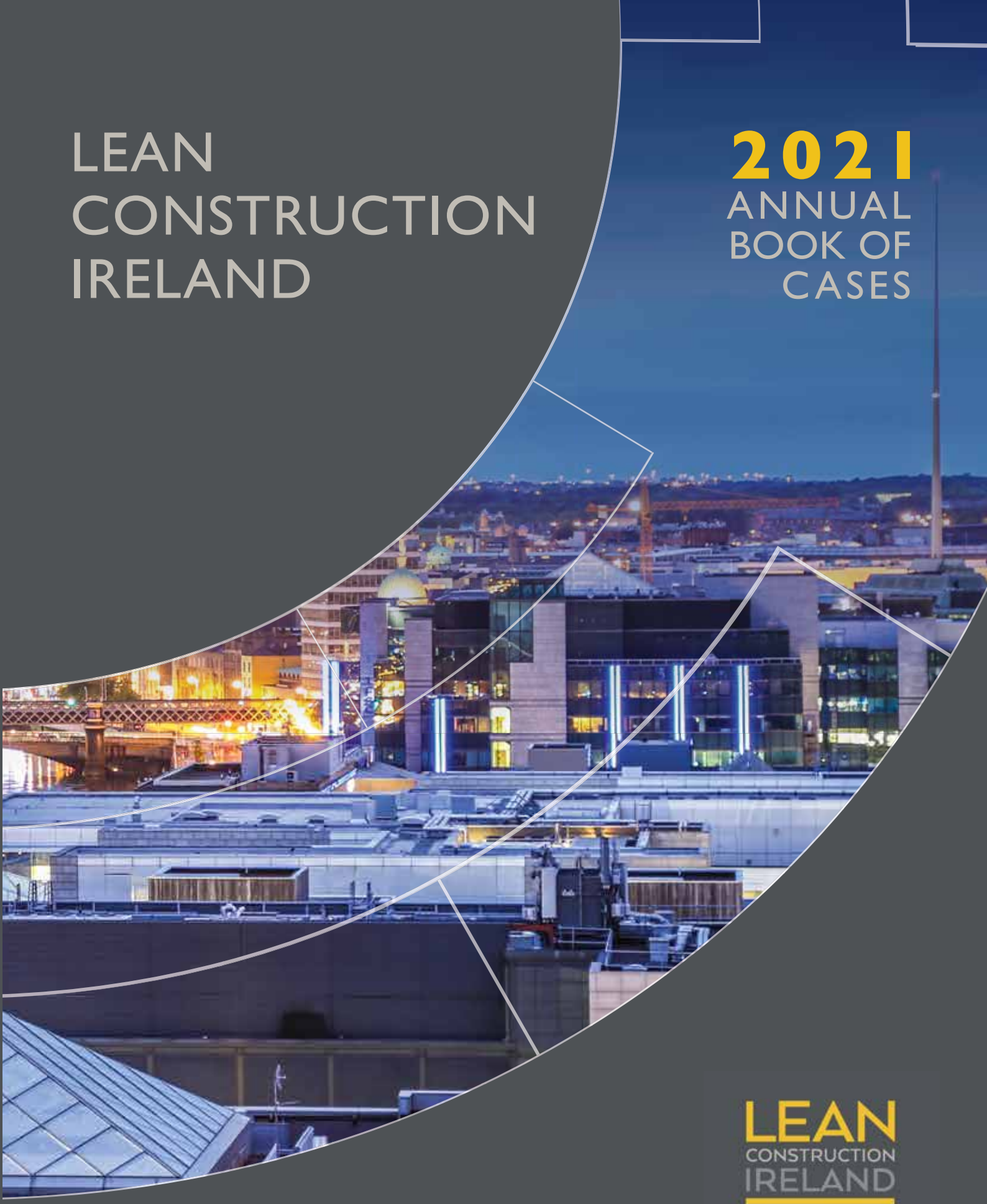
LEAN CONSTRUCTION IRELAND

2021 ANNUAL BOOK OF CASES



LEAN CONSTRUCTION IRELAND

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BETTER, FASTER, TOGETHER

Bristol Myers Squibb, Multi-Product Cell Culture Facility at Cruiserath, County Dublin (Image courtesy of Bristol Myers Squibb)

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 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 MBS in Lean Enterprise Excellence, the Executive MBA, the Diploma in Lean Fundamentals, and the Diploma in Supervisory Practice. He supervises postgraduate research on Lean management, operational excellence, continuous improvement, and Lean in construction.

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

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Foreword

Richard Fitzpatrick
Chairperson of Lean Construction Ireland

The Lean Construction Ireland Annual Book of Cases has established itself as the "go to" publication for our Irish community of learning and practice. It is the key Lean Construction reference for the Irish construction sector in providing core knowledge and case studies on Lean implementation for clients and their professional services providers, contractors, sub-contractors, and suppliers, and it continues to be the only such publication in the world.

In the volatile, uncertain, complex, and ambiguous (VUCA) world we live and work in, Lean thinking and practices provide individuals and organisations the opportunity to embrace the philosophy, principles, tools, and techniques to deliver value-add for clients and project delivery partners, as well as create collaborative and respectful working environments.

This Book provides clear evidence that the Irish construction sector is beginning the process of normalisation of Lean thinking and practices and aligning with the complementary areas of digitalisation and sustainability. Additionally, collaborative contracting arrangements are increasingly accepted as the most optimal approach to design and deliver value on capital projects – a point referred to in the National Development Plan 2021-2030. This year's Book demonstrates where sectoral organisations have adopted Lean for both internal operational excellence purposes as well as to enhance value-add in the design and delivery of capital projects.

Alongside this Book, Lean Construction Ireland has its website, annual conference, monthly webinar programme, and other resources that provide a vast and rich repository of knowledge and information on Lean thinking and practices that are freely available to the Irish construction sector.

I wish to acknowledge all involved in the publication of our Annual Book of Cases 2021, namely the case contributors, the book sponsors, and our publishing partner, Box Media. Sincerest gratitude to Darrin Taylor for his role as Editor and in coordinating and compiling this invaluable publication for the Lean Construction Ireland community of learning and practice.

Finally, on behalf of the Board of Lean Construction Ireland, it is my great pleasure to welcome you to the Lean Construction Ireland Annual Book of Cases 2021 and it is hoped that this Book inspires you and your organisations on your continuing Lean journeys.

Sincerely,

Richard Fitzpatrick
Chairperson, Lean Construction Ireland

CHAPTER 1

Case Studies

Company Overview | SUIR ENGINEERING |suireng.ie

Established in Ireland in 1984, Suir Engineering is an Irish-based European provider of Mechanical & Electrical services to high-profile clients in the data centre, life sciences, manufacturing, commercial, substation, and renewables sectors.

Suir Engineering has offices in Waterford, Dublin, London, Sweden, and Denmark, and across the UK, and directly employs over 1,000 highly skilled staff. Suir Engineering has developed a reputation for delivering cost-effective solutions for its clients whilst ensuring an uncompromised approach to safety, quality, and project delivery. Suir Engineering is a wholly owned subsidiary of EDF Energy Services, a JV between EDF Energy & Dalkia.

Author

Seán McHugh

Overview & Background to the Lean Initiative

Since 2015, Suir Engineering has invested in its strategic and company-wide improvement initiative entitled "Suir Way". Since April 2018, Suir Engineering has rolled out new processes for managing the entire organisation based on Lean principles and PDCA. Suir Engineering has invested heavily in its employees by providing a significant amount of both off-site and on-site training, and has developed its own purpose-built training centre at its Dublin location.

Thanks to the company's investment in its people, it is now seeing a transformation within the business. Employees are using their new skills on projects of all sizes to remove the eight wastes; introduce JIT for site deliveries; run Kaizen events; value stream map processes; utilise look-ahead planning based on the Last Planner System (LPS); apply 5S and Kanban systems to site stores; and develop standard work.

These Lean tools and techniques are driven by Suir Engineering's management system that promotes discussion, is data-driven, and ensures the correct and relevant information is channelled through the business, thus empowering everyone from the SMT, project managers, supervisors, and trades, to make informed decisions with all the necessary information.

Suir Engineering looked at solutions as to how it could best make use of all the information and data it had collected, and how this could best be shared across the business. Its solution was the development of a bespoke app for the business that is referred to as the "T2 APP", and this case study examines this initiative.

Figure 1. Training Room Citywest

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

ISO 90001:2015 highlights the importance of the PDCA cycle. First proposed by Walter A. Shewhart, and further developed by W. Edwards Deming, the PDCA cycle is a widely-used four-step model that can be used to manage and control any continuous improvement process, including the quality management system. A vital aspect of Suir Engineering's vision for the Suir Way is to utilise this cycle of Plan, Do, Check, Act.

Whilst data recording and information gathering has always occurred within Suir Engineering, the successful implementation of the Suir Way across all Suir Engineering's sites has resulted in a considerably greater volume and level of detail of information being gathered than a few short years ago.

Figure 2. PDCA Cycle

In order to make best use of this information and present it in a visual way to the Senior Leadership Team (SLT), it required

substantial resources and time to gather the information from each site and produce and share the information across the business. The significant amount of time taken to complete this work meant that, by the time the documents had been complete and presented to the SLT, the information was almost two weeks old. This had a significant effect on the business's ability to make decisions and the SLT did not have the ability to be proactive with their decision-making. Decisions were, therefore, often reactive given that they were based on information that was several days or weeks old.

A Kaizen event was held to address this issue using Lean principles. At this event, we discussed how we could standardise the recording of information across sites, reduce the workload in order to produce reports, and also make the information easier and more accessible throughout the business.

Whilst there are many software packages that claim to offer solutions to these problems, when we engaged with the solution providers we found that we would need to spend significant time and effort working with developers to make their software work as we needed, or that the software on offer did not have the flexibility to provide what we required to drill down for the business's areas of focus and we would thus be confined to working within its limited parameters.

Therefore, the decision was taken to create our own platform as this would allow us to develop a bespoke solution. While working with the developer on the design of the app, a critical consideration for us related to Lean Waste, namely Muda, Muri, and Mura. Working closely with the developer allowed us to simplify the application, thus making it extremely user-friendly and ensuring that even users with the most basic of computer skills could easily use the system and not feel overburdened (i.e. Muri) by the data collection. With a standard dataset being recorded across the business, it means everyone is working in the same way, thus removing ambiguity and potential imbalance (i.e. Mura). As only information that is needed is being requested by the app, there is no unnecessary data collection, thus eliminating waste overall (i.e. Muda).

A 5S approach was applied to the T2 app. This approach was taken when it came to information requested by the app, and the order in which it would be requested, as we wanted to ensure there would be a natural flow when the T2 questions were being completed and that there would be no unnecessary questions that would be recorded in the app, thus keeping completion time to a minimum. By implementing a 5S approach to the project, we could develop a better and easier product to use, thus resulting in greater buy-in from management and site teams.

Sort

Remove data and information that was not needed and only keep what was needed. By doing this, the app becomes easier, quicker, and more efficient.

Set in Order

Arrange the questions in an easy to follow arrangement where information flows easily one step after the other.

Shine

Keep things clean and tidy. The app interface was kept simple to ensure a barrier-free and user-friendly approach.

Standardise

Establish standards and guidelines to maintain the first three S. Every site would then be recording the same KPI in the same format.

Sustain

Make 5S a habit. The benefits of 5S are only truly to be seen if it is maintained in the long-term. With the app able to generate beneficial real time data, users could see the benefit. Another critical aspect was that the senior management bought-in to getting their information from no other source other than via the T2 app and this was a considerable factor giving sites no choice but to adopt the app.

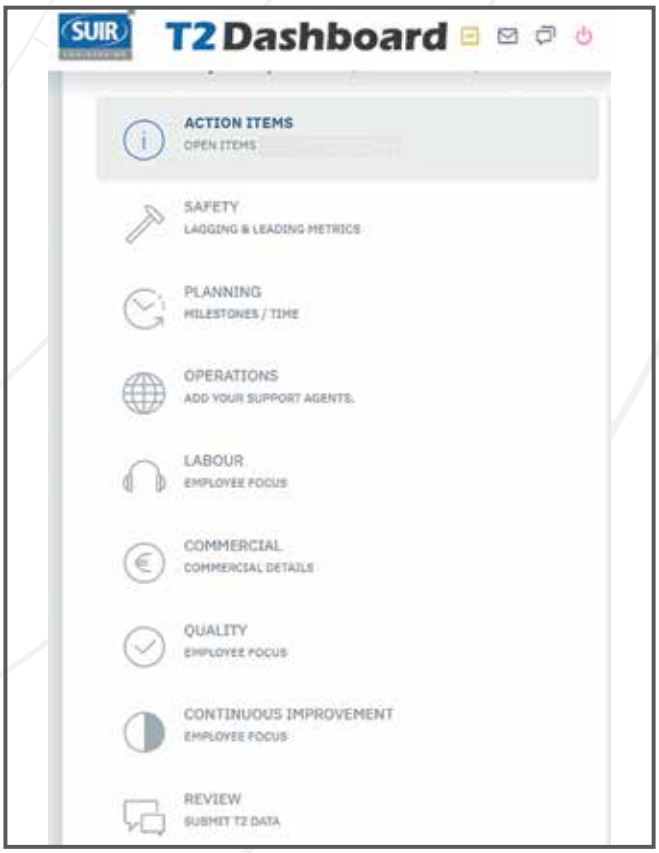

Figure 3. Sections of the T2 app

Figure 4. Data presented simply and without clutter

Lean Initiative Improvements & Impact

The improvements gained from the development and roll out of the T2 app across Suir Engineering's sites have been significant and improvements have been made both on-site and off-site.

At SLT level, information and charts can be called upon instantly, giving the user the ability to have a real time visual representation of how the overall business, individual projects, or even a variation within a job, is performing on a weekly basis. This information is then being used to determine the deployment of resources within the company. It is also becoming a steering device pointing the SLT team in the direction they need to focus their efforts. This enables the SLT to focus time and resources where they will have the greatest impact for the business. By placing an emphasis on those projects requiring the most input, a greater focus is placed on utilising more Lean activities such as Gemba walks, problem solving, and reaffirming the Suir Way on the project in order to ensure that the problems on the project are uncovered and rectified as quickly as possible.

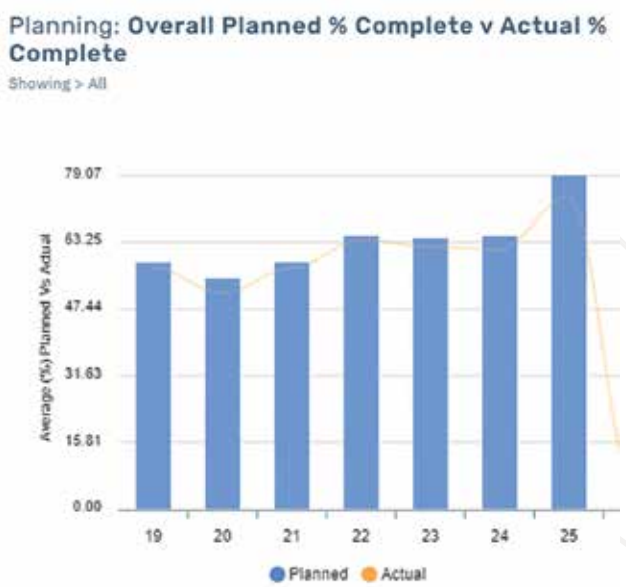

Figure 5. Weekly Progress Report

At the project level, Project Management Teams have the ability to perform a deep dive on the data being generated from their projects and use this information to analyse trends, compare actual progress to predicted progress, and ensure any steps to complete corrective actions that are within their control are taken swiftly. This ensures that negative trends do not begin to develop.

Amongst Suir Engineering's Supervision, the T2 app has been responsible for an increased focus on the importance of planning tasks in advance and ensuring we maximise customer value. This increased planning has meant that staff have had to make more of an effort to work more collaboratively with each other, therefore improving communication on site. The result is that issues are raised in a timely manner and with more time to discuss and resolve the issues, and items are being resolved before they have a chance to make an impact on the project timelines.

With more people aware of the overall company objectives and goals, Suir Engineering personnel are able to see how their contributions make an impact within the organisation. This high level of employee engagement has resulted in improved morale. Additionally, there have been reductions in over-processing and Takt-time as we begin to see and address problem areas. The importance of a right first time mentality has been generally adopted by staff who are showing positivity towards Lean thinking and practices.

Figure 6. Example of information being tracked on site

Staying true to the PDCA philosophy that made the app come to fruition, the T2 app is continuously being developed and updated to implement more improvements and features that will better serve the business. As the volume of data we capture increases over time, the company will be able to better predict areas of risk when taking on new projects and build up the adequate resources in the required areas. This will allow Suir Engineering to continue to be a trusted and reliable provider of Mechanical & Electrical services to some of the world's most high-profile companies.

Company Overview | GRAHAM | graham.co.uk

GRAHAM is a privately owned contractor with an impressive 200-year history. Specialising in building, civil engineering, interior fit-out, facilities management, and investment projects, we operate from a network of regional offices throughout the UK and Ireland. With an annual turnover of GB£808.1m and a healthy GB£1.7bn pipeline of opportunity, we are a trusted delivery partner to a range of prestigious clients across a broad spectrum of sectors. These include education and health, highways and maritime, and commercial and retail. We also participate on over 50 national and regional frameworks. Strengthening our reputation, we are an Investors in People (IIP) Platinum and Health and Wellbeing accredited business, and we were named as the inaugural winner of the IIP Excellence in Health and Wellbeing Award. With over 2,200 employees, these prestigious benchmarks demonstrate our commitment to being a best practice employer that invests in its people, prioritising their health and well-being within a culture of Fairness, Inclusion, and Respect.

Author

Katie Jones

Author

Paramjit Lota

Overview & Background to the Lean Initiative

The Regional Delivery Partnership is a five-year framework whereby contractors are monitored on both their behaviours and performance. In parallel, they are incentivised to innovate and work efficiently. A central component of National Highways (formerly "Highways England") NEC Contract 3 model is a requirement for contractors to create the step-change desperately needed within the construction industry. The delivery of commitments is not only important to GRAHAM, but also to our clients. Our P6 Scheme Programme includes everything associated with delivery, but excludes programming for support functions such as tender commitments. From the outset, we identified the potential for software to allow us to programme everything outside of delivery whilst utilising the Lean Last Planner methodology. Our priority was that any proposed tool was cloud-based to meet the challenges presented by Covid restrictions, with the flexibility to run what were historically face-to-face collaborative planning meetings using post-it notes on the wall.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

What was the problem the Lean initiative was trying to resolve?

As part of the new National Highways Regional Delivery Framework, we were required to deliver 80 additional commitments as part of our tender. These commitments were established to support the National Highways ambition to move towards an alliance type framework. The commitments are activities which the contactor has agreed to deliver as part of the framework, with an expectation that they are industry leading in order to generate the much-needed step-change within construction. Each commitment is costed by National Highways, and the consequence of non-delivery is a financial penalty equating to the anticipated cost of that commitment.

At the heart of the GRAHAM Lean Deployment Programme is an understanding of our client needs. We recognised the importance of simultaneously driving delivery and demonstrating progress against these commitments, thus offering certainty to our client, National Highways. We also identified significant benefits in breaking these commitments down into more detailed sub-tasks.

Initially, commitment delivery was slow and cracks in our process appeared because:

- The Covid pandemic meant meeting up and having a collaborative planning session using post-it notes became impossible.
- There was no consistent approach for progressing and updating commitments. We did not know how we were progressing with the delivery of our commitments as they were being driven by people spread across different parts of the UK. This meant that people were working on multiple spreadsheets where data and updates were getting missed with no single source of governance.
- The plan for commitments, despite being so important to the client, is not factored into the existing P6 Construction Programme. This made it difficult to understand our progress and which commitments required renewed focus.

What was the goal of the Lean project?

We wanted a simple cloud-based solution that allowed staff to efficiently provide updates on the commitments using mobile technology. The creation of a common platform would remove double data entry requirements and eliminate errors and duplication. Having a bottom-up approach, using a pull flow system, would also generate accountability and increase team engagement. Furthermore, it would enhance productivity as it removed the time spent pursuing updates. Another requirement was to report progress to National Highways via a visual dashboard. This would ensure a focus on key areas identified through utilisation of the last planner methodology.

What was the Lean solution?

GRAHAM evaluated the capabilities of a range of software development systems, and, after a rigorous selection process, VisiLean was identified as the most suitable solution. VisiLean is a simple yet powerful Production Management Platform for managing large programmes of work. As a cloud-based platform developed on proven Lean Construction principles, VisiLean ensures flow, value generation, and waste minimisation across workflows.

Figure 1. Primary components of VisiLean

VisiLean allows organisations to visualise project plans at a programme level, with a typical Gantt that supports Task creation and even Plan import from P6, MSP and Excel, for example. Teams then utilise VisiLean to drive the Last Planner® System (LPS) for collaborative planning. It allows all teams to participate, visualise their commitments, discuss any potential issues, and map them in the look-ahead planning view.

Once a clear look-ahead picture is defined with the teams participating on the platform, each member uses VisiLean, either through the browser or the Mobile App (LiveSite), to update the progress on their commitments and flag any issues that require the team's attention. They supplement this with Notes that allow for healthy discussions during the collaborative review sessions.

Figure 2. Clear capture of short-falls, constraints, and conversations

Finally, all of this data populates a completely automated Dashboard that promotes a focus on Value Drivers that can help improve the planning and delivery of commitments as a team. As the commitments did not form part of our delivery programme, we had to try and organise the commitments into more manageable sub-groups. The sub-groups were identified as function areas which exist within GRAHAM, for example, customer, stakeholder, quality, or Lean.

Next, we completed Master Planner sessions where we placed all 80 commitment milestones on a programme and then worked backwards to understand what other sub-tasks we may have to deliver to ensure that we would meet the commitment milestones. GRAHAM now has a solid and more detailed 5-year programme for delivery. The commitments programme could have been produced directly into VisiLean, but we used spreadsheets and then imported them into VisiLean.

As our commitments are only over 5 years, we decided to run the collaborative planning meeting at 10:00 on the first Tuesday of every month.

Challenges

Setting up the LPS was challenging for the commitments for several reasons:

- There was no existing programme for the commitments, and the original dates that were identified in our tender were from almost 4 years prior. As expected, the programmes had changed significantly since then.
- Some commitments have evolved since the contract andtherefore more in-depth conversations had to be had with National Highways surrounding the amendment of contractual commitments to suit the current environment.
- Setting up the initial workshops and allocating owners to provide updates.
- Adaptations had to be made within VisiLean to make the system suit non-construction-related activities. The VisiLean team worked closely with us to swiftly make amendments.

Meeting Format

- Discipline leads within GRAHAM meet virtually on the first Tuesday of each month.
- The leads will have submitted progress updates throughout the month using their mobile devices.
- During the meeting, each discipline lead will take turns to run through their commitments for that month.

