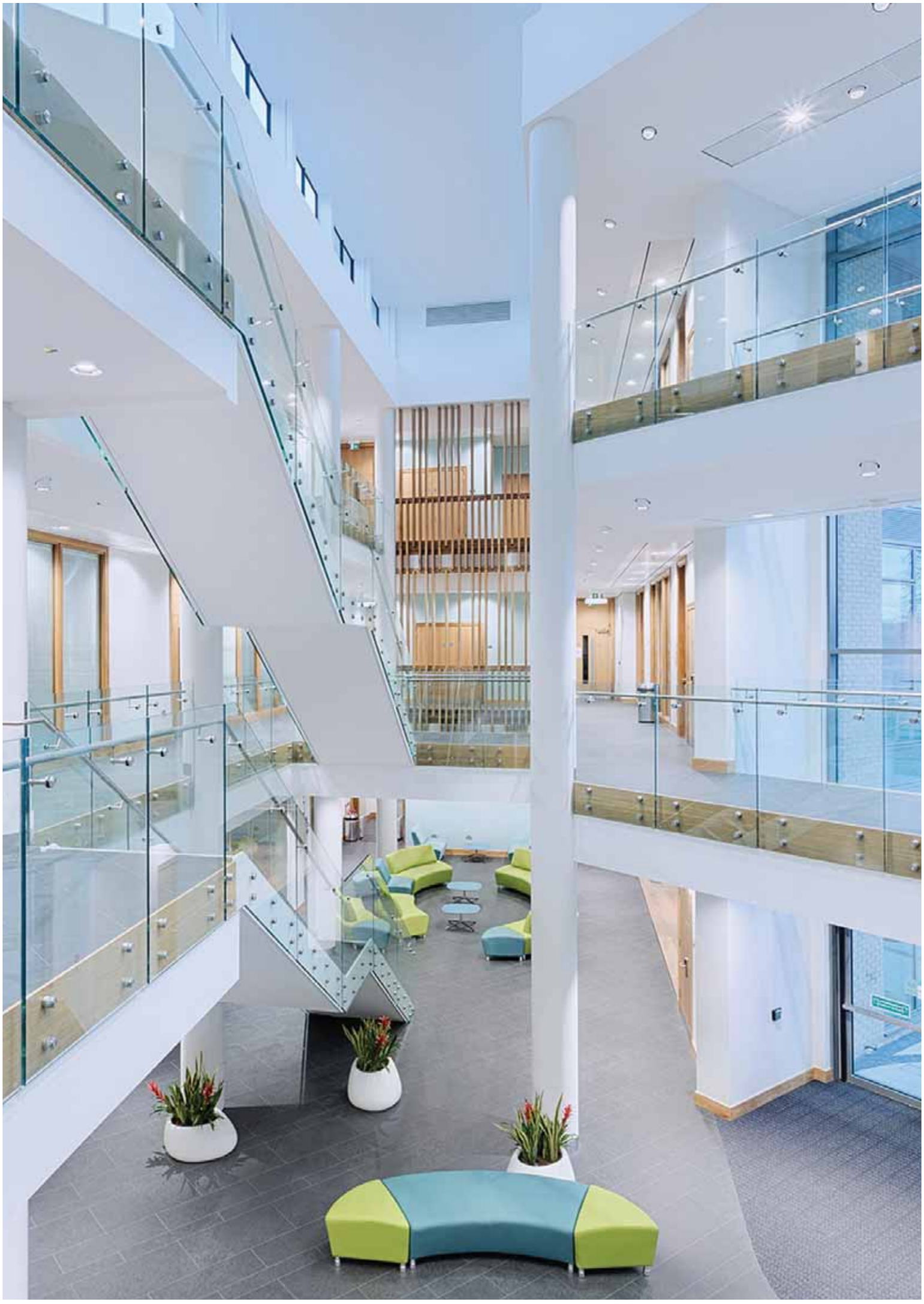

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Chapter 3

Glossary of Terms & Concepts

Glossary of Terms & Concepts

A3 – This is a one-page report prepared on a single sheet of paper that adheres to the discipline of PDCA thinking as applied to collaborative problem solving, strategy development, or reporting. The A3 includes the background, problem statement, analysis, proposed actions, and the expected results.