Lean Initiative Improvements & Impact

- Any re-planning is then done with full consent from the rest of the team.
- Completed commitments will already be marked as complete, but non-complete tasks will need to be pushed to a new date along with a reason for non-completion.

VisiLean has resulted in major improvements, including the certainty it has provided to us in delivering on our contractual commitments. National Highways has really supported GRAHAM by engaging in this new way of working and acting as the quality assurance approver for the commitments. Working collaboratively alongside the client on the same platform supports the ambition to work as an alliance with trust and transparency.

We are not only meeting but exceeding contractual requirements made by our client, National Highways, by driving Lean initiatives such as Collaborative Planning, identifying waste within the programme and construction processes, smoothing the flow and creating a pull system – meaning the programme is led from bottom-up with updates provided by the people that do the work.

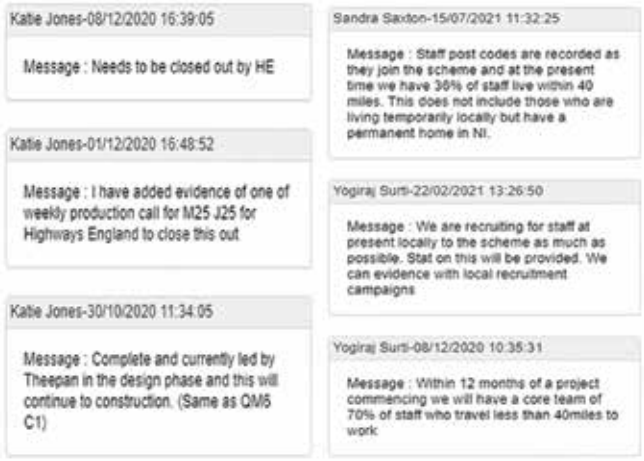

Figure 3. Clear capture of project conversations

We have noticed that staff now have increased time to concentrate on more value-adding activities. Traditionally, the people doing the work more often than not did not engage in the programme. Now, our programme is led by our staff who have full accountability of their tasks.

Not only is this more efficient, but we have seen an improvement on behavioural maturity assessments conducted on behalf of National Highways. There is much more communication and collaboration amongst the team, with a willingness to try and support one another.

VisiLean enhances communication through a simple interface that promotes conversation, allows users to add notes, drawings, pictures, and voice notes against each commitment. This data is particularly useful as it provides a lessons learned log for any given commitment. National Highways uses this information to share and increase maturity of its supply chain, supported by its data-driven improvement initiative.

We have detailed visibility of live commitment progress and performance in any given area. VisiLean enabled GRAHAM to quickly identify where it was consistently falling short on its PPC. The output report from VisiLean, very quickly and at the press of a button, provided a succinct business case to gain an additional resource. This meant that we have been able to identify a shortfall

Figure 4. PPC of 82% achieved through Nov-Dec 2020 – Design Primary Constraint

in our programme commitment to National Highways early in the process.

This traditionally would not have been identified until the end of the project when our programme was delayed. We have also found that VisiLean has strengthened collaboration between our support functions, office staff, and our site workers who add the real value.

The live dashboards and intelligence around commitments and highlighted areas, significantly reduce the time spent on reporting and administration. Equally, they provide us with reports against value drivers, themes, and potential efficiencies, all of which can be easily and quickly sent to National Highways. Notably, we have achieved 100% commitment programme certainty.

Figure 5. Single platform for capturing evidence for each commitment

The VisiLean team has supported us along the journey and made adaptations to the system to support our needs. This case study illustrates how GRAHAM and VisiLean, along with National Highways as the client, have established an exemplar collaborative partnership that mirrors the UK Government desire to drive productivity and increase collaboration as referenced in The Construction Playbook.

Tracking productivity and focusing on areas for improvement have been industry challenges for some time due to the lack of reliable data. GRAHAM, VisiLean, and National Highways continue to work closely to further expand the process to track productivity, drawing from live data taken directly from site.
Finally, our commitment relating to innovation was exceeded through this VisiLean Pilot as it guaranteed visibility and achieved maximum efficiency.

Company Overview | MACE | macegroup.com

Mace Technology (Ireland) has been established in Ireland for over 10 years and has constructed two of Ireland's largest and most prestigious projects, namely Dublin Airport Terminal 2 and Project CLN, a hyper-scale data centre campus in Clonee, Co. Meath. Mace Ireland operates not only as a general contractor here in Ireland, but also provides professional construction services such as cost management and programme management for blue-chip clients such as Microsoft, Irish Water, Eirgrid, and Facebook.

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Overview & Background to the Lean Initiative

This study was carried out on a hyper-scale data centre that entailed both design and build and design-bid-build phases. Preparation and approval of design documentation is a key factor for managing an efficient production control system. Construction projects are complex projects that involve multi-disciplined stakeholders with the preparation and coordination of design activities in line with strategic milestones. Design is linked to construction activities and then through to inspection and quality control. Design teams and construction teams need to collaborate to create and verify design documentation before procurement and site installation and inspection. Team fragmentation has been identified as a barrier for efficient design management, and design teams, contractor supply teams, and vender supply chain are dispersed.

The Last Planner® System (LPS) was identified as a possible solution to managing contractor drawing and technical submission improvements. In parallel with Lean and BIM management, design deliverable dates were identified in advance of programmed construction dates. Shop drawings and technical submittals were prepared for review by the design team. This was managed in line with the construction programme which allowed planned works to proceed safely and in a timely manner.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Design Last Planner System

Construction is a series of actions undertaken by construction companies which produce or alter buildings and infrastructure. Individual construction companies become competent at one or more of the actions over many years, and they apply their specialised skills and knowledge on construction projects. The design and construction of buildings and infrastructure are undertaken by specialist design and construction professionals, and supported by an integrated network of suppliers and specialist contractors.

Integrating project teams to work collaboratively has increased productivity in construction. The lack of approved design documentation had been noted as a significant factor for missed assignments in the construction last planner process. Improved coordination between trade contractors, main contractor, and design teams was required to improve the delivery of approved design information in line with planned construction activities. To integrate design and construction activities, a design coordination and last planner meeting was scheduled weekly. The purpose of that meeting was to improve communication between construction and design teams. The meeting was structured to provide a coordinated look-ahead document preparation schedule. This was managed in line with the construction programme for the timely preparation of documents to ensure that there was an uninterrupted workflow for construction activities. The vision for all stakeholders is to deliver the highest quality project with all documentation complete and defect-free at practical completion. To achieve this, a collaborative approach to design, construction, and inspection was required.

Design and Quality

At the interface between design and construction, the following questions accentuate:

- Has the design of the elements been completed?
- Have the necessary technical submissions and benchmarks been approved?

Work needs to be considered in greater detail as the make-ready process focusses on matching the available resources for work with the present realities on the construction site to ensure production can proceed at an optimum level. Information flows connect activities to design and quality to facilitate the make-ready process. Only when this is agreed can tasks be considered for execution in weekly work plans.

The importance of information management, and the ability to share information between project stakeholders to ensure that the project requirements are met, provides a robust platform for managing task allocations and sequencing.

The value-added data is one that supports the craft worker by ensuring that the planned works proceed uninterrupted and that any variance from the plan is forecast and mitigated to manage resource utilisation. This relationship between information and material flow suggests that design last planner improves the overall production

system by raising the efficiency of information logistical processes. The main challenge is to ensure the deliverables are issued in a timely fashion and at a standard to achieve approval right first time to allow works to progress in a timely fashion.

The traditional approach used the standard Information Release Schedule (IRS), which itemises all deliverables and their planned delivery dates. This normally results in the Package Managers having to spend a lot of resources to ensure their contractors deliver.

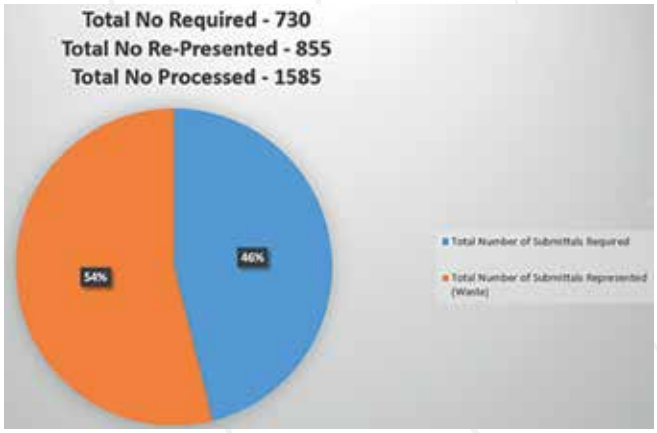

Figure 1. Submittal Production Waste

The delivery and management of the technical submittal reviews often proves protracted and inefficient due to the large number of stakeholders, from Contractors to Design Team and Client. A previous building phase, which utilised the IRS approach, required 730 technical submittals that resulted in these being presented a total of 1,585 times to achieve a Status A. Any technical submittal presented more than once is considered waste. This was therefore identified as an area for improvement for site production as technical submittals are crucial for procurement and quality.

The design last planner improved coordination of site activities and the last planner meeting provided a means for an integrated trade contractor and general contractor design interface. The design activities were identified and prioritised by identifying the make-ready needs for the construction process.

Short-term work plans were developed wherein design constraints were identified and systematically removed to successfully complete design documentation in advance of trade contractor construction activities. Measuring planned percent complete (PPC) of planned design activities provided a more transparent and efficient means for tracking design productivity and improved the quality of the information produced. As principal contractor, the conditions of satisfaction were communicated to multiple contractor design teams and the collaborative nature of the process increased the quantity and quality of the documentation.

Therefore, this improved productivity on the project. Tasks were planned with greater certainty and the quality of the installations improved by adhering to the correct documentation. This in turn improved weekly work planning. When tasks are deemed to be sound, they can be considered for inclusion in the weekly work plans for production units on site. This process requires multi-disciplinary teams to coordinate production unit activities for the project. Team members who are making commitments were able to commit defined assignments and interact with other production units for trade-to-trade hand-overs and quality assurance inspection teams.

Lean Initiative Improvements & Impact

Prior to the submittal process, the Design Team and the Client was where the technical submittal requirements were agreed, which in turn were relayed to the Contracting Teams individually via a series of workshops. The Last Planner requirements and expectations with all stakeholders were communicated and agreed.

All contractors and the Design Team were required to prepare 6-week look-ahead plans and weekly work plans that itemised committed deliverables on a rolling week-by-week basis. Weekly meetings were set up to review the make ready needs to avoid pitch points and ensure smooth information flow. The teams were encouraged to act collaboratively and as one. Prior to the formal submission, the contractors were required to discuss with the design team the requirements and expectations.

This approach resulted in significant improvements in reductions to the number of iterations required to achieve a Status A, right first time, and in turn saw a substantial improvement to the ratio of waste.

Analysis to date is limited to work packages that have enough technical submittals presented, namely:

1. Civil.
2. Steels.
3. Mechanical.
4. Electrical.

Figure 2 encompasses the mechanical work package of the delivery of technical submittals of planned versus actual, and is representative of all work packages analysed to date.

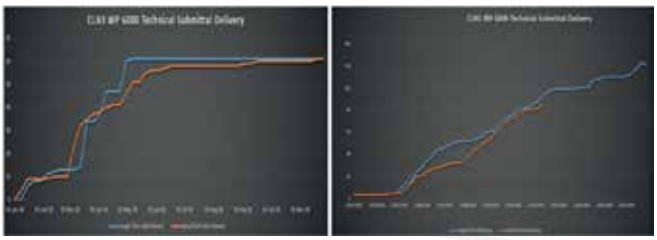

Figure 2. Package Delivery Planned Vs. Actual

The Mace Last Planner approach results in a smoother flow of information. It gives foresight to the Design Team of impending workloads, thus allowing provisions to be made to resource

manpower to meet the workload. It is also dynamic, allows for change to be accommodated, and enables ease of tracking.

Figure 3, for the mechanical services, compares the delivery of technical submittals iterations for the current phase to the previous phase and is representative of all work packages analysed to date.

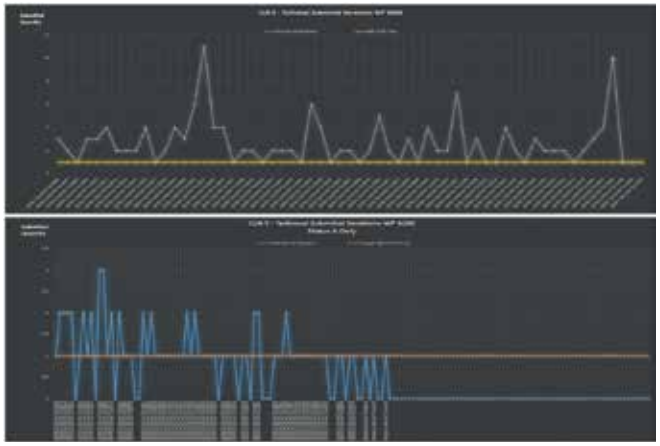

Figure 3. Technical Submittal Number of Iterations

The number of iterations required to achieve Status A has reduced and the quantity of technical submittals being approved right first time has also increased.

Right First Time Improvements

Civil Work Package WP 6000	CLN3	CLN5/6	Comment
Total No of Submittal Required	67	109	CLN5/6 Stats comparison for submittals received up to project working week 31
Total No Right First Time	39	55	
Percentage Right First Time	58%	50%	

Steels Work Package WP 2600	CLN3	CLN5/6	Comment
Total No of Submittal Required	20	27	CLN5/6 Stats comparison for submittals received up to project working week 31
Total No Right First Time	6	15	
Percentage Right First Time	30%	56%	

Mechanical Work Package WP 6000	CLN3	CLN5/6	Comment
Total No of Submittal Required	61	65	CLN5/6 Stats comparison for submittals received up to project working week 31
Total No Right First Time	17	48	
Percentage Right First Time	28%	74%	

Electrical Work Package WP 6000	CLN3	CLN5/6	Comment
Total No of Submittal Required	21	85	CLN5/6 Stats comparison for submittals received up to project working week 31
Total No Right First Time	3	62	
Percentage Right First Time	14%	73%	

Work Package Sample Totals	CLN3	CLN5/6	Comment
Total No of Submittal Required	169	286	CLN5/6 Stats comparison for submittals received up to project working week 31
Total No Right First Time	65	180	
Percentage Right First Time	38.46%	62.93%	

Figure 4. Right First-Time Percentage

The average right first time after implementation of LPS increased to 62.93%. The number of iterations post-first release has also reduced following the implication of the Mace LPS, resulting in significant improvements to the ratio of waste.

Work Package (Ratio of Non Right First Time to No of Integrations of Submittal Type Issued = Ratio of Waste)	CLN5/6
Civil Work Package	0.47
Steels Work Package	0.93
Mechanical Work Package	0.55
Electrical Work Package	0.53
Average / Trending	**0.62**

Figure 5. Ratio of Waste

The ratio of waste is trending at 0.62 for the current project compared to 1.17 for the previous phase. For the Civil Work Package, the percentage right first time has marginally reduced, and Ratio of Waste has marginally increased. However:

- The Civil Work Package was starting from a higher success ratio for the previous phase compared to the other Work Packages.
- The Civil Work Package was the first work package to employ the last planner approach, which required a learning curve period to bed in.
- The current project had a new design team and there is an element of trust building to be developed.

For the current project, the quantity of required Technical Submittals is trending at c.1,600 and projecting the ratio of waste would see c.1,600 number of Technical Submittals being presented c.2,592 times. Using LPS, we were able to measure and recognise variability and highlight trends to improve our productivity. If we did not introduce the Mace Last Planner to the submittal process, it would likely have seen the quantity of technical submittals being presented c.3,473 times – a delta of c.880.

An analysis of the time spent by the project team to prepare and review submittals for re-review equated to an average of 110 minutes of Project Time. The reduced number of re-submissions has resulted in a project saving of c.1,163 man-hours.

Figure 6. Submittal Time Calculation

Company Overview | ACB GROUP | acbgroup.ie

ACB Group is a 100% Irish owned company that has grown and excelled both nationally and internationally, having more than 18 years of industry experience on a myriad of complex and fast-moving projects. ACB's vision is to be the 'Go To external envelope solution provider in the global datacenter market' with a mission 'to differentiate our customer solutions using digitisation, innovation, and modern methods of construction'. At ACB Group we provide the complete design and build solution for your building envelope, including roofing and façade systems along with internal cladding solutions. We are accredited with ISO 9001:2015 (Quality), ISO 45001:2018 (Health and Safety), and are awarded BSI Verification Certification for Design and Construction.

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Overview & Background to the Lean Initiative

ACB Group is an organisation dedicated to Lean thinking and practice and continuous improvement for many years to enable the business to operate to its full capacity as it experiences exponential growth. With the advent of the Covid pandemic, and the associated worldwide shift to digital, ACB Group took the initiative to develop a new strategy plan to create a leaner system for lead evaluation through investing in a customer relationship management (CRM) system called ConstructionBos (see Figure 1). The initiative came about through the desire to move information to the cloud across the organisation. The growth and expansion of teams into an online world heightened the need for an online system that could see multiple users interact with projects simultaneously.

The agreed budget for the project was c.€15,000, including purchasing data, licences, and maintenance. The Lean initiative was implemented in two phases and based on making ACB CRM the master. Phase 1 entailed the implementation of the main CRM system, and getting data across and training users. Phase 2 entailed the live data feed to develop an automated governance mechanism.

Having a Lean approach to the way in which the business operates and the way the tendering team conducts its business, aligns to the Lean principle of 'Pursue Perfection'. This focusses on the business's Lean and continuous improvement principles making the organisation as effective as possible.

Figure 1. ConstructionBOS

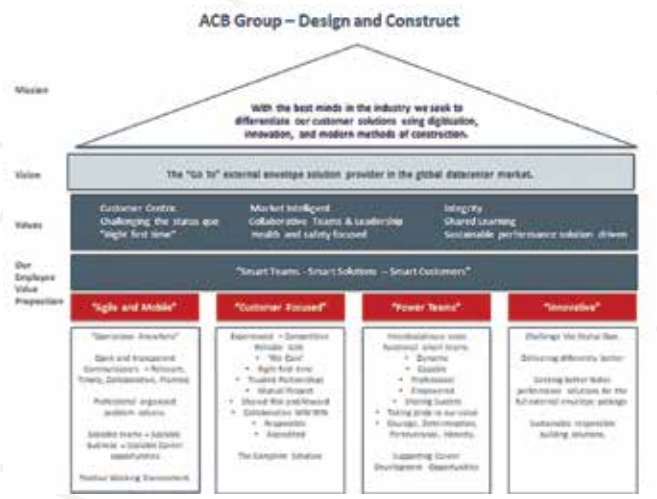

Figure 2. ACB Group Overview with Innovation Pillar

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

The Kaizen approach is heavily adopted by ACB Group with continuous improvement being a key pillar. One of the many business goals of ACB Group involves migrating all business data to the cloud, including the way in which leads and project data are held. Before the implementation of ConstructionBos, the organisation managed all tendering activities in one centralised excel sheet

stored on a server. The problem with that process, although a tried and trusted methodology for many years, was it had become too arduous to manage as the world adopted remote working due to the Covid pandemic.

As ACB Group continues to grow and remote work becomes the norm here in Ireland, the UK, and Europe, the logistics of using one excel sheet for a team of six to update was proving problematic. Users were only able to access the sheet one-at-a-time. The information being updated could become inconsistent, and any failure to internal servers (although rare) would interrupt the workday and potentially corrupt the data held within the excel file. One individual working on and updating the sheet via a screen share with the rest of the team giving the information, meant the process was slow in areas such as note-taking, discussions on individual projects, and organising the excel sheet.

The previous format relied on excel sheets to log notes against projects in leads and ones of high priority in the pipeline. Project 'Levels' did not exist – instead projects were categorised as a First or Second Pass. High-priority projects in the Second Pass bucket were generally highlighted manually as opposed to now where the system automatically flags the change in status, thus saving time resources. The key difference with the use of ConstructionBos is that more defined levels were developed by the Power Team (see Figure 2), with ConstructionBos tailoring the system to ACB specifications (see Figure 4).

As well as using excel sheets, Construction Information Services (CIS) was used by the business to track projects in Ireland. Notes and the status of these projects were shared between the excel and CIS. Figure 3 presents the process map that was followed before the implementation of ConstructionBos. The CIS system was not user-friendly nor fit for purpose based on the specifications that ACB Group was looking for. However, Figure 4 illustrates the new process mapping along with in-depth information on the ACB strategy, quantifying Project Identification (Level 1) to Project Win/Loss (Level 5), and this all resulted in a much leaner tendering process.

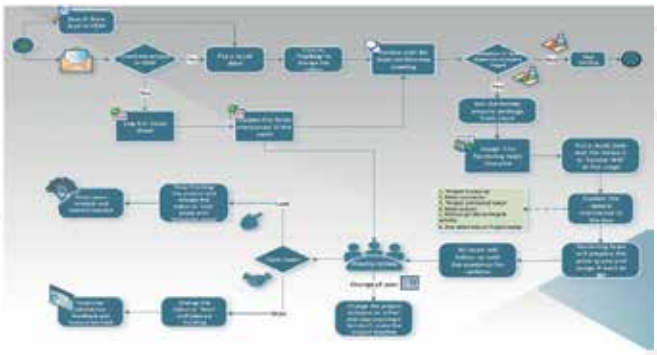

Figure 3. Old CRM Process Map

Leads were manually managed and counted weekly in the excel. Reports involving new leads, leads to tender, and other KPIs used by the business were controlled through the excel file. ConstructionBos is linked to Barbour ABI, a company providing project data through an Application Programming Interface (API) field into ConstructionBos. This means an easy passage of a lead into the ACB Group pipeline. With the integrated system to manage leads, ACB Group can build on and improve lead to tender reports with an automated system.

If a project enters in level one or two, it can be tracked from the moment it enters through to a tender being issued or the project being won or lost.

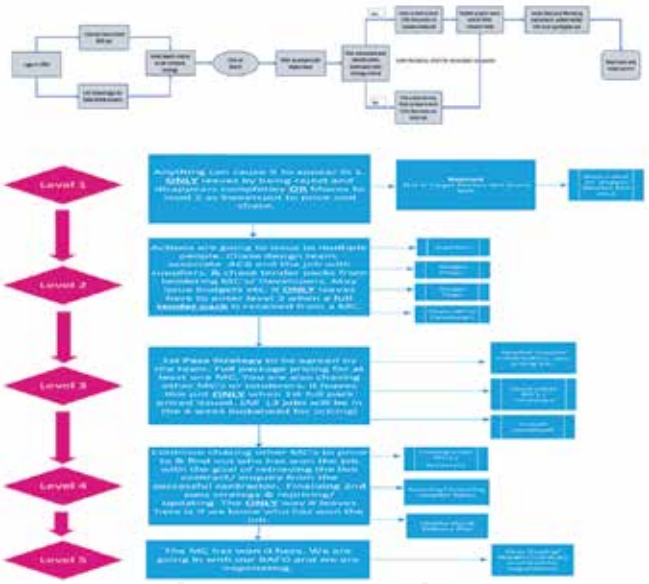

Figure 4. New Process Map and Deep Dive on Levels

The Power Team used the following Lean tools and techniques to map the process as we migrated from the traditional ACB system to the newer ConstructionBos system.

Bottleneck Analysis

A bottleneck analysis was used by the Power Team to map the process and identify issues. This was undertaken to look at the current workflows and processes in place, thus helping to improve the processes and eliminating most operational challenges, and thus enabling a streamlined tendering process.

Plan-Do-Check-Act

The team devised a plan using the Plan-Do-Check-Act (PDCA) framework. Figure 5 illustrates the detail of the process undertaken by the ACB team.

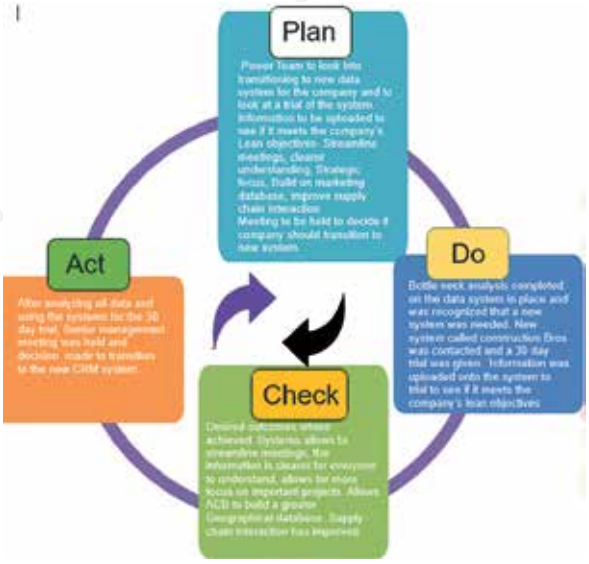

Figure 5. Plan-Check-Do-Act Map

Value Stream Mapping (VSM)

VSM was used to illustrate the roles all members of the tendering team had, how they should interact with the system, and what happens at certain stages of the process. This enables the team to have clear, open, and honest collaboration on all pipeline and tendering workload, whilst also encouraging continuous improvement as to how the organisation operates. ACB Group has achieved tracking on all data centre projects in Ireland and the UK, thus reinforcing a hard strategic focus on this market sector.

Overall Equipment Effectiveness (OEE)

The OEE is being analysed in phases by the PowerTeam in charge of implementing the CRM. As a high-level view, the system is available to all team members who require access. The performance of the CRM is smooth, with additional fields or fixes made effortlessly. The usability is, as expected, based on the tutorials given both internally and externally. The tendering team have refined reports and the way in which the system is used to enable the CRM to be highly effective.

Lean Initiative Improvements & Impact

There were several key improvements in the business process due to the implementation of ConstructionBos CRM.

Streamlined Lead Meetings

Before the CRM was introduced, projects were categorised as a first and second pass item. With the introduction of the CRM, meetings about pipeline became focussed. The old process saw meetings take place two days a week, lasting between 2-3 hours, to provide project updates. One meeting was held to analyse the pipeline of key opportunities and one for the analysis of current projects on which to tender.

With continued use and refining of the CRM from the PowerTeam, and input from all stakeholders of the tendering department, this has now reduced the meeting to one two-hour slot in the week. The team come prepared with their notes inputted into the CRM, so all stakeholders are aware of updates ahead of the meeting. The meeting is now used to focus on key updates and allows members to expand around other project related talking points.

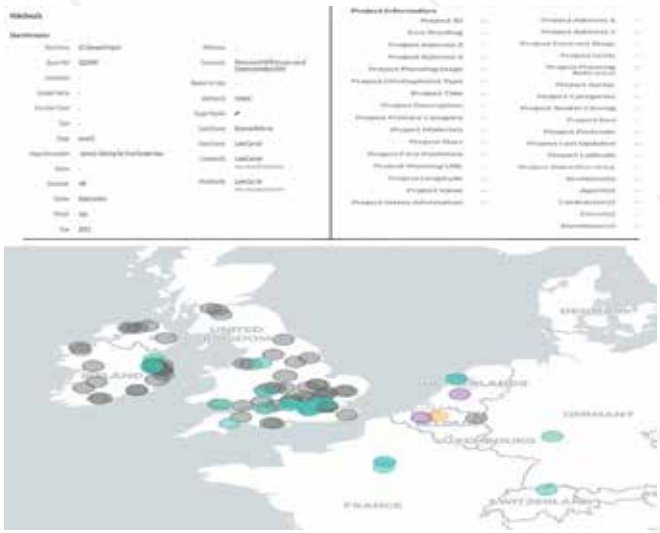

Figure 6. Deal Layout in ConstructionBos CRM & Geo-Mapping Overview

Clear Understanding

Since the introduction of the CRM, there has been greater breakdown of the pipeline and activities associated with each level (see Figure 4). A level is referred to by the team as the status of a particular project. Level 2 is the key level for the team where a project is identified as a 'Sweetspot'. Each stakeholder understands the activities mapped out and what actions happen at each level, with their actions taken away from the meeting. This actively helps ACB Group align, for example, with the LCi slogan of being Better, Faster, Together.

Strategic Focus on Sweetspot Projects

The CRM has allowed the business to understand the Sweetspot projects that are being targeted and where. The CRM allows all users and anyone else in the business understand which market the current pipeline of work is situated, what sector, and what actions have taken place against the project. This allows ACB Group to continually operate in an open and transparent manner with all PowerTeams throughout the business.

The geographical element (see Figure 6) of this is done through the ConstructionBos CRM being linked with Zoho Analytics which is included in the same suite of products as the CRM. Fields of information are synced from Barbour ABI to give the team geographical locations. Price reports and other features can be derived from the live data of ConstructionBos integrated with Zoho Analytics.

As well as internal transparency, the CRM allows all primary users understand conversations that have taken place offline with key contacts, as well as updates on individual companies with notes compiled against each Sweetspot company.

Simultaneously Building a Marketing Database

In migrating to a cloud-based CRM for all tendering and pipeline data, the CRM has also allowed ACB Group to simultaneously build a marketing database of information to ensure the best customer relationships are built on trust and transparency. It helps senior management identify those partners whose work aligns to ACB Group's win: win approach.

Improved Client Interaction

Supply chain interactions have improved because the data collected and used by ACB in the system can be arranged accordingly and then discussed with suppliers. Data is now being organised and used right first time. The team has lists that are easily filterable based on sector and supplier, meaning meetings can be streamlined and both parties can get a satisfied outcome. Merging the data gathered offline with data from Barbour ABI results in ACB being able to understand and interact with projects at an early stage.

Team Satisfaction

All the tendering team members have reported great satisfaction in terms of phase one of the implementation of ConstructionBos. The tendering team reported that the new procedure and processes

run smoothly and they are happy with the reduced meeting times.

Lessons Learned

As the market grew from Ireland-only data centres to include UK projects, the dataset of projects increased substantially. Given the long lead times with data centre projects coming to fruition (typically 18-24 months), the shift to identifying other projects in sectors such as Higher Education builds in the UK and complex industrial builds existed in parallel to data centre projects being nurtured. This tactic can result in the CRM becoming clogged up with projects that are off-strategy, with resources like time being wasted, discouraging a Lean approach. Therefore, the lesson learned was to have a hard strategic focus on the Data Centre sector, particularly in the UK as ACB learn the market trends.

ACB GROUP
Design and Construct

Company Overview | DPS GROUP | 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. Our sector expertise spans many markets, including Biotechnology, Pharmaceutical, Medical Technologies, Oil and Gas, Advanced Technology, Food & Beverage, Energy, Science & Education. 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 1,800 people worldwide.

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Overview & Background to the Lean Initiative

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. DPS Group has previous case studies on Last Planner® System (LPS), Target Value Design (TVD), and Takt Planning published in the 2018, 2019, and 2020 LCi Annual Books of Cases respectively. DPS Group strives to be innovative in continuously improving its delivery methodologies and is thankful to Felipe Engineer Manriquez for introducing us to the concepts and principles of Scrum and Agile. Our trade partner, Ardmac, hosted an on-site Scrum introduction facilitated by Felipe and immediately some of our staff recognised how Scrum could assist with project coordination and execution. DPS Group now commits to a full-time Scrum/Agility Coach, three Scrum at Scale (S@S) Practitioners, five Product Owners, 48 Scrum Masters, and over 500 trained Scrum development team practitioners.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Agile, with its roots in Lean thinking and practice, emerged from the software engineering world from dissatisfaction with the traditional waterfall, sequential, and time fence approach to scheduling product delivery and releases. As the demand for software increased, speed to market became an overriding priority, lowering the priority of other goals such as quality. In 2001, a group of software development professionals formulated and published the Agile Manifesto to break the traditional software development project mould and free software developers from unreasonable and unproductive constraints. A definition of Agile in the context of capital project delivery is given as: a collection of values, principles, and practices originating from the Agile Manifesto that is used to improve project delivery. An agile project is designed to be nimbler and more dynamic. Whilst a stable backbone defines clear deliverables and work packages at the standard project gates, dynamic capabilities are overlaid to react quickly to changes and allow projects to move more seamlessly through each stage.

The key characteristic of an Agile project is the empowered cross-functional team working across silos to create end-to-end accountability. Work is carried out in shorter and more iterative sprints that enable the teams to quickly test and adjust ideas, minimising risk of miscommunication or overdesign.

Scrum is a subset of Agile and allows people to manage complex and adaptive projects. It is based on the three pillars of transparency, inspection, and adaptation. The Scrum Guide (2020) describes Scrum as:

"Scrum is a lightweight framework that helps people, teams and organizations generate value through adaptive solutions for complex problems. In a nutshell, Scrum requires a Scrum Master to foster an environment where:

1. A Product Owner orders the work for a complex problem into a Product Backlog.
2. The Scrum Team turns a selection of the work into an Increment of value during a Sprint.
3. The Scrum Team and its stakeholders inspect the results and adjust for the next Sprint.
4. Repeat Scrum is simple. Try it as is and determine if its philosophy, theory, and structure help to achieve goals and create value.

The Scrum framework is purposefully incomplete, only defining the parts required to implement Scrum theory. Scrum is built upon by the collective intelligence of the people using it. Rather than provide people with detailed instructions, the rules of Scrum guide their relationships and interactions."

Scrum involves three key roles:

- Product Owner: Define and prioritise the features of the Product Backlog; Decide on release date and content; Responsible for the profitability of the product (ROI).

- Scrum Master: Facilitates the Scrum process and Team self-organisation; Removes obstacles and shields the team from interference; Responsible for improving performance of the team.
- Team: Cross-functional (including testing); self-organising and self-managing group of individuals has autonomy regarding how to achieve its commitments; typically comprises 3-9 team members.

Scrum entails four core meetings:

- Sprint Planning: Product Owner presents READY backlog to Scrum Master and Team; Deliverable is Sprint Backlog.
- Daily Scrum: Team self-organises to improve performance; Deliverable is new daily plan for implementation and impediment removal.
- Sprint Review: Team presents backlog that is DONE to Product Owner and Stakeholders. Deliverable is velocity (what Product Owner confirms is DONE), feedback (used to update Product Backlog), and potentially shippable Product Increment.
- Retrospective: Scrum Master and team identify the top process improvement; Deliverable is the kaizen project to put at top of Sprint Backlog for next Sprint.

The Scrum process, as illustrated in Figure 1, is initiated by the Team, Scrum Master, and Product Owner holding a Sprint planning meeting (1) which clarifies the batch of work to be undertaken. This work batch is refined into executable deliverables and assigned an effort measurement. These tasks are arranged in order of highest priority into a sprint backlog. The sprint is the event of executing these selected tasks and can be between 1-4 weeks in duration.

Generally, we find that two-week sprints work best for all parties. The sprint is reviewed at a daily Scrum stand-up (2) where impediments and exceptions are highlighted. During the sprint, change can be accommodated with constant refinement of the backlog. Also during the sprint, any deliverables to be handed-off are reviewed by the Team (3) to ensure the definition of done has been met and the next-customer's conditions of satisfaction are fulfilled. On completion of the sprint, a retrospective (4) is conducted to capture any learnings for continuous improvement of the process. Whilst change and iterations can be accommodated during the sprint, it is important that focus is maintained on the duration and the goal (5). The process circles back to (1) to initiate the next sprint and batch of deliverables. Figure 2 shows one of the early sticky-note Scrum boards where the objective is to work through the sprint by moving the highest priority sticky-notes across the board from To Do (Backlog) To Doing and to Done.

Figure 1. The Scrum Process

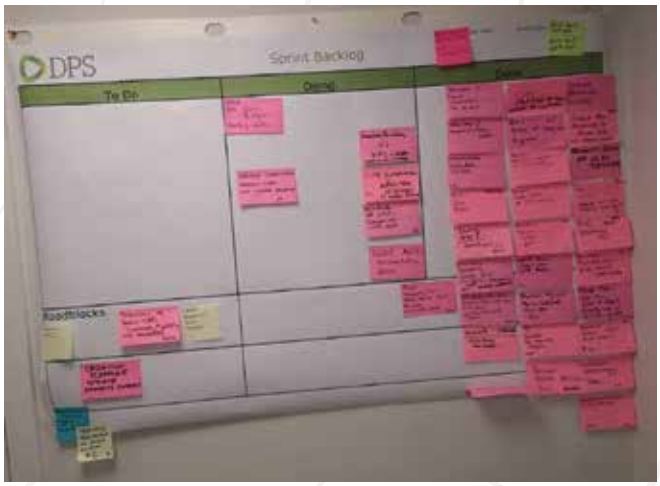

Figure 2. 'Sticky-note' Scrum Board

The nature of DPS Group daily work involves thousands of interactions and hand-offs between designers, constructors, vendors, contractors, and clients. Any process that can enhance the visibility and transparency of these interactions will positively contribute to project outcomes. DPS Group is recognised globally as being an early adopter of Agile and Scrum principles, and implement the Scrum framework for Concept, Basis of Design, Engineering, Construction, Commissioning, Procurement, Continuous Improvement, Tender Bid Analysis, Departmental Management, and Operations Management coordination. Scrum is now embedded as a core element of our execution process. Consistent application is assured with the development of a procedural Guideline and Implementation Health Check. The following case examples illustrate the versatility of the Scrum approach towards resolving issues as diverse as achieving Mechanical Completion (MC) on a HVAC system, constraints management in LPS, and pre-screening potential change within the TVD process.

Lean Initiative Improvements & Impact

Case #1 – MC on HVAC system

Systems Completion is the process of taking a project from engineering into construction, and transitioning to full mechanical completion ready for commissioning and operations. Completing the final one per cent of scope has traditionally been a major pain-point for Construction and Project Management teams. Niggling close-out issues pertaining to Building Management Systems, Loop Checks, System Safety Checks, and Design Compliance Alignment can easily add several weeks onto construction/commissioning hand-over dates. A DPS Group construction team successfully applied Scrum to achieve MC on a HVAC AHU system, and this development has resulted in Scrum becoming a standard way of working to assist MC transitions from construction to commissioning teams. Figure 3, taken in early-2019, shows the Scrum board and the Team transitioning

the detailed actions of each task from left (backlog) to right across the board. Each task is hyper-cared to hand-off and completion with twice-daily huddles at 10:30 and 15:00 daily to ensure all obstacles are removed to allow the Agile Craft Teams operate at speed in closing out tasks. In parallel, the next trade in-line had greater visibility of when they could, to the nearest hour, commence the critical tasks to bring the system nearer completion.

Figure 3. Early-2019 Scrum Board to achieve MC on HVAC AHU

The team members in the huddle in Figure 3 are DPS Construction Manager (Scrum Master), Client Representative, Electrical Contractor Supervisor, DPS Electrical Supervisor, DPS Commissioning Manager, DPS Mechanical Supervisor, and DPS HVAC Designer. To assist final hand-over of mechanical and electrical systems, Scrum achieves the micro-planning and task-step detail that would not be available from the traditional LPS as used on the project. Focused one-week or two-week sprints keep the eye on the prize.

Case #2 – LPS Constraints

Much has been written advocating the benefits of LPS towards improving project outcomes. LPS is a series of interconnected functions and optimum results will only accrue from effective execution of each function. The constraints identification and resolution process are a key enabler of smooth and even workflow – a constraint is anything that will prevent a task from starting or finishing as scheduled, except prerequisite work identified on the phase schedule. The DPS Group LPS and project execution experience has highlighted the constraints management process as the single greatest contributor to effective LPS implementation.

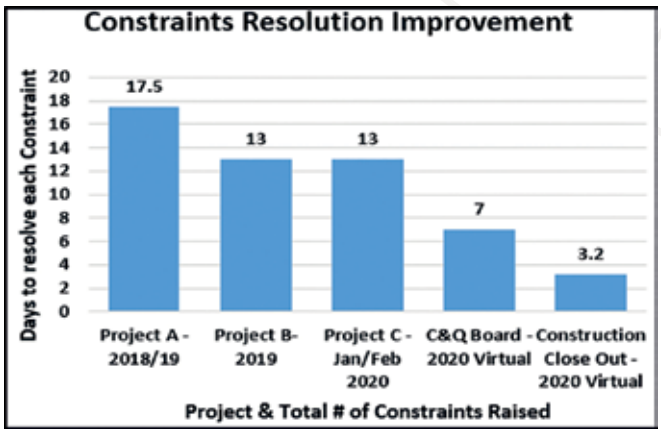

Figure 4. Construction Resolution Improvement

Traditionally, identified constraints would have been logged on an excel sheet and would be emailed to the person identified as best placed to resolve it. This process was slow and tedious as someone had to constantly chase individuals to address their assigned constraints, and there was much back and forth seeking clarity around both the ask and the response. In 2018/19 the average resolution time per constraint was 17.5 days. By applying Scrum and Kanban to the constraints process, this duration was reduced by mid-2020 to 3.2 days per constraint. Virtual platforms like Trello and Microsoft Planner greatly assisted this process, and Figure 4 illustrates the improvements generated.

The improvement presented in Figure 4 resulted from a dedicated implementation specifically focused on the constraints process. The steps were as follows:

i. Each Team member (DPS site supervision, design team support, Client representatives, Contractor supervisors) received training on the Scrum process and on setting up the Trello or Microsoft Planner platforms on their laptops, I-phones and/or I-pads.
ii Senior management commitment was received from each stakeholder's leadership relating to collaborative engagement with the proposed constraints process.
iii. Any identified constraint is logged on the backlog of the Trello Scrum board with a description of the issues and the ask. Photographs, drawings or sketches can be added to visualise the issue. The key person required to resolve the constraint must be identified. Others required to be informed or to support the process should be copied.
iv. At least once daily (sometimes twice), the Scrum board is reviewed by the Team to ensure the constraints resolution process is flowing and to prioritise focus on the highest value items.
v. When the process is working smoothly, constraints are often resolved before the huddle has taken place.
vi. The process requires an owner (Scrum Master) to confirm constraints noted as closed are indeed closed to the satisfaction of all parties, and to ensure any change introduced is recorded for financial, safety, and quality accountability.

An example of using a Trello Scrum board to transition construction to field close-out is presented in Figure 5.

Management of constraints through the Scrum framework has proven to positively supplement the LPS process on our construction projects.

Case #3 – Scrum in Design Scheduling

The design process often lacks effective planning and control to minimise the effects of complexity and uncertainty, to ensure that the information available to complete design tasks is sufficient, and to reduce inconsistencies within deliverables. While design work does not have the hard logic of construction work, it is still accomplished in a network of commitments made among specialists. That network can be designed and managed so that the work that should be done, can be done, and will be done. While some adaptations have been made, the Five LPS Planning Conversations remain the same except the Look-ahead Planning Conversation shifts to Design Cycle Planning. Also, instead of the traditional weekly work plan or commitments log, DPS Group utilise a Sprint Backlog to generate a two-week batch of design work. All design disciplines engage with

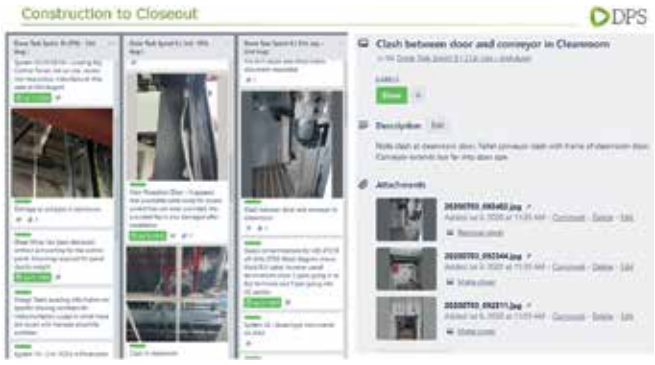

Figure 5. Construction to Close-out Trello Board

the six-week look-ahead interactive planning cycle conducted weekly. Handoffs and interactions are agreed and a two-week batch of work per discipline is agreed. Each discipline proceeds to run their own Scrum board to complete their own sprint. Figure 6 illustrates a two-week sprint for electrical design on a project.

The Trello board, as shown in Figure 6, starts off with a high-level six-week Product Backlog on the left-hand column. The Backlog tasks are broken into finer detailed deliverables in the To Do column by the team members who will execute the work. The tasks then move across the board from To Do to Doing to Done during the sprint

Figure 6. Two-week Design Sprint

duration. The recurring weekly six-week look-ahead session ensures the Backlog is always being topped up with new deliverables. A key aspect of the board is the Blockers/Risks column as this is where the team, through their Scrum Master, can reach to the Product Owner for assistance in rapidly removing constraints or impediments.

DPS Group has experienced tangible improvements in its delivery processes by adopting the concepts and principles of Scrum and Agile. While the impact of remote working has pushed virtual collaboration and accelerated innovative ways of communicating, the Scrum framework has enabled traditional methodologies to move faster and greatly reduced waiting and response time on projects.

Company Overview | SISK | johnsiskandson.com

John Sisk & Son Ltd. (Sisk) is an innovative engineering and construction company employing over 1,800 people in Ireland, the UK, and Europe. Sisk has the track record, scale, and capacity to successfully undertake large, complex, multi-disciplinary programmes, and we are recognised by our global customers as world leaders in sustainability and safe delivery. Sisk is a progressive business and Ireland's No. 1 ranked provider of construction services. Operating since 1859, we have built many iconic buildings and landmark pieces of infrastructure. Our continued success is due to:

- Our ability to collaborate with customers and supply chain to provide technical and delivery solutions in an open and can-do way.
- Safety, innovation, quality, efficiency, and value are integral to everything we do.