Activity – An identifiable chunk of work with recognised prerequisite requirements to begin, plus a recognised state of completion or condition of satisfaction. Another way to look at an activity is to establish the hand-offs for each chunk of work, thus defining the activity.

Assignment – A request or offer that has resulted in a reliable promise and is ready to be placed on the weekly work plan for performance. An assignment must meet the characteristics for a quality assignment prior to inclusion on the weekly work plan.

Buffer – A mechanism for deadening the force of reality unfolding in a manner that is contrary to what was anticipated in the plan. For example, a capacity buffer is created by committing to complete less work than what would be achieved according to the planned capacity of the resource. If production falls behind schedule, there is capacity available for catching up. Lean production/construction generally prefers capacity buffers to inventory buffers.

Building Information Model/Modelling (BIM) – The process of generating and managing building data during the life cycle of a building. BIM uses three-dimensional (3D), real-time, dynamic building modelling software. BIM includes building geometry, spatial relationships, geographic information, and quantities and properties of building components. BIM can include four-dimensional (4D) simulations to see how part or all of the facility is intended to be built and 5D capability for model-based estimating. BIM provides the platform for simultaneous conversations related to the design of the "product" and its delivery process.

Capacity – The amount of work that can be produced by an individual, specialist, or work group in a given period of time.

Choosing By Advantages (CBA) – This is a tested, effective, and sound decision-making system developed by Jim Suhr (1999) for determining the best decision by looking at the advantages of each option. CBA has five phases of decision-making: (1) Stage-setting: establish the purpose and context for the decision; (2) Innovation: formulate an adequate set of alternatives; (3) Decision-making: choose the alternative with the greatest total importance of advantages; (4) Reconsideration: change the decision if it should be changed or improved on; (5) Implementation: make the decision happen, adjust as needed, and evaluate the process and results.

Commitment-Based Planning – A planning system that is based on making and securing reliable promises in a team setting.

Conditions of Satisfaction (CoS) – An explicit description by a customer of all the actual requirements that must be satisfied by the performer in order for the customer to feel that he or she received exactly what was wanted.

Constraint – An item or requirement that will prevent an activity from starting, advancing, or completing as planned. Typical constraints on design tasks are inputs from others, clarity of requirements criteria for what is to be produced or provided, approvals or releases, and labour or equipment resources. Typical constraints on construction tasks are the completion of design or prerequisite work, or availability of materials, information and directives. Screening tasks for readiness is assessing the status of their constraints. Removing constraints is making a task ready to be assigned.

Constraints Log – A list of constraints with identification of an individual promising to resolve the item by an agreed date. Typically developed during a review of the 6-week look-ahead plan when it is discovered that activities are not constraint free.

Continuous Improvement (CI) – This is "Kaizen" in Japanese, and it refers to the never-ending cycle of incremental efforts to improve products, services, and processes. Lean is a CI methodology and Lean's 5th Principle of "Seek Perfection" and "PDCA" speak to CI.

Corrective Action Preventive Action (CAPA) – This is a process that investigates and solves problems, identifies causes, takes corrective action, and prevents recurrence of the root causes. The ultimate purpose of CAPA is to assure the problem can never be experienced again.

Cost Modelling – Developing a model of the cost components and systems specific to a project and structuring it in a manner that the components and system costs can be continually updated either via benchmarks, metrics or detailed estimates to provide the team with a constantly up to date cost model for the project. In the TVD environment, the cost model should allow for projecting 'what-if' scenarios based on value decisions that have yet to be made.

Critical Path Method (CPM) – The critical path method is a step-by-step project management technique to identify

activities on the critical path. It is an approach to project scheduling that breaks the project into several work tasks, displays them in a flow chart, and then calculates the project duration based on estimated durations for each task. It identifies tasks that are critical, time-wise, in completing the project.

Critical To Quality (CTQ) – These are the key measurable characteristics of a product or process whose performance standards or specification limits must be met in order to satisfy the customer. CTQs represent the product or service characteristics as defined by the customer/user.

Current State Map – This is a snapshot of how a process is currently done, showing the current methodology of how you produce products or perform services for your customers. It is a visual method of succinctly recording the key aspects of the current structure and processes in the whole, or any part, of a supply chain.