We deliver projects in key sectors such as Data and Technology, Pharmaceutical and Life Sciences, Infrastructure, Transportation, Healthcare, Commercial, Residential, Retail, Industrial, Leisure, Education, Water, and Energy.

Author

Rorie Considine

Overview & Background to the Lean Initiative

This case study is based on a new Dublin city-centre office development of approx. 250,000 square feet. The building superstructure is a 7-storey reinforced concrete frame over a double-storey basement, and the concrete slabs are designed to be post-tensioned.

Our goal was to complete a 19,500 square feet slab pour of a nominal 250mm thickness in one shift using 2 placing booms, 1 static pump, and a spider pump extended to reach all corners of the C-shaped slab. The plan was to break each slab into 4 separate pours. Because we chose to use Jump Form formwork to construct the cores, the use of placing booms was restricted. For this reason, we used spider pumps to reach areas around the rear of the two central cores. A second significant constraint was the working time restrictions imposed by the Local Authority which meant that we were restricted to working between the hours of 06:00 and midnight.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Define

The first slab pour commenced on schedule and in line with the out of hours working arrangements we had agreed with the Local Authority. All local residents had been notified of the pour 48 hours in advance. Placing booms had been set up from the evening before and the spider pump was also in position.

The concrete supply all morning was in line with the planned delivery rate. We hit our first milestone mark on schedule and started to ramp down for the placing boom line clean-out and swap-over. The planned timeline for the swap-over was 45 minutes, but on the day of the pour it took over 2.5 hours from the time placing boom 1 stopped pumping to starting again with placing boom 2. This was the main cause of the knock-on delays to the second half of the pour and completion of the overall schedule, which ran much later than planned. It also meant that we were not able to get the quality finish to the last 30% of the slab as planned because we had to complete all floating work within the working hours imposed by the Local Authority.

Measure

The steps involved in the process are outlined in Figure 1. We created this process flow to detail the steps involved, ensuring any critical milestone activities were tracked. Setting up the placing booms the day before and ensuring all equipment was in full working order were key.

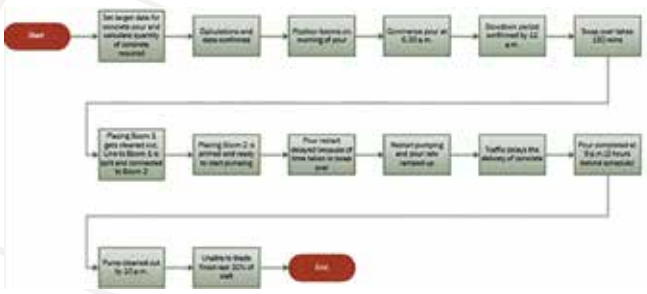

Figure 1. As-Is Process Map

The costs incurred because of the late finish included:

- Fifteen resources tied up working out-of-hours at a cost in the region of €3,700. Had we not developed the solution we did, this figure would be multiplied by 19 pours on-site for the duration of the superstructure, equating to €70,000 in overtime costs.
- Where the slab could not be finished completely, the knock-

on effect on quality required a crew to grind the slab to achieve the finish at a cost of €1,680. Again, the overall cost could have amounted to €31,920.
- The total exposure on this issue equated to more than €100,000.

We created a Cause and Effect diagram to help with the determination of the elements of the problem. This helped us to focus on the critical few causes of the problem we were trying to solve.

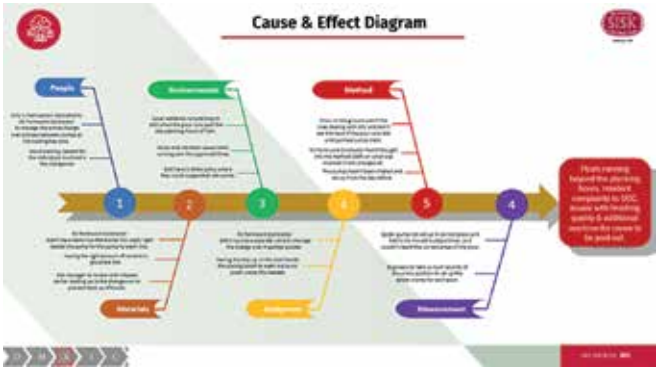

Figure 2. Cause and Effect Diagram

Figure 3 shows the concrete pump and the area of the swap-over where the root cause of the problem lay.

Figure 3. The Concrete Pump

Analyse

Having completed the first pour, it became evident that some streamlining of the process would be required to improve efficiency. We therefore held a Kaizen event with the team to review the current process and the issues it raised, and to develop solutions for subsequent pours. To get the pour completed within 10 hours, the swap-over between placing boom 1 and placing boom 2, whilst washing out the line back to the pump, was highlighted as being critical. It became clear that it was more beneficial to pour the slab in two separate large pours rather than split it up into the four smaller pours as originally planned. In addition, we determined that the swap-over needed to be achieved in 45 minutes and not the existing 150 minutes.

From our analysis, it became evident that the main issue we faced was the swap-over between the placing booms. A secondary issue was the spider pump locations. Although we had picked these beforehand, we still had to lift them with the tower crane three times instead of the planned two because they didn't reach exactly where we wanted to. The solution we proposed to adopt included the following elements:

- Ensure that the slab pours were completed between 17:00 and 18:00 to allow time for the quality of finish required on the last 30% section of the slab.
- Work with the Local Authority to determine if they would agree to start the pour 1 hour earlier and allow us to take advantage of this time before peak morning traffic.
- Determine the optimum number of pours for the slab in conjunction with the reinforced concrete formwork contractor and the concrete supplier.
- Review and standardise the procedure around cleaning out the lines from the first placing boom to the static concrete pump, and then swapping over the pipework connections to the second placing boom to complete the second half of the pour.
- Determine the optimum positions for the spider pumps so as to maximise their use and minimise the number of moves required, thus releasing the tower crane for other critical tasks.
- Take an as-built record of the ideal locations of the spider pump on the deck by our engineers and set these out again for each pour.

Figure 4 is an isometric view of a typical floor. Our original plan was to divide the pour into 4 sections. Having discussed this with the team involved, we decided to go with 2 pours as depicted in Figure 4.

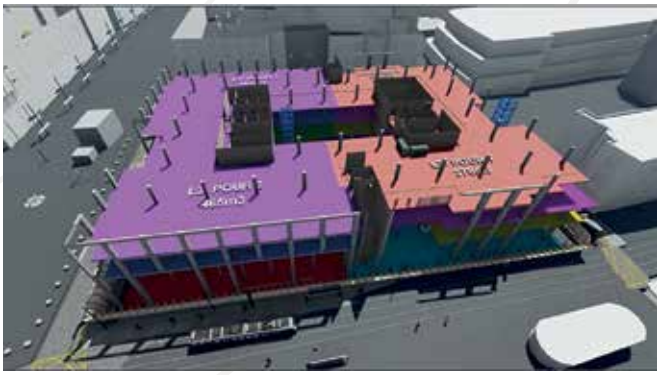

Figure 4. Isometric View of a Typical Floor

Another key item was ensuring that we efficiently ramped up the flow rate from the commencement of the pour to the point in time at approx. 11:00 when we needed to clean out the first placing boom line and swap-over the pipework connections to place boom 2.

We communicated this process to the concrete supplier so they were aware of the need to slow down the pour rate for approx. 45 minutes while the changeover happened. They then needed to ramp back up to the original rate to start pouring again at full pace, either through the placing boom on its own or through the placing boom connected to the spider pump.

Figure 5. Actual View of Slab Showing the Locations of the Placing Booms

Figure 6. Placing Boom Locations

Lean Initiative Improvements & Impact

Improve

We looked at the-swap-over for the placing booms as being the area where we would focus our improvement efforts. We needed to reduce the time taken to complete the swap-over and we used SMED as the principle for achieving this. Additional resources were needed by the formwork contractor to manage the changeover, and we developed the following solution:

- Break the task into its constituent parts and ensure there were separate crews for:
  - Washing out the placing boom on the slab.
  - Cleaning out the line back to the pump.
  - Changing the line over from one placing boom to the other.

Each of these crews went through additional training in advance so they were very much aware of their specific tasks on the next pour day.

We also ensured that some additional SMED elements were in place on the day of the pour:

- Having a mortar bin full of water adjacent to the pump.
- Having the compressor within reach of the pump.
- Having a skip to blow the line safely on the slab so that no crane time was taken up locating these and getting them into position.

There have been several notable wins for all involved in achieving the changeover process on schedule. The 2 hours saved overall in the middle of the pour had a knock-on effect that meant that the following could be achieved so as to impact positively on the remainder of the project:

- The risk of the late pours costing more than €100,000 was mitigated.
- Better relationship with local residents by completing the pours on schedule and not impacting them in terms of out of hours work.
- Local Authority relationship maintained because there would be fewer complaints from the local residents.
- Client relationship is also key, and, by achieving the changeover procedure on time, the pours would finish on time. This meant power-floating the slabs could happen earlier, giving us a significantly better chance of achieving a better quality finish to the entire slab as opposed to the 70% of the area on the first slab.
- In this case, the addition of something as straightforward as additional trained and skilled operatives made the difference to enable a swifter and more efficient changeover.
- The importance of having simple things like a mortar bin in the right place for washout, the right amount of cement to grout a pump, the concrete skip in place to wash out the placing boom, and so on, all meant that the tower crane was not required to lift over each of these items and further delay the changeover process.

Control

A dedicated Sisk package owner and dedicated reinforced formwork contractor supervisor were required each time to supervise this process and ensured everything went according to schedule.

Company Overview | DUGGAN BROTHERS | dugganbrothers.ie

Duggan Brothers (Contractors) Ltd. ("DBL") was founded in 1923 and is one of Ireland's leading general building contractors with over 120 managerial staff. As a medium-to-large sized construction company, we have successfully completed c.1,000 projects (and counting) in both the public and private sectors. These projects range in value from €5m to €80m across commercial, pharmaceutical, educational, healthcare, residential, and industrial sectors. Construction Excellence is at the heart of everything we do, and we are proud to continue to deliver high-value and high-quality projects for our clients.

Author

Michael Greene

Overview & Background to the Lean Initiative

DBL began its Lean journey in 2014 through attending many of the LCi events and conferences. DBL could see real value in adopting Lean principles and tools to enhance what we do for our clients and customers. Through adopting a leaner approach, we continue to review and improve our systems to ensure we deliver value across our projects for the benefit of all, including our staff, design team members, clients, and end users. Our continuous improvement and learning organisation approach has helped DBL to review many aspects to our company and seek out opportunities for improvement.

One area of our company that has developed greatly is our approach to quality control and quality assurance, and how we manage our entire quality process. DBL first achieved the ISO9001 Quality Management Standard in 1993, and we are proud to retain this standard year-on-year. We recently carried out a Lean project on our quality management systems across all our projects to identify opportunities for improvement. Our comprehensive quality auditing process gathers valuable information to allow each project team to become aware of what is required to be addressed to improve the results for each individual project and our company overall.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

This case study focuses on our organisation's quality audit process to ensure we comply with our company's own quality requirements and to the requirements of ISO9001:2015 international standard. The purpose of this project was to identify areas for continuous improvement within our quality control and quality assurance processes.

The desired outcome of this project was to ensure that our company standards, along with local and international standards, are effectively implemented and maintained throughout the lifecycle of our quality management processes. The purpose of this Lean initiative was to identify ways to eliminate waste in our systems and to deliver an efficient service to both our internal and external customers, namely, internal staff and external third parties.

Through gathering information during our internal quality auditing assessments, this process improvement project identified several opportunities that could be improved.

One of the key aspects to developing our Lean approach was to adopt PDCA across all aspects of our company, whilst implementing the various Lean tools to improve our approach to delivering high-quality projects for our clients. Control measures, such as standard working procedures, along with implementing regular continuous improvement workshops ensure we become a leaner construction company as we remove waste from various processes.

Our continuous improvement approach has allowed us to become leaders in the industry and enabled our staff to develop initiatives to improve many areas of our organisation, both on-site and off-site, including our office-based staff.

Quality Assurance and Quality Control is a centre point to DBL delivering high-quality projects for our clients. Our quality management objective is to achieve "Right First Time Every Time" within every aspect of our company in order to deliver the most efficient and cost-effective projects for our clients.

Our company's policy is to maintain and continuously improve our record of providing buildings of the highest quality in conformance with our client's specified requirements, safely, on time, and within budget. We endeavour to work as a team in a spirit of cooperation with our clients and their professional representatives to achieve our successful project outcomes. It is essential that everyone working in our company is fully aware of their role within the organisation and their responsibility for carrying out this function to the highest standard as part of an overall team effort, and in full compliance of ISO 9001:2015.

This Lean initiative allowed us assess the current state and future state of our quality management processes, and the findings from this initiative were reviewed in detail to improve what we do. Our quality audits are carried out to ensure that we comply with

ISO 9001:2015 Quality Management Standard. Each audit is scored to evaluate the compliance criteria, and these scores provide a mechanism to assess the compliance of our system through the construction stage of each project. The results and findings from each audit provide an opportunity to improve our quality management system for both internal and external customers. The findings and results of each audit are assessed and then calculated and placed within the following compliance ranges:

- Compliant: 95-100
- Mainly Compliant: 90-94
- Non-Compliant: 0-89

Each audit report is then circulated to the relevant project teams for action as required. Through our continuous improvement programme, and flexible approach with adopting our quality auditing processes, we have successfully gathered valuable information to allow our systems to be improved.

We recently carried out an A3 Lean project to assess our overall findings between Aug 2018 and March 2021, and our average score in 2018-2019 was 93.68, which was within our mainly compliant range. In 2019-2020, we improved our average score to 94.25. It should be noted that the project stages change over time and therefore the items being audited may vary from project to project depending on the stage of the project. DBL sets a high standard when it comes to quality control and quality management, and thus projects that reach the mainly compliant range are achieving a high result. That said, there is always room for improvement in any process, and thus our commitment to continuous improvement is integral to who we are. Figure 1 outlines our assessment of the current conditions and the Voice of the Process during an assessment from Sep 2019-Sep 2020, plus the average scores noted in Aug 2018-Aug 2019.

Goals/Targets

Our overall goal was to increase our audit results to achieve a score of 95 and above by April 2021 following a deep dive into available opportunities, and it can be seen that a number of our projects had already achieved 95 and above at our baseline stage. However, some projects required more focus to bring our average scores across the nine projects into the compliant range. The frequency of the audits was also assessed, and the goal was set to ensure that audits were consistently carried out every 2 weeks on each project, and our target was to achieve 95 and above. Table 1 outlines our baseline scores versus our intended goals and targets to be reached.

Metric	Unit of measure	Baseline	Goal
Specific - The goal and target behind this Lean Project is to increase our overall score rating from being within our Mainly Compliant range to be within our Compliant range.	Score / percentage	Average 93.68	95 +
Project 1	Score / percentage	93.09	95+
Project 2		94.5	95+
Project 3		96.83	+
Project 4		95.26	+
Project 5		97	+
Project 6		89.14	95+
Project 7		92.76	95+
Project 8		95.61	+
Project 9		94.08	95+
Frequency of Audits to reach goals	Time	Ranges from 2-4 weeks	2 weeks consistently

Table 1. Baseline Versus Target

Having identified the key items, we were then able to analyse root causes and determine where we needed to focus in order to make improvements. Our quality management team assessed our audit reports in detail and analysed why we were not reaching 95 and above as standard across our projects. Our assessment can be seen in the Cause and Effect Diagram (Figure 2) and Failure Mode Effects Analysis (FMEA) chart (Figure 3).

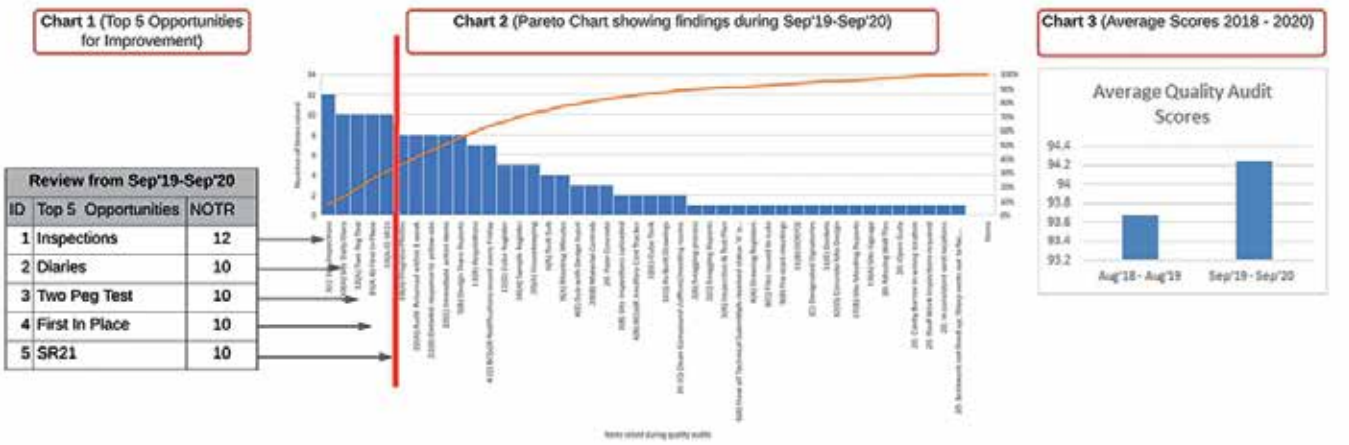

Figure 1. Outcome of Current State throughout Sep 2019-Sep 2020

Opportunities for improvement were identified though our bi-weekly quality audits across nine live construction projects at the time of auditing. Key items selected for improving included site inspections, site diary records, two peg test recording, first in place/ benchmarking recording, and recording of SR21 granular fill. Once we assessed the opportunities for improvement, we were able to take a deeper dive and outline our goals and targets to make the improvements happen.

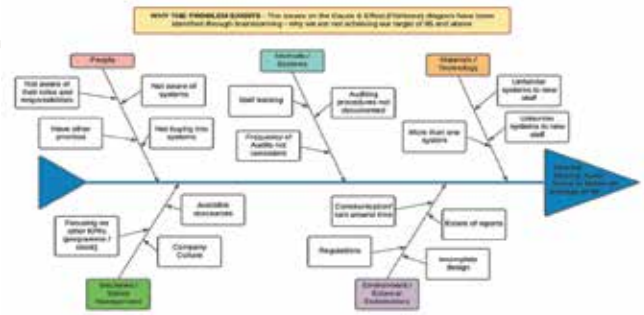

Figure 2. Assessment of Cause and Effect

Our FMEA review outlines the current state (what we do today) versus the future state (what we will do tomorrow) to improve how we work. We assessed our People, Methods/Systems, Materials/Technology, Machines/Senior Management, and the Environment/External Stakeholders in order to outline failures, causes, controls, and future actions to make the improvements happen. The FMEA tool and Fishbone diagram allowed DBL to develop countermeasures and create a Last Planner action plan to implement specific actions required to make sure the opportunities for improvement were actioned by specific team members and by specific dates.

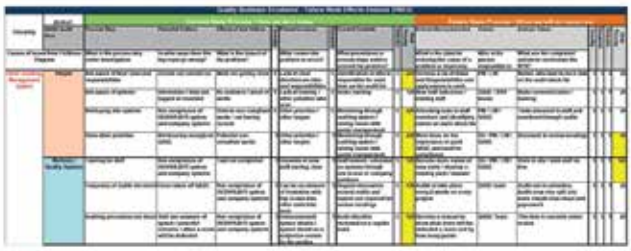

Figure 3. FEMA Assessment Extract

Figure 4. Last Planner and Action Plan Extract

Lean Initiative Improvements & Impact

Five key areas were assessed to identify areas for improvement and we undertook initiatives to ensure that our continuous improvement approach operated for the benefit of our internal and external stakeholders (see Table 2). A key focus was put on our People and providing further training, a review of our Methods and Systems, the Materials and Technology used, continuous reviews with our Senior Management, and a review of our dealings with External Stakeholders.

Extract from Action Plan		
1	People	Develop a list of Roles and Responsibilities and apply names to each
		Allocating tasks to staff members and identifying names on audit check list
		More focus on the importance of good QA/QC and need for compliance
		New staff inductions / training staff
2	Methods / Quality Systems	Become more aware of new starts / develop a training pack / manual
		Audits to take place every 2 weeks on every project
		Develop a manual to show what items will be deducted a score and by how many points
3	Materials / Technology	Engage early in the project to agree a single platform
		Create training plans for staff
		Full onboarding / induction programme with follow up reviews
4	Machines / Senior Management	Demonstrate data findings to raise awareness of issues
		Continue with Lean Training, holding Lean Meetings and offering an opportunity for staff to suggest better ways of working
		Agree names to manage each item on list with entire team and individuals
5	Environment /External Stakeholders	Early engagement with client and their design team. Identify design shortfalls before project starts.
		Early engagement with project team, further education, raise awareness of issues
		Single platform with strict controls in place to manage the flow of information
		Early engagement with design team and inspectors - agree status and system to be used.

Table 2. Action Plan Tasks to Achieve Goals

Following the planned actions and improvements achieved, a positive outcome can be seen in the pareto charts, with the updated pareto chart showing findings from quality audits carried out from 01.10.20-26.03.21. The Voice of the Process has changed to show some positive impacts and new opportunities to improve our ISO 9001:2015 Quality Management System. Notably, there was a shift in the audit findings during our review period. Due to the ever-changing complex environment from project to project, the top five common items will inevitability continue to change over time.

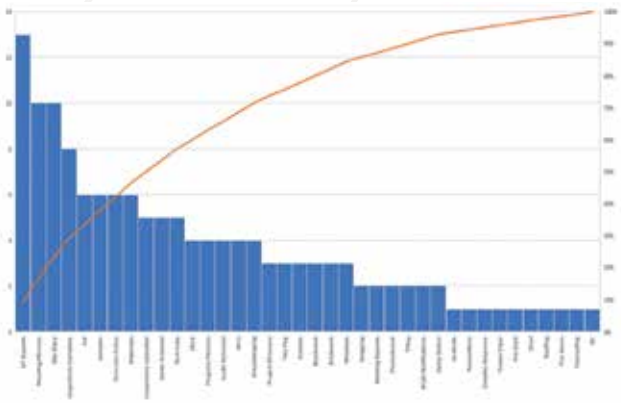

Figure 5. Pareto Chart Showing New & Updated Opportunities

It should also be noted that our quality audits consist of approximately 80 subject items which are assessed during each audit, and which includes a documentation review both on-site and off-site, including a visual inspection of our works on-site. Table 3 presents the top five opportunities identified ("NOTR" = number of times raised) during Sep 2019-Sep 2020 and Oct 2020-March 2021 with notable changes in the opportunities between these periods.

Review from Sep 19-Sep'20			Reviewed Oct'20- March'21		Status
ID	Top 5 Opportunities	NOTR	Top 5 Opportunities	NOTR	
1	Inspections	12	DT reports	13	New Opportunity
2	Diaries	10	Minutes	10	New Opportunity
3	Two Peg Test	10	Inspections	08	Positive Impact
4	First In Place	10	Diaries	10	No change
5	SR21	10	First In Place	06	Positive impact
			Two Peg Test		Positive impact – no longer in top 5
			SR21		Positive impact – no longer in top 5

Table 3. Top 5 Opportunities Identified

DBL also took the opportunity to Value Stream Map its auditing process so as to adapt and change to improve the system for our auditors. This allowed us to review our list of items within the audit

check sheet and the time it took to conduct an audit. The sequence of questions was also reviewed to correspond with our filing system to make the system most efficient for our auditors. Our visual inspection lists were also assessed at that time to ensure that we captured a sufficient range of construction elements that required inspection across all CSA and MEP elements.

Additional items are assessed during each audit, and it is clear where improvements have been made along with new opportunities for our staff and teams to focus on. There have been 412 audits carried out across 23 projects in recent years, which demonstrates our continued focus on Quality Control within DBL. The number of audits depends on the number of projects live at any given time, and 37 audits were carried out between 01.10.20 and 25.03.21. The average score over this period was 95.6 which was achieved following a key focus on our action plan items and the top five common items identified during that period.

Figure 6. Audit Findings

Overall, our target to reach 95 and above was achieved and this is a successful outcome for our organisation. DBL will continue to raise its standards and achieve those high expectations with our Quality Management System throughout our company to ensure that we continue to deliver best-in-class service to our internal and external customers including our clients and end users.

The next phase of the project will be to focus on improving new opportunities identified during the period 01.10.20-26.03.21, and we have seen improvements with the current status showing consistency in achieving 95 and above from Mar 2021-Aug 2021. DBL also monitors its KPIs on a monthly basis, and this is a critical aspect to improving all opportunities identified on an ongoing basis and coincides with our PDCA procedures. The cycle of continuously improving will continue as data is gathered throughout the auditing process to identify opportunities that can and will be improved to raise our standards further.

In terms of training and development, 85 of our staff have undertaken various Lean training courses, including the LCi Lean Pass (via Crystal Lean Solutions), Yellow Belt training, Green Belt training and Diploma in Quality Management – Lean Systems at the University of Limerick. Our focus on Continuous Improvement, Automation, and Standardisation is key to the continued success at DBL, and we look forward to our ongoing Lean Construction journey. DBL has managed to retain its target of 95 and above average, and, in some cases, projects have exceeded 96. Benefits from our regular audits are shared amongst our project teams and clients, by way of reducing waste through eliminating defects, rework, introducing change management, and eliminating over-production for the benefit of the project. Other benefits to our comprehensive auditing system include ensuring that we continue to deliver a competitive service and continuation of delivering high-quality right first time everytime. Our systematic approach ensures our Quality Management system minimises rework, which is closely linked with our auditing system. Credit must be given to our project management and quality management team and quality auditors for their continued endeavours to deliver high-quality projects for our clients on each and every project.

Company Overview | MERCURY | mercuryeng.com

Mercury is a European contractor that builds and manages complex engineering projects that reimagine how people work and live in the built environment. Mercury believes that real innovation happens if you're willing to be brave. Its determination and sharp focus enable Mercury to deliver leading-edge construction solutions across a range of key sectors, taking its clients to new territories they never thought possible.

Mercury's purpose is to deliver its clients vision through leading-edge construction solutions, going beyond their duty which turns clients into partners and builds relationships that thrive across the following sectors: Enterprise Data Centres, Advanced Technology & Life Sciences, Hyperscale Data Centres, Fire Protection, Technical Support Services (TSS), Data Centre Facility Management, Healthcare & Building Services.

Mercury employs over 6,000 people, including sub-contractors, across over 15 locations in Europe and had an overall turnover of €1bn in 2020. Mercury employs the best people, invests heavily in training and education, and ensures that the highest standards of health, safety, and governance are applied throughout the organisation

Author

Jason Toomey

Overview & Background to the Lean Initiative

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 Mercury strives for. Mercury's default position is if there is an activity or a task that we're going to perform for our client, safely, we will always make it happen – better, faster, and smarter.

In recent years, the construction sector has started to see the benefits of modular construction and Mercury senior management made a strategic decision to embrace this new way of building all projects that we are involved in. Off-Site Assembly (OSA) is redefining our industry. Across the Group, Mercury's teams are implementing OSA across all services, including: Electrical, Mechanical, CSA, Information Communication Technology (ICT), and Fire Protection.

Modular construction can be considered as a hybrid of manufacturing and construction, and in many ways lends itself to Lean Production, which permits significant improvements in terms of productivity, reduction in waste, schedule certainty, and improved quality. The latest challenge of Lean Production is its implementation in the modular building industry, where the full potential in terms of productivity is yet to be achieved.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

This case study is centred on a large data centre project recently completed by Mercury. Several Lean tools and techniques were used to successfully complete the project.

Just In Time (JIT)

JIT is a technique developed by Taiichi Ohno and his fellow workers at Toyota. It was developed as a method of pulling work forward from one process to the next just in time. The goal of JIT is to reduce, and eventually eliminate, variations and waste from a process. On construction projects, this waste is normally waiting, storing inventory, and moving materials.

As the construction sector has tried to become more productive over the years, it has adapted the JIT technique to suit the needs of its sector. The application of JIT in construction differs greatly from the manufacturing industry because of the complexity and schedule uncertainty of large construction projects. With construction adopting the OSA module, JIT is now becoming an essential tool in today's construction sector.

On this particular data centre project, JIT delivery was implemented for the fabrication and delivery of the cable containment modules. We were fabricating the modules in Mercury's off-site fabrication workshop in sequence of install on-site, and the project engineer was calling down the modules as the workface opened up on-site. The project engineer used a digital pull plan on Mercury's project management tool to request the delivery of the modules he required.

When the request was made on the pull plan, the module would be delivered to site the next morning and installed the same day. The Last Planner® System (LPS) was in operation on the project, and this collaborative approach helped alleviate any trade-stacking in certain areas of the site. It also helped with the JIT process we had implemented.

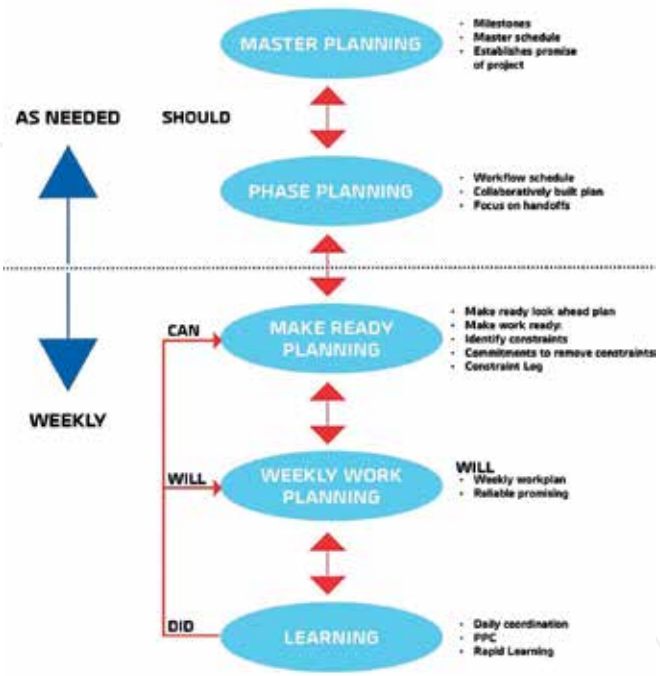

Figure 1. Last Planner System Outline

Gemba Walks

The term Gemba is a Japanese term which means actual place and that is exactly what it is: observing how a process really works, engaging with employees, and exploring opportunities for continuous improvement. It allows people of every level, from senior managers to key stakeholders, to walk the process, understand it, and improve it. Several Gemba walks took place over the duration of the project, and a particularly successful one was on the installation of cable containment modules. When the project launched and the first cable containment modules were delivered, the project manager decided to go on a Gemba walk with the electrical supervisors and one of the mechanical supervisors to observe the installation of the modules. By following the Gemba Walk seven steps, it helped in completing a successful Gemba walk and then improve the process.

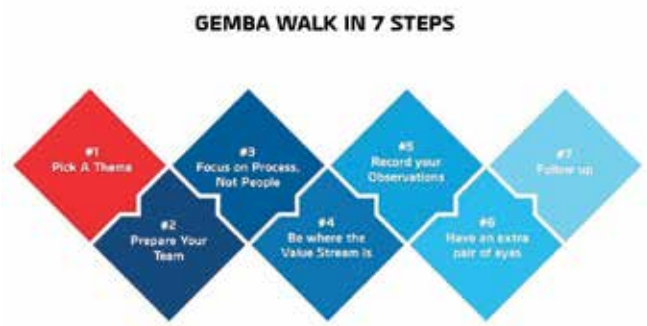

Figure 2. Gemba Walk 7-Step Model

1. Pick a theme

The project manager had a precise process that involved walking to see if there was any productivity gain to be made in the process. He wasn't observing the entire process of the modules being delivered to site and installed, rather he was only walking the process from when the modules were lifted into place and connected to the previous containment module.

2. Prepare your team

The supervisors informed their crews that a Gemba walk would be taking place, and they reassured them that it was the process they were observing and not the operatives. The ultimate goal was to develop a better process through continuous improvement and make life easier for all involved in the process. By informing their crews, the supervisors hoped the operatives would feel that they were part of the initiative and be more willing to collaborate.

3. Focus on process, not people

This step can be hard for some managers. When a manager observes someone not performing to the standard they expect, they often find it very hard not to say something to that person, but this in fact goes completely against the principle of the Gemba walk as you are only there to observe, understand, and improve the process, not evaluate an operative's performance. The project manager on this particular walk reminded the project supervisors of this fact before they began the walk.

4. Be where the value stream is

This Gemba walk was on a very precise process, so the value stream was small but could still be made very efficient.

5. Record your observations – don't make suggestions during the walk

Again, this is not an easy step for some managers to follow. They must not fall into the trap of trying to fix an issue on the walk or offering a solution to a problem they witness. The best approach is to take notes and analyse them later. These notes can be used as part of a problem-solving technique such as PDCA or DMAIC. The project manager and supervisors talked to the operatives and asked them how they felt the process could be improved, and did so without telling them how they themselves would improve the process. The operatives seemed to appreciate this and were happy that their point of view was being listened to.

6. An extra pair of eyes

The mechanical supervisor that was on the walk was the extra set of eyes. He was less familiar with the cable containment installation process than his electrical counterparts, but he had a fresh point of view. He was asking different questions to everyone else on the walk.

7. Follow up

It is essential that you share any findings from the Gemba walk, significant or not, with everyone involved in the process, and especially the operatives in the field. If you do not share the findings, they may feel like you were accessing their performance and not observing the process.

After analysing the data they had collected from the Gemba walk, the team learned that there was a significant amount of motion waste in the process. When the containment modules were lifted into place, often at a high level, they were joined together with small nuts, bolts, and washers. They observed people shuffling through their toolboxes that were full of tools that they didn't require for the task they were carrying out, looking for these materials. In one case, an operative couldn't find the bolts required and so they had to walk to the central site stores which was a 20-minute round trip. As a solution, the mechanical supervisor suggested using mobile toolboxes on wheels similar to the wheelie suitcase that we all use today. A new process

was put in place where all installation crews were supplied with a mobile toolbox complete with only the required tools. Each toolbox was filled at the start of the week with the materials needed and sorted into separate compartments. This is a very good example of 5S being implemented. The operatives were happy with the new process as it made their job easier. They were supplied with the new toolboxes and thus didn't have to carry their own heavy toolboxes around with them all day. They also didn't have to walk to the central site store to collect materials.

Summary

Performing Gemba walks on a regular basis on this project offered some significant advantages such as:

- Improving processes by identifying the problems, no matter how small and taking actions for achieving continuous improvement much faster.
- It helped build a stable relationship with those who carry out the on-site activities and the management.
- Processes were standardised accurately.
- It encouraged collaboration within the project team.

Lean Initiative Improvements & Impact

As stated above, OSA is becoming an increasingly essential part of construction today. On most Mercury projects, we are seeing Lean initiatives and improvements based around OSA. Advanced manufacturing firms routinely achieve productivity rates of 80%, whereas productivity rates can drop as low as 20% for on-site construction workers.

At the end of Q1 of 2021, Mercury was producing 27 module types, using 51 different suppliers, on 27 projects across Europe. By the end of Q2, Mercury was producing 34 module types – an increase of 26% from Q1 – and 27 projects were implementing OSA – an increase of 17% from Q1.

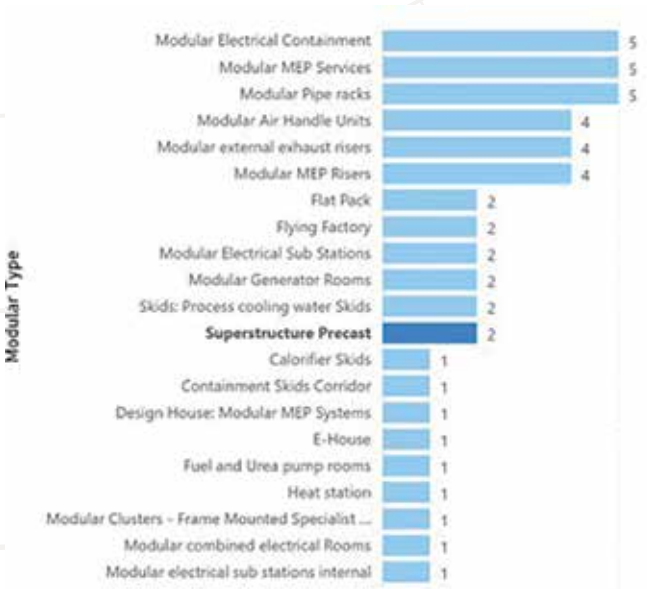

Figure 3. Module Types

Some of the main measurable improvements Mercury has seen with the implementation of OSA include:

- Reduction of on-site labour, which has had a direct impact on lowering Health & Safety risk, welfare costs, and motion and waiting wastes.
- Improved Quality – Manufacturing modules in a controlled environment has resulted in a substantial reduction in defects and rework.
- Productivity has improved by standardising work. Having a more comfortable and consistent working environment has also contributed to productivity gains.

Figure 4. Advantages of Off-Site Assembly (OSA)

Some of the Lean tools Mercury has introduced in its own OSA facility, and encouraged its supply chain partners to adapt, are:

- Value Stream Mapping – VSM highlights the module cycle-time and wait-time between the production functions. With this Lean tool, Mercury's OSA facilities have been able to identify waste within and between their processes. They are able to visually demonstrate the current state of their production line and then map out the future state, which highlights the opportunities for improvement.
- Kanban – This is a visual production system in which a supply of parts is delivered to the production line as-needed, thus increasing efficiency. This Lean tool works by making sure that operatives have what they need, where they need it, and when they need it.
- 5S – This is one of the first Lean tools Mercury encourages its OSA supply chain partners to implement. The 5S system is designed to improve efficiency through a systematic approach to organisation and cleanliness in the workplace. The system includes five fundamental guidelines that help improve workplace efficiency: Sort, Set, Shine, Standardise, and Sustain. Implementation of this method "cleans up" and organises the workplace, basically in its existing configuration.

5S makes workplaces more efficient and effective by:

- Removing unneeded items from each work area (Sort).
- Customising each unique work area to maximise efficiency (Set).
- Cleaning each work area after every shift to help find and eliminate issues before they become major problems (Shine).
- Documenting improvements so they can be more easily applied in other work areas (Standardise).
- Making 5S a way of life to enable continuous improvement (Sustain).

Figure 5. Mercury Module Placement

Company Overview | ARDMAC | ardmac.com

Established in 1977, Ardmac is an international construction specialist delivering complex and high-value workspaces and technical environments. Headquartered in Dublin, with offices in Manchester, Craigavon, Brussels, Cork, and Switzerland, Ardmac is supporting projects all over Ireland, the UK, Denmark, Belgium, the Netherlands, Switzerland, and have this year announced their expansion into Finland and Germany. Ardmac employs over 350 people and are a leading global provider of cleanrooms, data centres, fit-out and refurbishment, and modular solutions.

At Ardmac, we work Smart, meaning we deploy innovative technology throughout our business to empower our people, drive performance, and delight our customers. We believe in setting new standards for our industry and driving innovation, we believe in tailoring solutions to our clients' evolving needs, and in working hard to harness our unrivalled knowledge to deliver safety first and excellence as standard across award-winning projects.

Author

Peter Lonergan

Overview & Background to the Lean Initiative

The successful construction of complex technical environments for the data centre industry involves the carefully sequenced integration of multiple building components. To aid this process, modern digital construction techniques within the data centre construction sector require the use of BIM to integrate and coordinate components in a 3D virtual environment ahead of construction. The process of coordination through unique digital replicas of the building has become an established industry norm. As a consequence of the proven benefits to cost and schedule certainty, clients or end-users of the building expect a high standard of BIM from their specialist supply chain partners as standard.

Although the use of BIM is an established practice, the level of detail and accuracy required to leverage the benefits of BIM at a pre-construction stage vary from project to project, and, furthermore, from component to component. Equally, reliance on competent specialist fire-stopping has become increasingly important to clients for the safety of personnel and the protection of assets. Herein lies the challenge for providers of specialist interior architectural partitions, and inter-dependent service providers needing to pass piping, ducting, cable-trays, and other sector-specific building components through the partitions from one internal space to another. This case study describes how a Lean initiative developed and utilised by Ardmac leverages a technology-based process to apply an innovative digital construction process, namely "Service Penetration Management".

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Challenges in Service Integration

Where services interface with or pass through internal partitions, a tertiary construction element is created and upon which multiple stakeholders depend. This interdependency is represented in model form by a penetration in a partition, allowing services to pass from room to room clash-free. The sum total of penetrations can be costly to clients, with varying commercial impacts based on quantity, size, height above floor level, location, and type. Often, the true cost of the penetrations is unclear and can remain largely undefined until well into the construction programme. Additionally, service penetrations require specific and often expensive firestopping materials to maintain the integrity of fire rated partitions and to conform with building standards. However, at the time Ardmac developed the Service Penetration Management Process, there did not exist any one end-to-end dedicated sectoral standard or defined BIM process for the modelling and management of service penetrations. The existing standard management procedure for this element of works was limited in most cases.

Figure 1. Example of Complex Service & Partition Integration within BIM Model

Typically, service providers identify physical openings through marking and cutting openings through in-situ marking and cutting, sometimes in error or out of sequence, and at scales or locations that can impact schedule and cost. This unstructured format is untraceable as the openings are not recorded as individual elements and therefore do not leverage the potential Lean Construction benefits made possible through BIM. Without an established BEP (BIM Execution Plan) to define the processual sequence of works required for interdependent contractors to model and track openings, clients do not have full visibility of the quantity, potential cost, or impact on the construction schedule, thus elevating the project's overall risk profile. Furthermore, without adequate modelling of openings through an established, controlled, and agreed process, the openings marked or cut in error are typically unidentifiable from those which are genuinely required. As a consequence, clients do not have visibility of what they should or, arguably, should not be paying for. For contractors, the risks are equally high as seeking commercial recovery for untraceable service openings within the partitions is difficult and more likely to become a source of conflict.

BIM Execution Plan & Best Practice

Ardmac's BIM-led Service Penetration Management Process is fully coordinated from modelling through to site install, giving our clients full visibility of project progress through the use of a tailored BEP, software, and live progress tracking to keep all stakeholders informed on project coordination and commercial outcome. The ECI (Early Contractor Engagement) stage of the programme is utilised in this case to insert Ardmac's tailored BEP as a supplementary guide for service providers and the project BIM team. The step-by-step process outlines the most efficient and impactful methods for identifying service penetration locations, generating penetration models with unique identifiers and freezing penetration models before construction commences.

The model freeze is a key milestone in the BEP and creates the opportunity to evaluate the impacts of the penetrations on the structural stability and passive fire protection required at each interface. Where the structural stability of partitions may be compromised due to large openings, or where clusters of openings occur, identifying long-lead, high-risk elements such as secondary support steel becomes possible at a much earlier stage in the programme. A bespoke master tracker tool provides instant feedback to the site teams, clearly identifying the quantity, locations, sizes, and types of openings. In turn, this sequence of works forms the basis of the interlinked fire-stopping register handed over to clients at project completion stage. The master tracker can forecast the true extent of the works to be carried out in a particular area of the building ahead of commencement dates, feeding directly into the weekly work plans and project production plans. From a safety perspective, the frozen models create an opportunity for the site safety teams to review and understand the extent of works to be carried out at height ahead of time, and sequence the works in a way that reduces constraints.

Using BIM, and a plug-in software for Autodesk Revit, all openings can be auto-formed around services penetrating partition models. Openings are formed as per recommended sizing and deflection limits. Opening information is inputted using the naming conventions outlined with the BIM Execution Plan. All trade contractors have the ability to move and change the size of openings up until the builders' work freeze date. Following the freeze date, Ardmac can consult with relevant supply chain partners, including partition panel manufacturers and the fire-stopping material suppliers, for review and comment. Should comments be received, requests for openings to be adjusted to comply with the structural and fire integrity of the wall are addressed and models are updated where necessary. Once the review process is completed, the openings become frozen within the federated model. Builders Work Elevations for the frozen area will be issued to all project teams, and any change or additional penetrations can be communicated through the Service Penetrations Change Process, thus creating a level of flexibility to account for error or change.