Customer – The individual engaged in a conversation for action who will receive the results of performance either requested from, or offered by, the performer. That is, the person receiving goods/information from a performer. Customers can be internal (for example, a foreman receiving answers to an RFI; or an architect receiving mechanical loads from an engineer), and external (for example, end users; or client organisations).

Cycle Time – The time it takes a product or unit of work (e.g. a room, building, quadrant) to go from beginning to completion of a production process. That is, the time it is work-in-process.

Defined Task – A quality task must be "defined". It must have a beginning and end, and it should be clear to all when it has been completed.

Dependence – This refers to where two or more tasks are sufficiently related that one cannot be started (or finished) without a certain measure of progress or completion having been achieved by the other. Waiting on release of work.

Direct Observation – Also known as "Observational Study", this is a method of collecting evaluative information in which the evaluator watches the subject in their usual work environment without altering that environment.

DMAIC – Define, Measure, Analyse, Improve, and Control. DMAIC is a data-driven improvement cycle used for improving, optimising, and stabilising business processes and designs. The DMAIC improvement cycle is the core tool used to drive Six Sigma projects.

Earned Value (EV) – This is an approach involving monitoring the project plan, actual work, and work completed value to see if a project is on track. Earned Value shows how much of the budget and time should have been spent, considering the amount of work done so far.

Eight Wastes – A framework of eight types of activity that do not add value, that is they are "Waste". They can be summarised as "DOWNTIME" (Defects, Over-Production, Waiting, Non-utilised resources/talent, Transportation, Inventory, Motion, Excess-Processing), or as "TIMWOODS" (Transportation, Inventory, Motion, Waiting, Over-Production, Over-Processing, Defects, Skills).

Enterprise Resource Planning (ERP) – This is the integrated management of core business processes, often in real-time, mediated by software and technology and providing an integrated and continuously updated view of core business processes using common databases.

Expected Cost – An expression of the team's best estimate at the conclusion of the Validation Phase of what current best practice would produce as a price for the facility reflected in the accompanying basis of design documents. Typically, the Expected Cost will also be supported by benchmarking or other market data to calibrate the Expected Cost in light of the market context.

Fishbone Diagram – This was developed by Ishikawa – often referred to as an "Ishikawa Diagram" – and is a cause-and-effect diagram used in root cause analysis to better understand the factors contributing to a problem.

Five Big Ideas – A set of organising concepts that support Lean Project Delivery. They were developed to explain and organise the Sutter Health Lean Construction Initiative: Optimize the project not the piece, Collaborate, Really Collaborate (originally implied "specialty contractors involved at schematic design"), Projects as Networks of Commitment, Increase Relatedness, and Tightly Couple Action and Learning.

Five Core Principles – These are the core principles underpinning Lean that were developed by Womack and Jones (1996), and include:

i. Value – It is defined by your customers who buy results not products (clean clothes vs. washing machines). We should give the customer what they want rather than what is convenient for us to give them.
ii. Value Stream – The sequence of all processes from raw material to customer.
iii. Flow – Keep value moving; avoid batches and queues; there should be few non-value-adding steps.
iv. Pull – Short-term response to customer's rate of demand and no overproduction.
v. Perfection – Delivering exactly what a customer wants, when they want it, at a fair price, and defect-free, with minimum waste.

5S – (1) Sort; (2) Set in order; (3) Shine; (4) Standardise; (5) Sustain. This five-step process for workplace efficiency uses visual controls to eliminate waste, and helps us organise what we need and to eliminate what we don't need, thus allowing us to identify problems quickly.

5 Whys – An iterative questioning technique, using cause-and-effect analysis, to get to the root cause of a problem by asking why successively whenever a problem exists in order to get beyond the apparent symptoms. As each answer to the why question is documented, an additional inquiry is made concerning that response.

Flow – Movement that is smooth and uninterrupted, as in the "flow of work from one crew to the next" or the flow of value at the pull of the customer.

Future State Map – A vision of the desired future Lean system that is used as the guide for the change process.

Gemba – The Japanese term for where the actual value is added or where the actual work takes place. Lean experts encourage

"going to the gemba" to see how things are really done and where there is opportunity to eliminate or reduce waste.

Hand-Off – The act of releasing an item or activity to the person or group performing the next step or operation on that item or activity, for example, a structural steel design is handed-off to the steel detailer to complete shop drawings; a room (or portion) that has been framed is handed-off to the drywall installer; or all construction on a floor of a hospital is completed and handed-off to the hospital personnel to begin staff-and-stock activities.