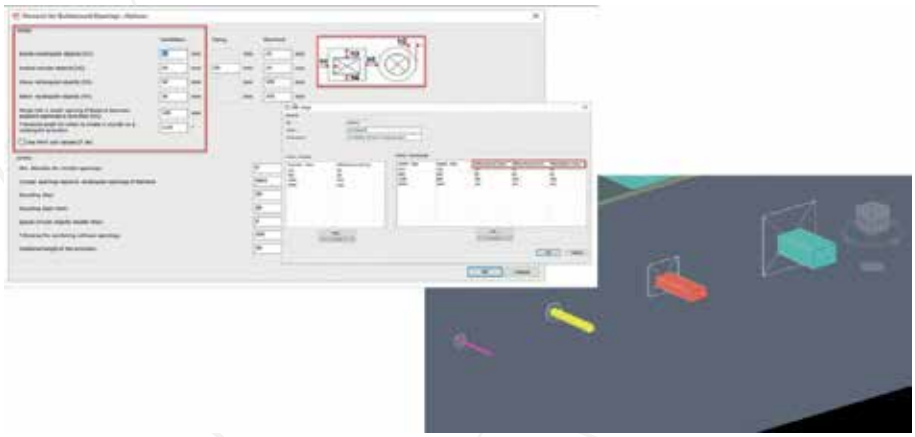

Figure 2. BIM Software Parameter Input Creates Auto-generated Service Penetrations within the Partition Models when Interfacing with Services

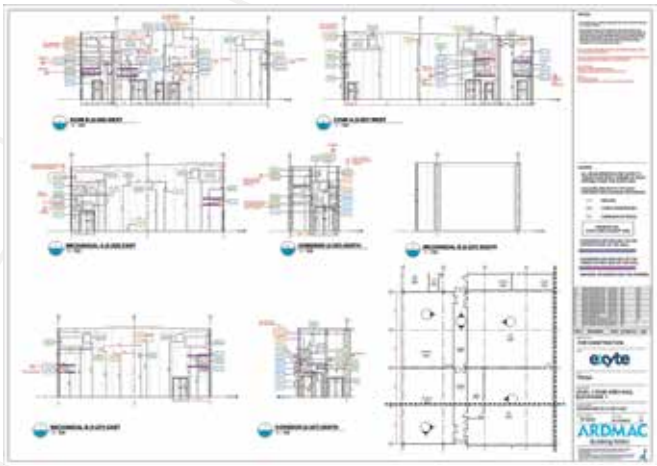

Figure 3. Example Partition Elevation showing Service Penetrations with Unique ID Tags

Certified Fire-Stopping

Ardmac is certified, based on a stringent evaluation program, as a Competent Fire-stopping Contractor with UL® who are widely recognised as leading experts in the testing, inspection, and certification of building materials as well as fire-stopping contractors. This gives clients and building owners confidence knowing that our installation processes have been reviewed and management

system certified through passing of UL Fire-stopping Examinations, maintenance of a prescribed 10-element management system evaluated through an annual audit, and the designation of a DRI (Direct Responsible Individual) within the organisation.

In line with operational quality plans, the Service Penetration Management Process results in a detailed combined system of records for fire-stopping including a register, location plans, details, product data sheets, and installation records. The BEP has been created to manage and track service openings through reliable real-time, reportable data, giving clarity on detailed costs and reduced risks for all stakeholders. As each of the penetrations is modelled and given a unique ID reference within the model, the tracking and commissioning of the building fabric becomes much clearer from a passive fire-stopping perspective. Coupled with competent installation of the fire-stopping systems in line with manufacturer's recommendations and project specification, dedicated install teams carry out and record their works in line with competent fire-stopping contractor guidelines under the supervision of quality inspection plans and guidance from a fire-stopping DRI.

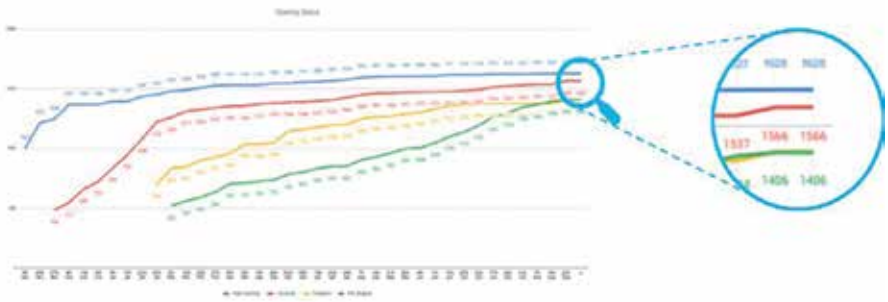

Figure 4. Live Tracker Extracts Model Data to Monitor Quantity & Status of Service Penetrations under each Service Provider along the Project Timeline

Lean Initiative Improvements & Impact

Managing labour can present significant challenges when applied to more complex non-sequential construction programmes. The Ardmac Service Penetration Management Process defines the critical path for the formation of service penetrations within partition systems and informs the LPS, thus creating opportunity to effectively sequence and track productivity against targets and timelines. This reduces the risk of production area revisits and out of sequence works when compared to more traditional service integration, and it delivers excellent results by linking multiple platforms together through custom built integrations, thus achieving even greater benefits for safety, quality, and cost certainty.

Given that the model and supporting data is accessible through mobile technology on tablets, site management can devote time to site-based activities and communicate with the tracking system through the FMS (Field Management Software) and live tracker rather than physically moving between the production area and site office to communicate issues with coordinators. An FMS introduced on all Ardmac projects in February 2019 provides a central cloud-based platform to share and manage project information. The in-built inspection, quality, and safety management aspects of the platform enables the completion of inspections, audits, and reporting using any mobile device. Project performance data captured in real time gives insight into the progress and proactive problem solving rather than reflective analysis.

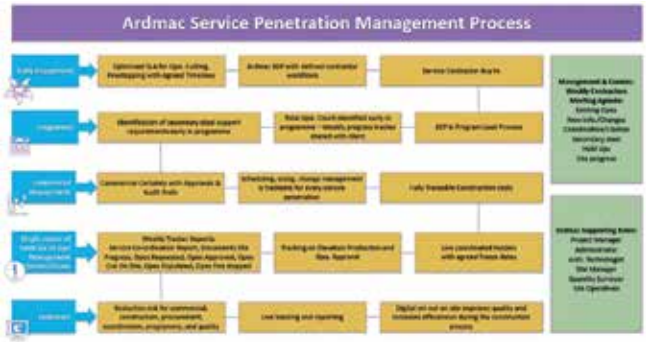

Figure 5. Service Penetration Management Process Map

In summary, the coordination and management of service penetrations within the internal partitions is a sectoral issue creating challenges for contractors and clients. Resolving this issue through the application of a robust, well-defined, and controlled BIM process introduces value to projects as a unique service offering with value generation potential for multiple interdependent stakeholders. Where the Service Penetration Management Strategy is applied as an agreed processual BIM approach to managing and tracking service openings, it results in reliable quantitative and reportable data, clarity can be given on detailed costs, and it reduces risks for all stakeholders. It has been observed on large-scale data centre projects that application of the process results in leaner outcomes, including over 50% reduction in site production hours required to mobilise, mark, and cut service penetrations throughout the construction phase.

Following initial project implementation in 2019, customer insight interviews have been carried out with key collaborators from amongst client teams. Resulting data has allowed further exploration into the performance of the initiative, and offers insight into how the Service Penetrations Management Process can contribute to value generation for multiple stakeholders. Interviews reveal the initiative as processual in nature, combining several established Lean tools and practices such as BIM, productivity tracking, and LPS, along with other digital communication tools, FMS, and software. It has been described by clients as "the most effective service penetration management strategy seen to date". It is Ardmac's goal, as an early adopter, to contribute to the Lean performance of the sector and to promote the likely eventual wider adoption of this approach to Service Penetration Management.

Effective implementation of the initiative presents some challenges that must be overcome if Service Penetration Management is to be effective on complex construction projects. The collaborative nature of the process and the reliance on multiple contractors to each contribute to the defined workflow means that a collaborative ECI period must be leveraged. Stakeholder buy-in, with a desire to understand roles and responsibilities in line with the published BEP, is essential to the success of the process and a positive outcome. When

combined with other digital technologies to streamline workflow and improve productivity, the Service Penetration Management Process aligns with Lean Construction Principles and the Building SMART initiative underpinning Ardmac's approach.

Deploying Innovative Technology throughout Ardmac to Empower our People, Drive Performance, and Delight our Customers

We place our customer at the centre and apply Lean Construction principles and technology to everything we do at Ardmac. Our goal is to maximise value for our customers, allowing access to project information and performance in real time on any mobile device. These digital processes not only improve efficiencies for Ardmac, but also for our customers. They enable us to deliver projects faster whilst enhancing safety and quality. Working Smart allows us to consistently deliver excellence across multiple sectors and geographic regions. Technology has the power to drastically change the face of the construction sector, and Ardmac is committed to staying ahead of the curve.

Figure 6. Building SMART

ARDMAC

Company Overview | JACOBS | jacobs.com

Jacobs leads the global professional services sector, providing solutions for a more connected, sustainable world. Headquartered in Dallas, Texas, with approximately US$14 billion in revenue and a talent force of more than 55,000, Jacobs provides a full spectrum of services including scientific, technical, professional, construction, and program management for business, industrial, commercial, government, and infrastructure sectors. Jacobs established its first international office outside the USA in Ireland in 1974. Today, the company employs more than 1,100 people across its Dublin, Cork, and Belfast offices, serving the Life Sciences, Advanced Manufacturing, Data Centre, infrastructure, utilities, transportation, and environmental sectors, amongst others.

Over the past 30 years, we have developed one of the largest global data centre practices in the world, providing integrated planning, design, and construction services for critical facilities. Ranked #1 in data centres by ENR and Building Design + Construction magazines, we have delivered over 17 million square feet of data centre space and have 15 mission-critical centres of excellence housing our global subject matter experts, including one in Dublin.

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Overview & Background to the Lean Initiative

This case study focuses on Lean in Design and the application of Lean thinking and practices to help bring Hyperscale to Colocation, and outlines our journey to "Cloud Condos". The world's biggest hyperscalers are also big users of colocation ("colo") services.

This case study presents how Jacobs incorporated Lean thinking and methodologies to innovate and develop a standardised but nimble design approach – "Cloud Condos" approach – to colocation for hyperscalers, which are plugged together 5MW modules at a time and can provide a better fit for their needs. This helped bridge Hyperscale and Colocation data centre design approaches and provided solutions for both.

Figure 1. CloudCondos

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Colocation & Hyperscale Definitions

In the data centre sector, Colocation (Colo) is the practice of renting space for servers and other computing hardware at a third-party provider's data centre facility. Typically, colocation services include the building in which everything is housed, as well as networking, physical security, redundant power, and redundant cooling components, which then support the servers and storage provided by the customer.

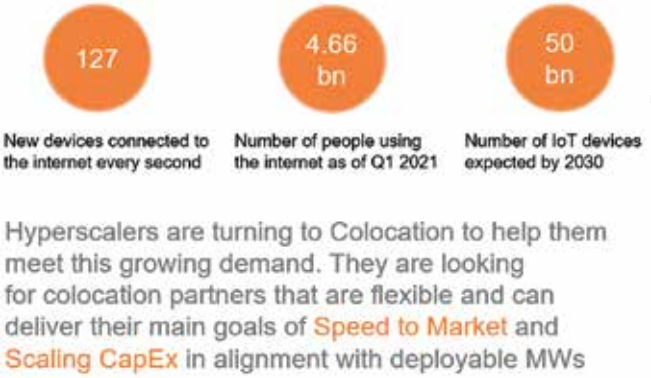

Figure 2. Colocation

The term "Hyperscalers" refers to large companies like Google, Facebook, and Amazon that design and build large-scale computing facilities which dominate the public cloud and cloud services industries. In computing terminology, hyperscale is the ability of the architecture to scale appropriately as increased demand is added to the system.

The Nimble Initiative

With the rapid growth of the data centre sector over the past decade, accelerated even further by the Covid pandemic, data centre providers are seeking solutions to accelerate their entry into new markets as well as capacity growth in existing ones. To meet demand as quickly as possible, many of the hyperscale data centre providers are turning to colocation developers who have

existing sites and the ability to quickly bring new data centres online. Working with both colocation and hyperscale builders, Jacobs could see where gaps and opportunities were in the two design-delivery models, and we understood the drivers behind both.

Hyperscale data centre operators are always building, and when they're not building – or can't due to various constraints – they're also big users of colocation services. Sometimes, that's driven by risk management decisions as a company enters a new market or geography, or to manage the ever-present risk that demand could flatten or fall. Often, it's because permitting, securing permission for, and building new facilities can be challenging.

Working with our clients, we could see that hyperscalers need a more bespoke solution to help give them flexibility to navigate these challenges more nimbly. We could see an opportunity in how the colo business operates that may benefit the larger clients. Using tools such as A3 Thinking, Root Cause Analysis and 5-Whys, Jacobs' solution began to take form and the concept of 'cloud condos' (condominiums) emerged as a strategy to provide fast, efficient options to data centre providers and customers.

Figure 3. Enabling Clients with Bespoke Solutions

The condominium concept brings together the best of both hyperscale and colocation data centre design, refining it into a plug and play approach that provides both flexibility and scalability whilst accelerating speed to market and providing greater alignment with sustainability goals.

This framework offers colocation developers the flexibility to scale-up with minimal investment and faster time to market and revenue generation. For hyperscale customers, it provides greater efficiency with the ability to scale individual costs in alignment with deployable megawatts.

Jacobs cloud condos are designed to provide computing space in discreet 5MW server hall modules as part of a larger data centre building with varying degrees of shared services between different occupants. The intent is to afford companies who require larger computing capacity beyond the traditional colocation caged areas the opportunity to secure separated private server hall spaces in 5MW increments. The Cloud Condo facility masterplan allows up to 30MW per building in an expedited manner and with the flexibility to allow for a degree of bespoke configuration options to suit each individual user. Unlike standard colocation, clients won't be forced to use only standard offerings with limited opportunities for modification.

In other words, while colo is like renting a room in a shared house, re-thinking the problem using a structured approach enabled Jacobs to think differently – a Cloud Condo is like renting or owning an entire spacious apartment, complete with your own front door. This concept appeals to both providers and hyperscalers.

The Jacobs solution is intended not just for colo users with (much) bigger needs, but to enable data centre operators to build out campuses in 30MW blocks in a form that makes them faster to design and build than conventional data centres. The finished building can come in the form of a self-performed client fit-out or a full-service turnkey deployment for IT, electrical, mechanical, security, network operations, administration, and more.

The modular design approach enables larger colo providers and their customers to cost-effectively consolidate their colocation contracts in a form that better suits their security, management, and sustainability goals, as well as other needs, and helps everyone balance risk better in a rapidly-changing world.

Need for Speed

Like many industries, the Cloud industry is driven by speed to market and the ability to provide capacity. Jacobs estimates that the Cloud Condos will enable design-to-online availability up to 40 percent faster than conventional data centres' project delivery timelines.

Leveraging Adjacent Industries

Many buildings, such as hotels, apartment buildings, and schools are built with pre-fab off-the-shelf designs. These building types have repetitive design elements which helps to cut costs and expedite the design process.

Jacobs modular design is intended to be highly configurable, depending on the geography, market, and particular customer needs. Cloud Condos is designed as a repeating structural grid that allows for flexibility and evolution over time. Depending on the site, the solution can be single-storey or stacked, and it can be concrete or steel. The modular design is future-proofed by enabling future changes to the mechanical-electrical equipment sets without affecting the overall architecture.

Today, we're all dealing with supply chain issues, and the Cloud Condos design enables flexibility in terms of vendors. The equipment that goes into each server hall is determined by the end-user and the model can be adapted to any geography or climate.

As we all strive for a carbon-zero future, the Cloud Condo configuration will enable clients to easily plug-in hydrogen backup generator or hydrogen fuel cells should the technology shift in that direction. The team are continuously looking for continuous improvement opportunities in this space also and are currently evaluating other renewable energy sources like micro-nuclear.

Lean Initiative Improvements & Impact

This innovative development provides significant benefits for stakeholders, including:

- Accelerated design process.
- Improved speed to market.
- Flexible scalability for each client's growth needs.
- Future-proof – ability to incorporate sustainability based on client priorities.
- Standardisation and elimination of waste.
- Modular and scalable building block design and construction.
- Global deployment capabilities.
- Lean, standardised designs with customisable kit of parts.
- Embedded sustainability options.
- Flexible Mechanical and Electrical systems – adaptable to different configurations and climates.

Additional Lean benefits include:

- Greater flexibility compared to pre-fab data centre with the same timeline reduction.
- Vendor agnostic for a truly independent plug-and-play experience.
- Sustainable options are embedded in our pre-designed solution.
- Major changes can be made to the mechanical-electrical equipment sets without affecting the architecture.
- Jacobs de-risks the process with our deep expertise in regulatory and compliance which are frequent causes of delays.
- A global footprint and expertise across multiple industries.

Figure 4. Data Centre Excellence

Jacobs

Company Overview | SISK | johnsiskandson.com

John Sisk & Son Ltd. (Sisk) is an innovative engineering and construction company employing over 1,800 people in Ireland, the UK, and Europe. Sisk has the track record, scale, and capacity to successfully undertake large, complex, multi-disciplinary programmes, and we are recognised by our global customers as world leaders in sustainability and safe delivery. Sisk is a progressive business and Ireland's No. 1 ranked provider of construction services. Operating since 1859, we have built many iconic buildings and landmark pieces of infrastructure. Our continued success is due to:

- Our ability to collaborate with customers and supply chain to provide technical and delivery solutions in an open and can-do way.
- Safety, innovation, quality, efficiency, and value are integral to everything we do.

We deliver projects in key sectors such as Data and Technology, Pharmaceutical and Life Sciences, Infrastructure, Transportation, Healthcare, Commercial, Residential, Retail, Industrial, Leisure, Education, Water, and Energy.

Author

Laura McPadden

Overview & Background to the Lean Initiative

This Dublin city centre-based project required the demolition of an existing 12-storey commercial building with a 9-storey tower over a 3-storey basement. In its place, a new 8-storey over triple basement, 150,000sq foot office development was constructed. The overall project value was approx. €65 million, and it was a very demanding programme made even more challenging by Covid-19.

When the construction programme was first developed, a clear critical path through the substructure, precast stair and lift cores, the structural steel frame, and the façade was identified. As a result, it was necessary that the actual progress on these elements required close monitoring and control to ensure the project was delivered on programme.

Due to the large volume of materials to be installed, the planned work was broken down into more manageable and quantifiable daily outputs. The actual daily output was then recorded and tracked against the planned output to determine the programme status. Added complications brought about by Covid-19 meant collecting accurate and consistent daily data became more challenging. Therefore, a more streamlined process was required to ensure certainty when assessing the current project status.

Figure 1. Sisk Operative Scanning the QR Code

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Current Lean Initiatives

Since the outset, the project team implemented weekly collaborative Pull Planning sessions in conjunction with sub-contractor supervisors to gain input and buy-in from the entire team. By depicting the master schedule in an easy-to-read 6-week look-ahead broken out into the various zones, the programme of works became more transparent and encouraged discussion and collaboration. Sectional milestones or target dates were then used to focus the team on the most critical tasks and helped plan how we would reach those goals. Because each of the milestones was based on achieving a specific quantity of works by a certain date, elements of Takt time planning were employed to complement the Pull Plan. Using the Takt time technique of establishing a pace, or a steady planned daily output in this case, the Pull Plan became more reliable. Alongside this, we tracked the actual daily output and the reasons for delay on a whiteboard located beside the Pull Plan.

If the recorded actual outputs varied from the planned outputs, we were able to react to make the necessary adjustments by, for example, increasing resources, resequencing, or removing blockers, and then updating the Pull Plan to achieve the target date.

A prime example of this was evident during a Kaizen event that occurred during the steel frame installation. It resulted in the final torqueing of the bolts being completed on windy days when the crane was not operational so that time wasn't lost as a result of the crane being winded off. This allowed the crews to be more productive when the crane wasn't operational.

While many benefits were realised from this data collection approach, as the project progressed and more trades came on board, a reduction in the level of detail, quality, and consistency in the data collection was noticed.

Figure 2. Six-Week Pull Plan

New Lean Initiative

Define: During this stage of this Lean continuous improvement project, we discussed the current data collection process and why there were varying levels of detail and consistency. It was accepted that the then data collection strategy focused on lengthy non-value-adding data inputting with no owner assigned to the information flow. For example, the data was input both on the whiteboard (for communication at the weekly Pull Plan session) and the Master Excel Tracker (which we used for overall activity analysis) before being fed back into the Master Programme at the end of each week.

There was an underestimation of the time required to collect and input the data into the various trackers before filing the information away. There was also the added risk of erroneously wiping the board and losing the data before it was captured on the Master Excel Tracker.

Using Lean tools such as drawing the As-Is Process Map and SIPOC, we determined areas for improvement and settled on our goal statement: Improving the planning and tracking of progress by streamlining the data collection process and whilst also reducing non-value-adding work.

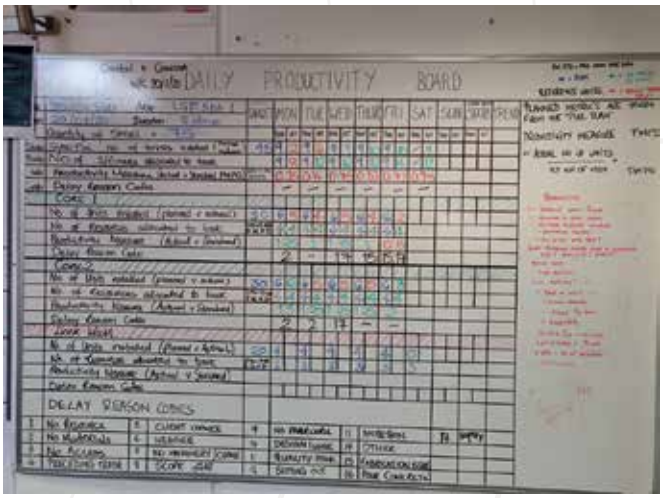

Figure 3. Daily Productivity Board

Measure: When reviewing the collected data, we noted several instances of incomplete information. With the complete data, we were able to compile a Pareto analysis of the reasons for delays encountered during the installation period of the key trades. This graphical analysis helped create a picture of what 'pain' we were suffering in the process. While this information is good to capture, it focuses more on a reactive approach than being proactive.

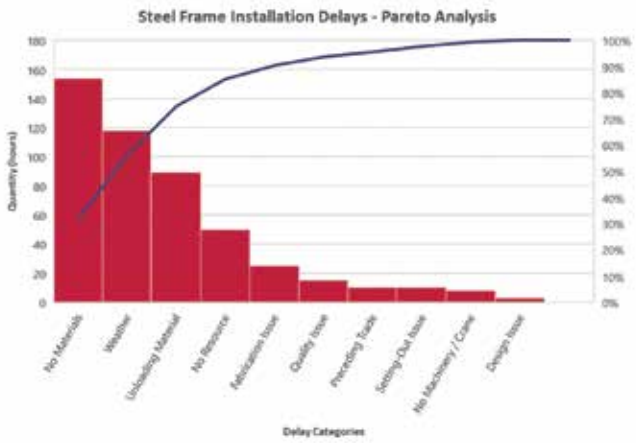

Figure 4. Pareto Chart

Analyse: Here we listed the probable reasons for incomplete data collection and used the Cause & Effect Matrix and Five Whys to get to the root cause. Primarily, the reasons were:

- Not understanding the benefits of data collection; and
- Not being prompted to input complete information.

Improve: As a group, we brainstormed possible solutions and depicted the improvement ideas on a PICK chart to gauge the potential payoff and level of difficulty of implementation. A quick and easy solution that was deemed to have a high level of pay-off was an online form that would be filled out at the end of each day by the Package Manager on-site on their mobile device. It would quantify the actual work completed that day, plus any issues ('pain') encountered, as well as planned work for the following day. This form could be accessed easily via a QR code positioned at the site exit.

We also applied Poka-Yoke for error proofing by using compulsory fields to prevent non-responses and incomplete data collection. Once submitted, the data would be instantly available for several parties to view, improving levels of communication since several members of

the project team – like the Planner and Commercial team – were working from home.

We applied the Plan Do Check Act (PDCA) cycle to the creation of a prototype form and sought feedback from the team. We then created a refined solution and tested with potential users. Following some tweaks, we standardised the form and trained participants before implementing amongst the wider team.

Control: To prevent people slipping back into the old way of doing things, we put a Control Plan in place to ensure the new process was executed correctly. Amongst other things, this detailed the frequency and the method of communication, how the new process would be integrated, and who would be monitoring future performance.

Finally, a Lessons Learned document was compiled to capture and share knowledge.

	Communicating the Results	Integrating the New Process	Monitoring Future Performance
Who	• Subcontractor Supervisor • Package Manager / Planner	• Project Team	• Project Team
What	• Daily output compared with planned output • Assessment of accrued delays	• Online form	• Continue gathering data and monitor against planned output
How	• S-curve graph • Whiteboard • Project Programme	• QR Code	• Track data weekly • Review regularly
Where	• Project Team Meetings • Daily Whiteboard Meetings	• Sisk Shareview	• Continue to post data in Controls Room • Email
When	• Weekly basis	• Daily	• Weekly
Why	• Gives team the results of the improvement	• Old forms to be discontinued completely so they don't affect the change	• Ensure form is operating as efficiently and effectively as possible

Figure 5. Control Plan

Lean Initiative Improvements & Impact

This process-improvement initiative is still in its early stages, so the full list of benefits has not yet been realised. One of the key advantages of the Lean roll-out on the project is that the wider team now has a better understanding of waste, value-adding activities, and non-value adding activities.

Other anticipated benefits include:

- Improved Data Collection: It is expected that the collected data will see increased accuracy due to it being captured at the end of each day before it is forgotten. It will also be collected by the individual responsible for that area of work. The obligatory fields will prevent items being skipped, resulting in a higher quality of data being captured. This data will be better placed to paint a more accurate picture of the installation period and can be used by the pre-construction team when tendering for similar jobs. This data can also be shared with the sub-contractor.
- Increased Visibility Boosts Collaboration: The data collected inn the online form will automatically generate graphs to depict any delays encountered. It can be used to provide discussion points when collaborating at the weekly Pull Plan. If actual output varies from the planned output, the established daily output required can then be altered to achieve the target date.
- Reduced Abortive Work: Given that the data must now be recorded by one individual on one form, the time lost recording the same information in different trackers is reduced. The online form takes less than 1 minute on average to populate.
- Documentation of any Deviation in Planned Works: The planned works for the following day are documented in the form and can be used to compare against actual output. This will be helpful when tracking productivity levels and monitoring any deviations.
- Readily Available Data: Now, data is immediately available for multiple parties once the form is submitted. This data can be accessed by package managers, engineers, planners, quantity surveyors, and so on. This has been most beneficial for those working from home throughout the pandemic.
- Lean Thinking: The concept of seeing pain points as opportunities has been established. Applying Lean thinking to problems has demonstrated the benefits of this approach and encourages us to seek further opportunities on our projects.

Company Overview | ARDMAC | ardmac.com

Established in 1977, Ardmac is an international construction specialist delivering complex and high-value workspaces and technical environments. Headquartered in Dublin, with offices in Manchester, Craigavon, Brussels, Cork, and Switzerland, Ardmac is supporting projects all over Ireland, the UK, Denmark, Belgium, the Netherlands, Switzerland, and have this year announced their expansion into Finland and Germany. Ardmac employs over 350 people and is a leading global provider of cleanrooms, data centres, fit-out and refurbishment, and modular solutions.

At Ardmac we work Smart, meaning we deploy innovative technology throughout our business to empower our people, drive performance, and delight our customers. We believe in setting new standards for our industry and driving innovation, we believe in tailoring solutions to our clients' evolving needs, and in working hard to harness our unrivalled knowledge to deliver safety first and excellence as standard across award-winning projects.

Author

Peter Gough

Author

Fergus Nugent

Overview & Background to the Lean Initiative

In most construction projects, particularly those that are complex and large in nature, the scope is divided into multiple trade packages that are delivered by specialist organisations. It is only natural for each party to maximise their productivity by planning their use of resources in a streamlined manner. However, each package is not executed in isolation and often requires significant interaction with other parties. These interactions are known as hand-offs. Optimising each package independently often results in conflicts across trades, and results in waste. To maximise value for the customer, an overall project view should be taken and, if the hand-offs between trades can be managed well, flow can be achieved. However, this is a significant challenge. According to the Lean Construction Institute, the Last Planner® System (LPS) gives the last planners the tools and language to focus on flow by optimising the hand-offs between trades. This is achieved by improving the reliability of commitments made by participants.

Ardmac was an early adopter in 2014 of LPS, and we have observed significant benefits from its implementation. On a recent major project, Ardmac was engaged as a specialist contractor working as part of a group of trade partners. Ardmac implemented LPS internally, but the other trade partners and main contractor did not. This case study describes the challenges and benefits of adopting LPS on a project without the full participation of other stakeholders.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Buildings are becoming more complex in parallel to construction schedules becoming more condensed. Organisations operating within the construction sector are being challenged to deliver cheaper, faster, and better. It seems as if the sector is being forced to accelerate at an unprecedented pace and notwithstanding the ongoing resource challenges across the globe. Customer and client expectations haven't lessened and the challenge is how we as a sector adapt.

LPS is an excellent Lean Construction planning tool that Ardmac engaged with in 2014. It is easy to understand, is not overly expensive to implement, and it focuses on collaboration and cooperation. Scheduling is used as a tool on every large project. Anecdotally, the scheduling process leads to inaccurate time estimates on a regular basis, resulting in delays and lost time when work cannot be executed as planned. LPS has been proven to improve scheduling accuracy to >85% when implemented fully.

In the LCi Annual Book of Cases 2020, we described the success we have had using LPS. Significant investment has been made in employee training, software rollout, and the creation of an Ardmac LPS Workbook that people can use as a guide when using LPS on their projects. We use a combination of visual planning to supplement the LPS process, as outlined in Figure 1, and Figure 2 provides examples of LPS metrics and visual weekly work plans.

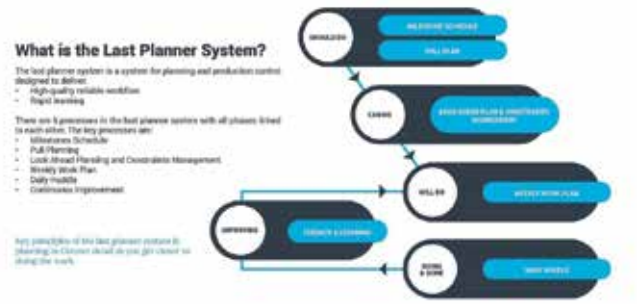

Figure 1. LPS System Description

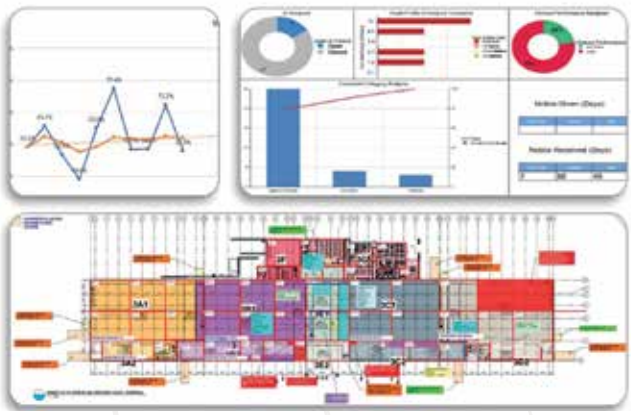

Figure 2. Examples of LPS Metrics and Visual Weekly Work Plans

This case study describes how one of our teams implemented LPS on a recent project when acting as a trade partner and with LPS not being adopted by the wider project team. The challenges faced by the team and the merits of using LPS in this situation are discussed. Regardless of the client, management team, trade partners or colleagues, we all have a part to play in the effective and efficient completion of our scope of work to ensure a project is handed over to the end user successfully. Nevertheless, sometimes the last gasp heroic type efforts to get a project to an end user can be forgotten when milestones and project dates are achieved. Scrambling to hit milestones can be an extremely rewarding feeling for a team, and can often improve morale; however, doing this for every milestone is not sustainable across the course of a major project. Construction projects are marathons not sprints, and they need to be treated as such.

The project in question was complex in nature and involved multiple organisations, some working in partnership and others working directly with the client. Initially, a high-level schedule was created that all parties agreed to and a sequence was agreed describing which levels, zones, and elements would be completed in order of priority.

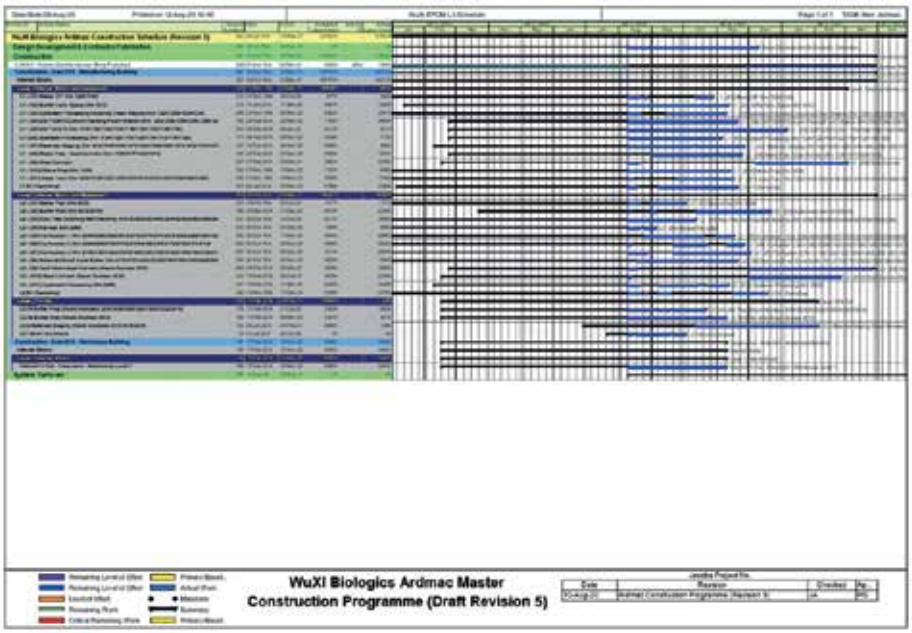

Figure 3. Initial Project Baseline Schedule

Unfortunately, the project coincided with a few macro-economic events that had a significant impact, the two most impactful being Brexit and the Covid pandemic. The challenges posed by these events was added to by design changes and supply chain issues experienced by multiple project stakeholders. Material and labour shortages became a challenge, and the project was completely stopped for 10 weeks due to the pandemic.

The result was a schedule that lacked certainty and impacts that were not possible to predict. Elements that were not impacted would be accelerated to compensate for those that were delayed. Consequently, frustrations mounted in the field with supervision becoming increasingly disillusioned by unrealistic requests from management as original milestone dates began slipping. The hand-over priority originally agreed at project commencement began to blur and resulted in different trades working to differing sequences to minimise schedule impact.

Due to the ongoing pressures of unreasonable timelines, we experienced negative attitudes and lack of engagement from our field supervision. As a result, this created a significant issue internally which needed to be reviewed, resolved, and actioned with immediate effect. Our management team were highly motivated, enthusiastic, and safety-conscious, and had previously delivered projects using LPS at a high level.

As part of our project execution plans, we focus heavily on utilising LPS to ensure the successful completion of our works. Despite the investment in training, as a team, we unfortunately fell short of the fundamental requirements of LPS. Dates we were working towards had exceptionally tight timelines and people did not have faith they could be achieved. The effectiveness of the planning process was lost in the depths of unreasonable timelines, which could not continue. We sought opportunity to eliminate parts of the process that were not adding value. There was no alternative and a better solution was badly needed because, if the trend continued, we were inevitably going to fail. As simple as it seems, we re-energised our focus on what had delivered success previously – tasks that are available and work we Can Do through our LPS process.

We stopped, assessed, and re-evaluated our situation and recognised the issues within – failed commitments, missed dates, the appetite for success had dropped. Following lengthy and sometimes intense discussions with our management team, a change in the LPS set-up was agreed. A key finding in our original LPS arrangements were meeting times and schedule review timings didn't support field execution needs. Internal changes with a focused effort on detailed look-aheads at a time that worked for the entire team enabled more meaningful constraint management and effective communication amongst the group. With this subtle change, we immediately encountered a change in mindset towards what we were striving to achieve.

Recognising the issues enabled a revised set-up to our LPS approach, thereby allowing the team to voice their thoughts and opinions through constructive planning meetings and daily

reviews and conversations. This in turn created a more positive outcome with optimum performance. Whilst these issues identified are fundamental requirements for effective team performance and management, we had lost sight of the basics through a continuous firefight of unreasonable delivery requests. Utilising our field management tool, Procore, to effectively manage and support our performance with RTI was hugely beneficial. It enabled the team, in a timely fashion, to identify potential issues or roadblocks that could then be communicated to the construction management team and our trade partners for review and action.

Lean Initiative Improvements & Impact

After several challenging months on the project, it became apparent that the programme was not achievable by continuing in the same fashion. We had to step back from the detail and re-look at the project. We started by agreeing a priority hand-over sequence. Whilst it may sound so simple and basic, it was fundamental to our success for the duration of the project. The project schedule and sequence had started out as logical and well-planned, but with issues such as design changes, the Covid pandemic, Brexit, and other significant challenges, the logic no longer made sense. It was not possible to tell which elements of scope would be impacted with delays, and even more difficult to understand what interlinked elements would suffer as a result. By taking a step back and almost starting again, we were able to clearly align our priorities internally. We then worked with the main contractor to validate the order of priority.

Once realigned, we brought the delivery team together and started to map out the works remaining in each area to complete the project, starting with the priority areas along with durations. We worked together to walk the zones and created a detailed list of constraints per area, and we used Procore to attach images to each constraint for increased effectiveness. This simple exercise generated some momentum internally, which in turn brought optimism and positivity that was lacking in the team when hand-over dates were consistently missed. This had a powerful impact. Once complete, we had a works to go list, a visual constraint list per area, and a commitment from our internal team to hit a set of target hand-over dates. The exercise was almost opposite to the pull planning format we are traditionally accustomed too. To create a robust plan, we had to build from a starting date rather than pull from a completion date. Constraint management became paramount to limit unproductive time. The closure dates of constraints were difficult to predict due to high levels of uncertainty, as mentioned above.

We then discussed the plan with the Construction Management team for their input, and we got their buy-in and support and were able to amend some dates based on insights they shared, and the result was an extremely ambitious plan to hand-over 26 areas in 12 weeks.

Figure 4. Area Hand-over Plan

We met daily to review progress on constraints, and we would then issue a report to the CMT project director upon his request. We reviewed internal resources, materials, tools and plant, and other trades in the area that had the potential to impact our works. The daily report would filter down from the Project Director and initially resulted in conflict – in particular across organisational boundaries. Highlighting constraints can seem like a negative finger-pointing exercise if people are not familiar with the LPS process. Initially, our team appeared negative rather than proactive, and it took several weeks for other stakeholders to see the benefits of using visual constraints management. By identifying the work that could not be completed, we were able to focus on the works that could be completed, until such time as constraint closure commitments were made. Resources were deployed to productive work that could be completed rather than abortive stop-start tasks that would be impacted by, for example, missing materials. If constraints related to priority tasks were closed, we became better at readjusting the plan to focus on urgent items. Whilst this is against the standard LPS mentality, given the volatility being experienced at the time, we felt an element of flexibility was crucial to success.

As part of our LPS approach, we target 80%+ percent plan complete (PPC) each week. The before and after graphs in Figures 5 and 6 demonstrate how our original PPC performance was not consistent and below our target. Figure 6 shows how, with the refocused approach to the Last Planner set-up on site, we increased the weekly average. It is clear that the team's performance significantly increased when the set-up supported the project needs and the system was utilised as an aid as opposed to a requirement.

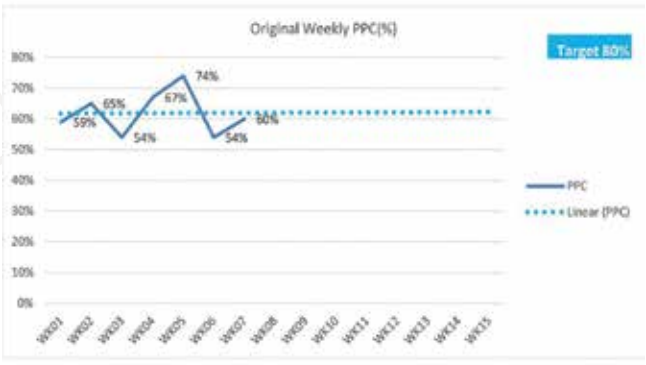

Figure 5. Original Weekly PPC Performance

Finally, Figure 6 shows that all 26 areas were completed 3 weeks after the original planned completion date. Rather than being negative,

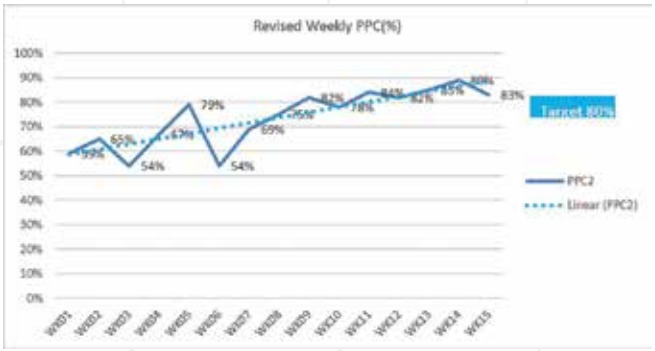

Figure 6. Final Weekly Team PPC Performance

this was an excellent achievement by the project team due to the high levels of uncertainty during that period. Whilst the project was challenging, the team learned that extreme circumstances can require specific solutions. In this case, rather than abandon the LPS process, the team adapted it slightly, reframed the challenge in a positive way, and engaged the entire delivery team to create a sense of togetherness and collaboration that is vital to the success of LPS.

Figure 7. Plan V Actual Area Hand-overs

Company Overview | PM GROUP | pmgroup-global.com

PM Group manages the design, construction and commissioning of high-tech facilities. We are an employee owned company with over 49 years' experience working for the world's leading pharma, food, data centre, and medical technology companies. We deliver projects across Europe, the USA, and Asia.

Trusted Partners – To excel at the complex, we always seek to understand our clients' needs. At every level of our business, a culture of honesty, openness, and flexibility prevails. Our approach has led to long-term, trusted relationships with our clients.

Author

Brendan Kealy

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David Moody

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Paul Martin

Overview & Background to the Lean Initiative

This case study looks at Takt planning excellence in project delivery. Takt Time Planning is based on using location break-down structures to plan, with the objective of making the work flow continuously.

Implementation benefits include:

- Reduction in work phase durations and associated costs.
- Increased transparency and predictability of work flow.
- Improved ability to deliver design on time with reduced quantity of RFIs.
- Improved efficiency in the workplace with materials arriving to suit the work being executed, which leads to reduced waste (moving materials) and a safer environment to work.

This demonstration of Takt Time Planning comprises three main sections:

i. Creating the Takt Plan.
ii. Implementing the Takt Plan.
iii. Maintaining the Takt Plan.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Creating the Takt Plan

Takt Planning starts with the Scope Breakdown structure and design areas. Construction zones and Takt zones are well-established before the end of Concept Design, and this applies to all subsequent stages of the project. The earlier this volumetric segmentation happens, the more profound the impact. The four high-level partnership groups are Vendors, Trade Partners, Client, and A&E. These four groups became the "team of teams", and within each team there was subdivision, and, as the project progressed, their membership changed. By the time it came to construction execution, the teams were mainly trade partner and A&E construction, with design as participants.

The planning work begins with the Overall Process Analysis (OPA) where all trade partners come together to:

- Understand the scope of the works involved and agree on the constructability.
- Break the area into zones (Takt Zones) to maximize efficiency and flow of work. These Takt Zones were evolutions of the design areas and the segmentation setup to enable digital delivery.
- Generate individual tasks per trade partner that will accumulate in the completion of the works.
- Agree, as multiple trade partners working with a team ethic, on the sequence that the works need to be carried out in each Takt Zone.

Agreement on sequence of works can be done using traditional post-it stickers or by using new technology (an online scheduling platform). The design team is a key partner in this part of the process, and the construction team has the opportunity to pull design and to target certain scope in order to make schedule improvements on site.

After the OPA sessions are completed, trade partners come to the Process Planning (PP) session with their durations and resource requirements prepared. Here, the full schedule for the work is developed. The access/start date and the target completion date are provided from the project master schedule. The data is populated

Figure 1. PP Generated from Takt to Support Project Milestone

into the digital platform at the session, and we can see where trades can work in parallel to reduce work phase durations. It is also where we strive to provide flow of work for trade partners from zone to zone.

After this Takt is completed, the next sequence of works (or next Takt) is planned out in the same way, for example:

- Cleanroom Ceiling.
- Cleanroom Flooring.
- Cleanroom Walls.

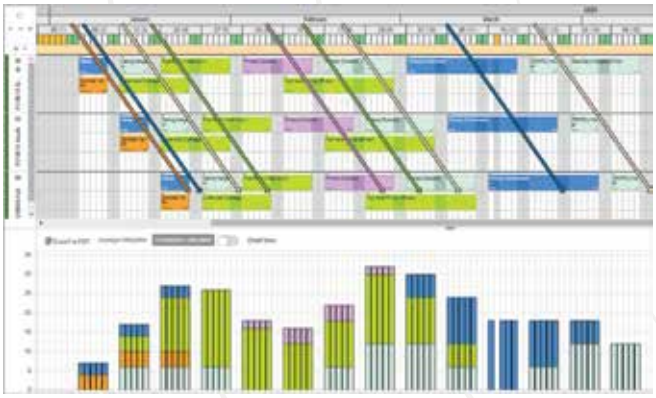


Figure 2. Takt PP illustrating Flow of Work & Levelled Personnel

Density to Suit Trade Partners

The resourcing function on the digital platform allows the group to see the personnel that will be working in the Takt Zone based on the PP that has been generated. This technology can group work fronts together to see the combined personnel across a number of Takt Zones to, for example, give the total in one building. Of note is the flow of trade partners from zone to zone, which reduces waste and is a key component of Takt Time Planning. It can also be used to see the personnel required for an individual trade partner per zone, per building, or across the whole project.