Hoshin Kanri – The Japanese term for direction management or strategy/policy deployment. Ho means direction; Shin means Focus; Kan means Alignment; Ri means reason.

Integrated Form of Agreement (IFoA) – A multi-party agreement that includes the owner, design professional, and constructor as signatories to the same construction contract.

Integrated Project Delivery (IPD) – A project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimise efficiency through all phases of the project, from early design through project handover. The three contractual components of IPD include: Organization Structure, Lean Operating Systems, and Commercial Terms.

Just In Time (JIT) – A system for producing or delivering the right amount of parts or product at the time it is needed for production.

Kaizen – The Japanese term for incremental continuous improvement. Kaizen is a structured process to engage those closest to the process to improve both the effectiveness and efficiency of the process. Its goals are to remove waste and add standardisation. Kaizen has come to mean the philosophy of continuous improvement.

Kanban – The Japanese term for a signposting mechanism associated with the demand pull principle. The signal tells workers to pull parts or refill material to a certain quantity used in production, they are a signal that a downstream or customer process can use to request a specific amount of a specific part from the upstream, or supply, process.

Key Performance Indicators (KPIs) – These are a set of measures designed to benchmark a business's most important characteristics against a set of strategic targets.

Last Planner – Integral to the LPS, this is the person or group that makes assignments to direct workers. Project Architect and Discipline Lead are common names for last planners in design processes; and Superintendent or Foremen are common names for last planners in construction processes.

Last Planner® System (LPS) – This is a system for project production planning and control, aimed at creating a workflow that achieves reliable execution, that was developed by Glenn Ballard and Greg Howell, with documentation by Ballard in 2000. LPS is the collaborative, commitment-based planning system that integrates should-can-will-did planning: pull planning, make-ready look-ahead planning with constraint analysis, weekly work planning based upon reliable promises, and learning based upon analysis of PPC and Reasons for Variance.

Last Responsible Moment (LRM) – The instant in which the cost of the delay of a decision surpasses the benefit of delay; or the moment when failing to take a decision eliminates an important alternative.

Lean – The concept that all processes contain waste. Lean is an integrated, value-driven approach to designing and improving work towards a customer-focused ideal state through the engagement of all people aligned to common principles and practices. It is associated with the ability to accomplish more with less – Lean Enterprises use less human effort to perform their work, less material to create their products and services, less time to develop them, and less energy and space to produce them. It implies a culture of respect and continuous improvement aimed at creating more value for the customer while identifying and eliminating waste.

Lean Construction – This is a respect-oriented and relationship-oriented production management-based approach to capital project delivery, and it is a new and transformational way to design and build capital facilities.

Lean Project Delivery System (LPDS) – An organised implementation of Lean principles and tools combined to allow a team to operate in unison to create flow.

Lean Thinking – The philosophical foundation, leadership mindset, and management orientation that enables all individuals in an organisation understand true Lean; and to design, develop, implement, manage, and maintain a Lean Enterprise.

Load – The amount of output expected from a production unit or individual worker within a given time.

Look Ahead Plan – A short interval plan, based on the pull/phase plan, that identifies all the activities to be performed in the next 6 (or other) weeks. The 6-week look-ahead is updated each week – always identifying new activities coming 6 weeks out so that the project management team can make appropriate arrangements to assure that the work will be ready to be performed in the week indicated.

Look Ahead Planning – The portion of the LPS that focuses on making work ready – assuring that work that should be done, can be done, by identifying and removing constraints in advance of need.

Look Ahead Window – The duration associated with look ahead planning. Typically look ahead windows extend from 3 to 12 weeks into the future, with 6 weeks preferred on most projects.

Make Ready Process – To make ready is to take actions needed to remove constraints from assignments to ensure the work can be done as planned.

Master Schedule – A schedule that identifies major events or milestones in a project (for example, start- up, turn-over to client, order long delivery components, mobilise in field, complete design, government reviews) and their timing. It is often the basis for contractual agreements between the owner and other team members. It is seen as a way to identify long lead items, the feasibility of completing the project as currently required, the basis for defining milestones and phases – but not always as a way to control the project.

Milestone – An item on the master schedule that defines the end or beginning of a phase or a contractually required event.

Muda – This is the Japanese word for "Non-Value-Adding" or "Waste", namely any activity that consumes resources but adds no value. They are a target for reduction or elimination. All Muda is caused by Mura and/or Muri.

Mura – This is the Japanese word for "Unevenness", namely any activity that has not been levelled out creating consequential complexity and cost. They are a target for reduction or elimination.

Muri – This is the Japanese word for "Overburdening", namely any activity that causes excessive demand on a system that causes the system to produce beyond its reasonable capacity. Pushing a machine or person beyond natural limits. Overburdening people results in stress, safety, and quality problems. Overburdening equipment causes breakdowns and defects. They are a target for reduction or elimination.

Necessary Non-Value-Adding (NNVA) – Those support activities that are necessary under the present operating system or equipment, but which do not per se add value. One should seek to optimise these.

Network of Commitments – The web of promises necessary to deliver any project. The role of management is to articulate and activate the unique network of commitments required to deliver each project.

Non-Value-Adding (NVA) – Those activities/processes that do not directly add/contribute value to customers – namely those activities the customer would not be happy to pay for. One should seek to reduce and/or remove these.

Optimal Equipment Effectiveness (OEE) – This is a hierarchy of metrics to evaluate how effectively a manufacturing operation is utilised with results stated in a generic form which allows comparison between manufacturing units in differing industries. It is not an absolute measure and is best used to identify scope for process performance improvement. It is a composite measure of the ability of a machine or process to carry out value adding activity. OEE = % time machine available * % of maximum output achieved * % perfect output. It measures the degree to which machines are adding value by not being wastefully employed due to planned or unplanned downtime or in producing defects.

Pareto Analysis – Sometimes referred to as the "80:20 rule", this is the tendency in many business situations for a small number of factors to account for a large proportion of events. For example, 80% of total sales volume might be attributable to 20% of customers and 20% of the product range. In terms of quality, 80% of defects might be attributable to 20% of causes. The 20% is sometimes referred to as "the vital few".

PDCA – Plan, Do, Check, Act/Adjust. This is the cycle introduced by Walter A. Shewhart and popularised by Dr W. E. Deming as a method for continuous improvement.

Percent Plan Complete (PPC) – A basic measure of how well the planning system is working – calculated as the number of promises/activities completed on the day stated divided by the total number of promises/activities made/planned for the week. It measures the percentage of assignments that are 100% complete as planned.

Performer – The individual engaged in a conversation for action who agrees to undertake performance either requested from or offered to a customer.

Phase – A period of the project where a specific group of activities is scheduled to be accomplished such as building design, completion of foundations, erection of exterior walls, building dry-in. A phase can be either a time period or a group of activities leading to the accomplishment of a defined goal/milestone.

Phase Plan – A plan for executing a specific phase of a project using a pull technique to determine hand-offs. It is prepared by the team actually responsible for doing the work through conversation. Work is planned at the request/demand of a downstream customer.

Plan Reliability – The extent to which a plan is an accurate forecast of future events, it is measured by PPC.

Planning – The act of conversation that leads to well-coordinated action.

Plus/Delta Review – A continuous improvement discussion preformed at the end of a meeting, project or event used to evaluate the session or activity. Two questions are asked and discussed. Plus: What produced value during the session? Delta: What could we change to improve the process or outcome?

Poka-Yoke – A Japanese term for mistake-proofing method or device developed by Shigeo Shingo that is used to prevent an error or defect from happening or being passed on to the next operation.

Personal Protective Equipment (PPE) – This is the equipment worn to minimise exposure to serious workplace injuries and illnesses.

Process Mapping – A flowchart identifying all the activities, operations, steps and work times for a process.

Promise – The action taken by a performer to commit to a customer to take some action to produce a mutually understood result, for example CoS, by a definite time in the future.

Pull – A method of advancing work when the next-in-line customer is ready to use it. A request/demand from the customer signals that the work is needed and it is pulled from the performer. Pull releases work when the system is ready to use it.

Push – Push an order from a central authority based on a schedule; advancing work based on central schedule. Releasing materials, information, or directives possibly according to a plan but irrespective of whether or not the downstream process is ready to process them.

Quality – Conformance to a customer's valid and agreed upon CoS.

Quality Assignment – Assignment that meets quality criteria

for release to the customer process. The quality criteria are: (1) definition; (2) soundness; (3) sequence; (4) size; and (5) learning.

Reason for Variance – Factors that prevented an assignment from being completed as promised, used by the team to promote learning concerning the failure of the planning system to produce predictable workflow. By assigning a category of variance to each uncompleted task, a team is able to identify those areas of recurring failure that require additional reflection and analysis.

Reliable Promise – A promise made by a performer only after self-assuring that the promisor: (1) is competent or has access to the competence (both skill and wherewithal); (2) has estimated the amount of time the task will take; (3) has blocked all time needed to perform; (4) is freely committing and is not privately doubting ability to achieve the outcome; and (5) is prepared to accept any upset that may result from failure to deliver as promised.

Request – The action taken by a customer to ask a performer to take some action to produce a mutually understood result (CoS) by a definite time in the future.

Right First Time (RFT) – This concept involves making sure that all activities are carried out in the right manner the first time and every time. A quality management concept that defect prevention is more advantageous and cost effective than defect detection and associated rework.

Root Cause Analysis – A systematic method of analysing possible causes to determine the root cause of a problem.

SCAMPER – The SCAMPER technique is based very simply on the idea that what is new is actually a modification of existing old things around us. It is a creative thinking and problem solving technique developed to address targeted questions that help solve problems or ignite creativity during brainstorming meetings. The name SCAMPER is acronym for seven techniques: (S) substitute, (C) combine, (A) adapt, (M) modify, (P) put to another use, (E) eliminate, and (R) reverse.

Screening – Determining the status of tasks in the look-ahead window relative to their constraints, and choosing to advance or retard tasks based on their constraint status and the probability of removing constraints.

Sequenced – A sequenced assignment should release work to another performer, and in no case should it hinder another assignment or cause other crews to do additional work. It refers to quality criterion for selecting assignments among those that are sound in priority order and in constructability order.

Set-Based Concurrent Engineering (SBCE) – This emanated from the Toyota Motor Corporation's approach to product development. SBCE begins by broadly considering sets of possible solutions and gradually narrowing the set of possibilities to converge on a final solution. A wide net from the start, and gradual elimination of weaker solutions, makes finding the best or better solutions more likely. As a result, a company/design team may take more time early on to define the solutions, but can then move more quickly toward convergence and, ultimately, production than its point-based counterparts.

Set-Based Design (SBD) – A design method whereby sets of alternative solutions to parts of the problem are kept open until their LRM, in order to find by means of set intersection the best combination that solves the problem as a whole.

Shielding – Preventing the release work to production units because it does not meet quality criteria; the work is not a quality assignment. It is akin to stopping the assembly line, rather than advancing a defective product. The purpose of shielding is to reduce uncertainty and variation, thereby providing production units with greater opportunity to be reliable.

Should-Can-Will-Did – To be effective, production management systems must tell us what we should do and what we can do, so that we can decide what we will do, then compare with what we did to improve our planning.

SIPOC – Suppliers, Inputs, Process, Outputs, Customers. This is a visual tool to assist in documenting a process from beginning-to-end.

6S – This is all of the 5S with the addition of Safety as the 6th S.

Six Sigma – A method and a set of tools to reduce variation in processes, particularly quality, using mostly statistical tools.

Sized – Quality criterion for assignments whereby the amount of work included in an assignment is made to match the capacity of the production unit that will do the work. The performer should have a very reasonable expectation that the assignment can be completed by the number of people available to do the job.

SMED – Stands for Single Minutes Exchange of Dies. It is a Lean production method to enable improved line changeovers and reduce the waste therein.

Sound – Quality criterion for assignments that tests whether or not assignments have had all constraints removed. The performer of an assignment should know that the materials, tools, staff, and information to complete an assignment are available before accepting it.

Standard Work – Integral to Lean, this aims at creating standardised processes and procedures that are repeatable, reliable, and capable – this being the basis for continuous improvement.

Takt – Takt time may be thought of as a measurable beat time, rate time or heartbeat. In Lean, Takt time is the rate at which a finished product needs to be completed in order to meet customer demand. If a company has a takt time of 10 minutes, that means every 10 minutes a complete product, assembly, or machine is produced off the line because on average a customer is buying a finished product every 10 minutes.

Target Cost – The cost goal established by the delivery team as the target for its design and delivery efforts. The Target Cost should be set at less than best-in-class past performance. The goal is to create a sense of necessity to drive innovation and waste reduction into the design and construction process.

Target Value Delivery (TVD) – This is a disciplined management practice to be used throughout the project to assure that the facility meets the operational needs and values of the users, is delivered within the allowable budget, and promotes innovation throughout the process to increase value and eliminate waste (time, money, human effort).

Target Value Design – Encompasses the Target Value Delivery approaches implemented during the design delivery phases of the project.

Target Value Production – Encompasses the Target Value Delivery approaches implemented during the construction delivery phases of the project.

Task – An identifiable chunk of work.

Throughput – The output rate of a production process.

Total Productive Maintenance (TPM) – This is a technique designed to optimise the performance, reliability, and productivity of plant and equipment. Responsibility for maintenance is given to the actual operators.

Under-Loading – Making assignments to a production unit, or a resource within a production unit, that absorbs less than 100% of its capacity. Under-loading is necessary to accommodate variation in processing time or production rate, in order to assure plan reliability. Under-loading is also done to release time for workers to take part in training or learning, conducting first-run studies, implementing process improvements, or for equipment to be maintained.

Utilisation – The percentage of a resource's capacity that is used in actual production.

Value – What the customer wants from the process. The customer defines value.

Value-Adding (VA) – Those activities/processes that directly add/contribute value to customers – those activities the customer is happy to pay for. One should constantly strive to expand these.

Value Stream – The sequence of activities required to design, produce, and deliver a good or service to a customer, and it includes the dual flows of information and material.

Value Stream Mapping (VSM) – The process of mapping out and visually displaying a value stream so that improvement activity can be effectively planned. VSM is the meta tool that guides all other Lean tools. When we utilise VSM we visualise the current state plus desired future state of a process that take a product or service from its beginning through to the customer.

Variance – When an assignment is not completed as stated, it is considered a variance from the weekly work plan.

Variance Trend Analysis – This refers to the quantitative investigation of the difference between actual and planned behaviour. This technique is used for determining the cause and degree of difference between the baseline and actual performance and to maintain control over a project.

Visual Management – Placing tools, parts, production activities, plans, schedules, measures and performance indicators in plain view. This assures that the status of the system can be understood at a glance by everyone involved and actions taken locally in support of system objectives.

Waste – The opposite of value, these are activities/processes that do not directly add/contribute value to customers, and that the customer would not be happy to pay for. The aim of Lean is to reduce and remove waste from processes.

Waste Walks – These are a form of direct observation and are simply a planned visit to where work is being performed to observe what's happening and to note the waste. It differs from go-see activities in that you are specifically looking for waste.

Weekly Work Plan (WWP) – The commitment-level (will) planning step of LPS identifying the promised task completions agreed upon by the performers. The WWP is used to determine the success of the planning effort and to determine what factors limit performance. It is a more detailed level than the look-ahead and is the basis of measuring PPC.

Weekly Work Planning – The process by which the Last Planner establishes the plan for the coming period.

Work Flow – The movement of information and materials through networks of interdependent specialists.

Work Structuring – Designing the production system to determine who does what, when, where and how, usually by breaking work into pieces, where pieces will likely be different from one production unit to the next. The purpose of work structuring is to promote flow and optimize system throughput by focusing on handoffs and opportunities for moving smaller batches of work though the production system.

Workable Backlog – An activity or assignment that is ready to be performed, but is not assigned to be performed during the active week in the WWP. If the team agrees that performance of this activity will not hinder other work, then it can be placed on the list of Workable Backlog as part of the WWP. Completion or non-completion of these activities are not recorded or counted in calculation of PPC.

Work In Process (WIP) – The inventory between the start and end points of a production process.

X-Matrix – Used in Hoshin Planning, the X-Matrix is a template used in organisational improvement that concisely visualises on one page (A3) the alignment of an organisation's True North, its Aspirations, its Strategies, its Tactics, and its Evidence.

Editor's Note

This glossary has been compiled and adapted from a variety of sources, primarily the LCI (USA) Glossary of Terms and the Waterford Institute of Technology Lean Lexicon.

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