Figure 3. Individual View of Workflows & Density

Implementing the Takt Plan

The agreed PP for an area is the main tool for coordinating the works in the field on a daily basis. Permits to work are approved if the works are scheduled in the Takt Zone as per the agreed PP. At the daily site permit meeting, the works in each Takt Zone are reviewed. If there is capacity for additional work to be completed in a Takt Zone, then this is allowable if agreed amongst all trade partners. If the trade partner Takt into that zone cannot accommodate any additional works by others, then the work cannot progress.

Figure 4. Takt Zones & Area Coordination re Permits to Work

To reinforce the focus of the planned works through Takt, the Takt Zones were physically demarcated on site with barriers. Ingress/Egress points clearly marked with the Takt Zone identifier. The agreed PPs were on display in each Takt Zone so that PM Group area owners would be clear on what trade partners had the right to work in an area.

Figure 5. Demarcation of Takt Zones

Impact of the Covid Pandemic

After the onset of the Covid pandemic, Takt Planning became a critical enabler to keep crews separated and to manage the health of the team. The pre-Covid personnel requirements per Takt Zone were already known, as well as the maximum density of personnel per area. This information could then be used to take action after the onset of the pandemic. Revised personnel density limits were calculated for every Takt Zone with social distancing taken into account. This could then be applied to previously agreed PPs to see where action was required, like, for example:

- Shift-work in critical areas; or
- Re-scheduling in non-critical areas.

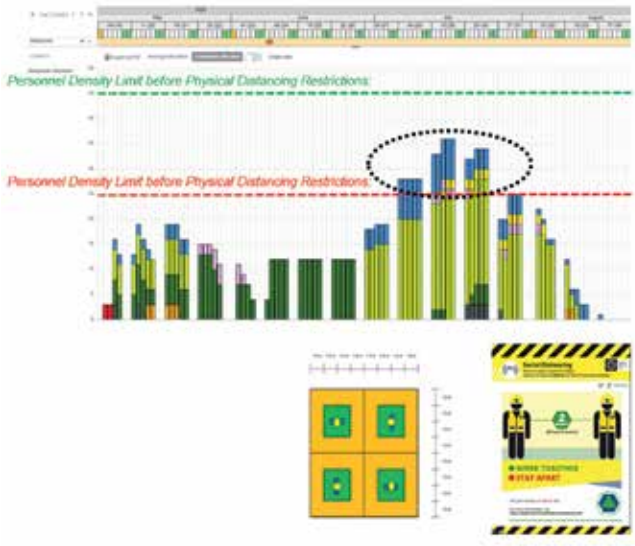


Figure 6. Personnel Density Limits & Physical Distancing Requirements

Maintaining the Takt Plan

After work in a Takt Zone has commenced, progress of the PPs are updated on a regular basis, and this was done daily on our project. The activities on the PPs were broken into daily Takt cards, with each card representing one day of work for a particular task. These cards are then placed into the Takt Boards on a rolling 4-week look-ahead basis. At the daily meeting, trade partners would turn their cards to confirm that the work for the day had been completed and that the task is on track overall. If progress is not as per plan, the card remains unturned. If there is a constraint or reason for the progress of that day not being achieved, a constraint card is placed in the board. The issue is then discussed immediately within the group at the meeting, with resolutions typically agreed there and then. Figure 7 illustrates this with the requisite QR code on the Takt card – cards can be turned in the field in advance of the meetings using smart phone or tablet.

After the onset of the pandemic, the use of the daily Takt board was no longer viable due to physical distancing. In order to keep the daily Takt updates running, we took the technology in use for the PPs and further adapted it for use as a daily Online Takt Board. A daily MS Teams meeting was set up and the cards were digitally turned with all trade partners participating online. An important part of the daily updating is the scoring system called OTP (On Time Performance).

OTP (%) = achieved cards ÷ planned cards

Figure 7. Daily Takt Tracking, Update of PP Tasks, QR Code

Unturned cards result in a lower OTP. Works can be re-forecasted at the sessions to ensure works continue to be coordinated between trade partners, and weekends are also available for works to be caught up on. OTP scoring can be detailed per area, per trade partner, and overall for the project.

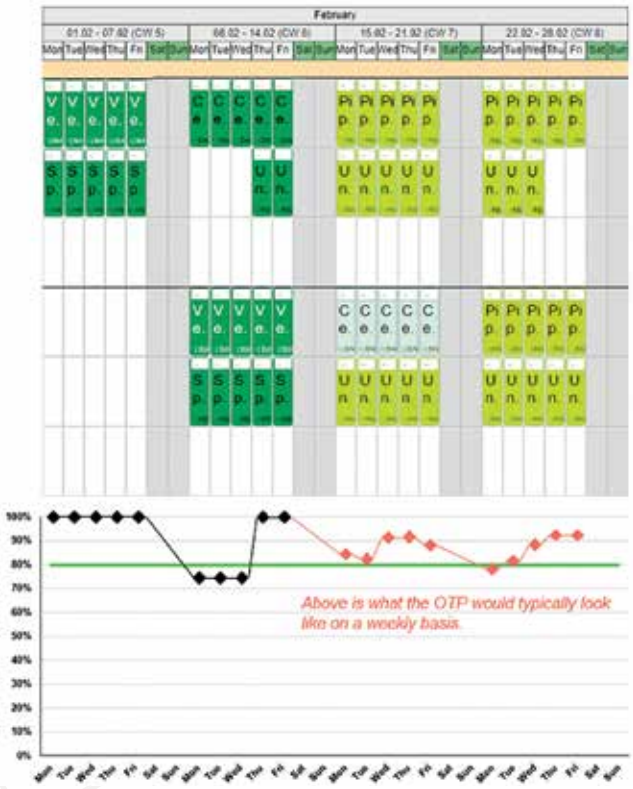


Figure 8. Online Takt Board

Lean Initiative Improvements & Impact

The implementation of Takt Planning on the project, coupled with other Lean project initiatives listed below, led to significant schedule savings, including:

- Tiered Agility.
- One Team Approach.
- Right First Time Construction Quality Culture.
- Enabling information flow through an RFI turnaround-focused metric.

Takt Planning enabled a visual demonstration of the work progress through the Takt zones, as well as of people and material. It communicated clearly the construction sequence intent in detail for the design team to focus their efforts in providing the correct information at the correct time (i.e. Flow). The colour coding of Takt Zones, coupled with the physical demarcation in the field and daily permitting meeting reviews, facilitated both the Trade Partners and PM Group area owners calculate the area occupation and capacity.

It was an easy headcount check thereafter to confirm personnel numbers within the defined zones.

The control granted by the Takt Planning also facilitated the following:

- Governing numbers of people within strict zones.
- Monitoring progression through the zones of the trades.
- Regulating the flow of material to and around site.
- Permitting of works by zone.
- Trade partner personnel forecasting.

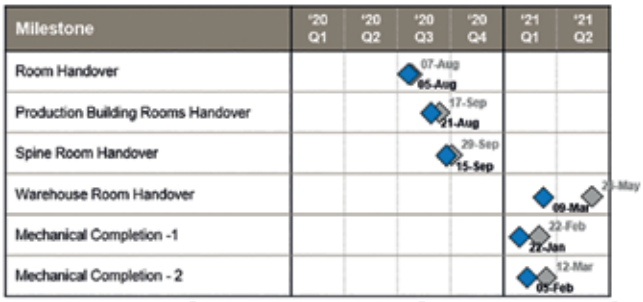


Figure 9. Project Milestones Achieved/Bettered

An unforeseen benefit of the Takt Planning was witnessed during the Covid pandemic after the return to construction sites was permitted. The previously defined Takt Zones had personnel allocations that were easily revisited and revised to allow for new maximum occupancies to accommodate the social distancing requirements. Proof of the benefits of Takt Planning can be seen in how we used it to specifically target the most critical milestones on our project with successful results in all cases. On a project that adopted a take-off-site approach at the concept stage, the trade partners used the Takt process to further enable off-site modularisation even into the construction stage of the project.

Testimonial

> "By creating this culture, we enabled the team, including the very important voices from key trades, to redesign the work to reduce waste and improve flow of information, decisions, fabrication, and work in the field. Takt became a foundation for everyone. By taking the time to plan together, from the bottom up, each trade learned how to better coordinate work among themselves. By resizing work and crews to optimise the whole project using Takt, we created a much better work flow." (Executive Director, Global Engineering Solutions, MSD).

Company Overview | SISK | johnsiskandson.com

John Sisk & Son Ltd. (Sisk) is an innovative engineering and construction company employing over 1,800 people in Ireland, the UK, and Europe. Sisk has the track record, scale, and capacity to successfully undertake large, complex, multi-disciplinary programmes, and we are recognised by our global customers as world leaders in sustainability and safe delivery. Sisk is a progressive business and Ireland's No. 1 ranked provider of construction services. Operating since 1859, we have built many iconic buildings and landmark pieces of infrastructure. Our continued success is due to:

- Our ability to collaborate with customers and supply chain to provide technical and delivery solutions in an open and can-do way.
- Safety, innovation, quality, efficiency, and value are integral to everything we do.

We deliver projects in key sectors such as Data and Technology, Pharmaceutical and Life Sciences, Infrastructure, Transportation, Healthcare, Commercial, Residential, Retail, Industrial, Leisure, Education, Water, and Energy.

Author

Kevin Burke

Overview & Background to the Lean Initiative

This case study is based on a project undertaken as part of a Green Belt training course. To complete the course, we were required to identify and solve a problem using the tools and techniques we learned on the course. The problem selected entailed examining how to reduce the time it took to install precast concrete panels on a project the author was working on. The issue was the additional time it took to install the non-standard unbalanced panels. These non-standard panels are unbalanced because of the uneven distribution of weight and the slinging arrangements were carried out on a trial-and-error basis with constant adjustment of lifting gear.

The project itself comprised a 472-bed apartment complex, configured in 5 blocks and constructed using a precast concrete frame. This precast frame uses three different types of panels: one with 2 lifting eyes, one with 3 lifting eyes, and one with 4 lifting eyes. The panels that presented the biggest challenge were the ones with 4 lifting eyes.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Define

As part of a Green Belt training programme, a problem was identified that impacted the progress of the construction project and which didn't have an obvious solution. We focussed on the main elements of the project and sought to identify a challenge that met these criteria.

Many of the potential opportunities we determined were of the just do it sort, where we had the solution to hand but were not using it. We decided to look at the precast panel installation as a potential source of an improvement project because of the variation in time it took to install different panels.

On a Gemba walk focused on the installation of the precast concrete panels, we discussed the challenges faced by the installation crew. Their biggest issue was how to determine the lifting chain lengths for the unbalanced panels due to their uneven weight distribution. The process they had been using was balancing the non-symmetric panels on a trial-and-error basis, with the chain lengths from the crane being adjusted until sufficiently balanced to enable the lifting of the panels into position.

As a result, time was lost trying to figure out the best way to fit these panels. The daily quota required to meet the construction of the building's frame was not being met and installation set-up times were identified as being a critical element of the process.

The typical response to these challenges is to apply more pressure to the installation crew or add more people to the task. However, the Lean training taught us to analyse problems and to understand

Figure 1. The 4 Lifting Eye Unbalanced Panel During Lifting

their root causes. In addition, the process of resolving issues required fact-based decision making, and for this we needed to understand what the contributory factors to the issue were and to measure their impact.

Figure 1 shows an unbalanced panel being lifted into position. A successful installation depends on the panel being presented evenly to the starter bars in the floor slab. To achieve this, the left-heavy side of the panel must be dropped vertically into place and level with the right side of the panel. The trial-and-error method meant that the panel had to be lifted back to the stillage and re-configured.

We mapped the process to understand the steps involved, from the arrival of the panel on site to its final placing in position (see Figure 2).

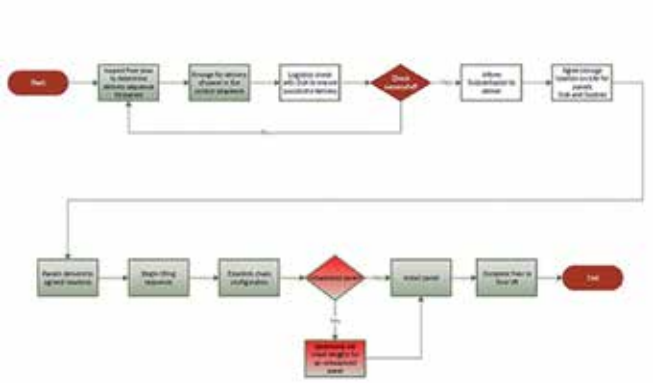


Figure 2. As-Is Process Map for Precast Panel Installation

We then used the process as the spine of a SIPOC diagram (see Figure 3).

Suppliers	Inputs	Processes	Outputs	Customers
Sisk/supply chainon-site package managers	Plan works with subcontractor	Inspect floor plan, identify areas of panel commonality and/or	Arrange lifting sequence of walls, coordination of logistics, crane usage/demands etc	Package managers
Package managers	Marked up drawing	Itemise panels	Programme of works	Project team
Project team	Site walk/whiteboard meeting	Check storage/access based on day's/week's activities	Ensuring continuation of works	Precast factory
Precast factory	Communication	Call off material	Material on site	Project team
Project team	Stillage arrival times, locations	Coordinate lifting plan	Having the correct material in the correct area at the correct time	Crane operator
Crane operator	Lifting of precast panels	Bring crane into position, lift and drop into position	Begin assembly of structural frame	Project team
Project team	Walk the finished area	QAQC check	Sign off	Project client

Figure 3. SIPOC for Precast Panel Installation

Measure

Figure 4 presents an isometric view of a typical floor, and shows that on Level 03 Block D2 there are 24 unbalanced panels.

Over the 3 blocks, each with 8 floors, we identified 969 potentially unbalanced panels. The details for each floor and block are shown in Table 1.

We measured the time taken to install 24 unbalanced panels from chain engagement to panel dropping on the slab on one of the blocks using the current process. The sum of these times was 7 hours, 34 minutes, and 36 seconds, equating to an average time per panel of 18 minutes and 56 seconds. By comparison, for a standard balanced panel, installation was completed in less than 6 minutes.

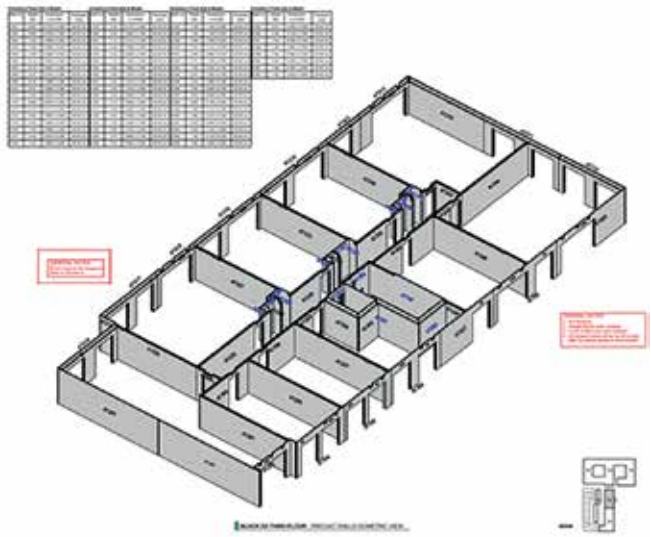


Figure 4. Isometric View of a Typical Floor Plan

Unbalanced Panels					
Block A1		Block A2		Block B1	
Level 00	37	Level 00	45	Level 00	29
Level 01	39	Level 01	47	Level 01	44
Level 02	42	Level 02	52	Level 02	51
Level 03	42	Level 03	52	Level 03	51
Level 04	42	Level 04	52	Level 04	51
Level 05	42	Level 05	52	Level 05	51
Level 06	40	Level 06	51	Level 06	48
Level 07	3	Level 07	3	Level 07	3
Total	287	Total	354	Total	328
Total unbalanced panels = 969no = 30.576 10hr working days					

Table 1. Potential Number of Unbalanced Panels in Blocks A1, A2, B1

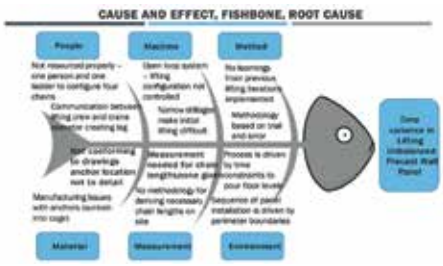
Analyse

In the analysis phase, we used a Fishbone Diagram (see Figure 5) to understand contributory factors to the problem. From this review we identified two main factors impacting the installation time:

i. The as-built anchor locations on the panels did not conform to the design locations.
ii. Due to a lack of communication between the precast panel factory and on-site precast installation crew, chain lengths had to be determined based on the actual locations of the lifting eyes.

While a major process error was found in the positioning of the lifting anchors, we decided to focus our improvement efforts on the time taken to manage chain lengths.

Figure 5. Fishbone Diagram for the Process of Lifting Precast Walls



Lean Initiative Improvements & Impact

Improve

We held a Kaizen event with the team involved in the process of installing the panels. From our analysis using the Fishbone Diagram, we knew that time was being lost waiting for the correct configuration of the chains to lift the panels. We thus arrived at a solution based on the geometry of the lifting chains.

To settle on the correct chain lengths we used the cosine rule. This states that the side 'c' of any triangle can be found with the following information:

- The angle gamma 'γ' (must be the angle opposite side 'c')
- Triangle side length 'a'
- Triangle side length 'b'

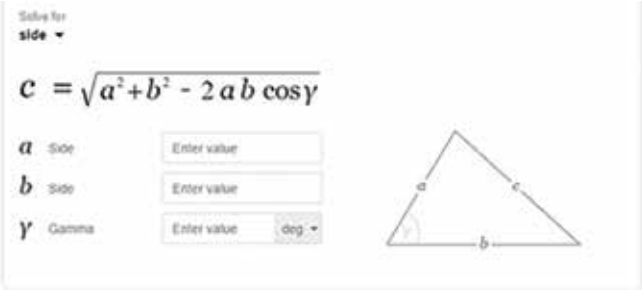


Figure 6. The Cosine Rule

With this formula, we could establish the correct chain lengths for the unbalanced panels. In a lifting configuration, such as the one shown in Figure 1, there are four chains. If we set these two exterior chain lengths to be the same length as the span of the panel, we have created an equilateral triangle. The three angles within the triangle are all 60, as per the equilateral triangle rule.

With these parameters set, we could factor in the two shorter, interior chain lengths within the lifting configuration, and we could now break the lifting configuration down into two further smaller obtuse triangles and designate these two smaller chain lengths as side 'c' in their respective triangles. Therefore, for a typical configuration

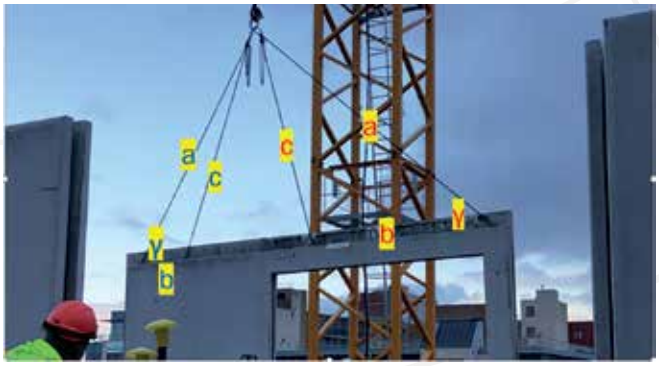


Figure 7. Lifting Configuration with the Cosine Rule Built-In

(Figure 7 shows these angles and triangle sides) these would be:

- a = wall span length
- b = distance between lifting hooks as per shop drawings
- γ = 60°
- c = formula in Figure 6

Having agreed that this formula calculated the correct chain lengths for the unbalanced panels, we created a spreadsheet where the correct chains lengths were calculated. To test our solution, we installed 8 unbalanced panels using the cosine rule formula. This resulted in an average installation time of 6 minutes and 48 seconds per panel. The floor-to-floor build cycle is 3 weeks, which gives sufficient time to plan and prepare for handling future unbalanced panels. Using the drawings from the precast panel supplier, we can make decisions based on their geometry.

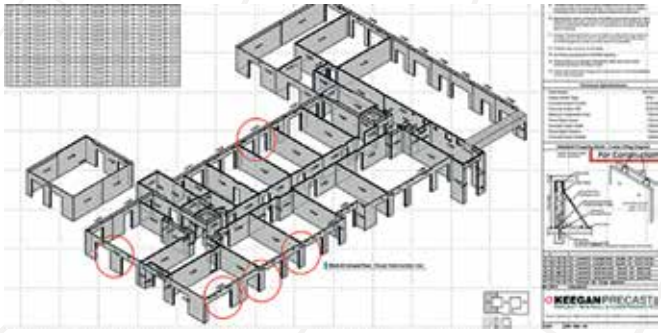


Figure 8. Isometric Plan of Block A1 Level 01 (samples of potentially unbalanced panels circled in red)

Some panels that appear to be unbalanced are in fact balanced. To find out which panel will require the additional work, we entered the dimensions into the spreadsheet we created for this purpose and arrived at the final number of unbalanced panels. As a result of this exercise, we arrived at a total of 96 unbalanced panels.

The installation times achieved using the solution above saves approx. 12 minutes per unbalanced panel. In addition, by using the spreadsheet we could calculate that the actual number of unbalanced panels was averaging at 4 panels per floor for 8 floors across 3 blocks. Therefore, over 24 floors there would be approximately 96 actual unbalanced panels. The cost of installing pre-cast panels approximates to €275 per hour and includes the following elements:

- Crane
- Crane Operator
- Installation Gang
- Sisk Supervision

Using our solution, time saved installing an unbalanced panel is approx. 20 hours, and, on that basis, the overall saving to the project is approximately €5,500.

Company Overview | SUIR ENGINEERING | suireng.ie

Established in Ireland in 1984, Suir Engineering is an Irish-based European provider of Mechanical & Electrical services to high-profile clients in the data centre, life sciences, manufacturing, commercial, substation, and renewables sectors. Suir Engineering has offices in Waterford, Dublin, London, Sweden, Denmark, and across the UK, and directly employs over 1,000 highly skilled staff. Suir Engineering has developed a reputation for delivering cost-effective solutions for its clients whilst ensuring an uncompromised approach to safety, quality, and project delivery. Suir Engineering is a wholly-owned subsidiary of EDF Energy Services, a JV between EDF Energy & Dalkia.

Author

Elaine Harrington

Overview & Background to the Lean Initiative

Since 2015, Suir Engineering has invested in its strategic and company-wide improvement initiative entitled "Suir Way". Since April 2018, the company has rolled out new processes for managing the entire organisation based on Lean principles and PDCA. As part of the Suir Way, and the drive to constantly improve, we wanted to transform our services into a centre of excellence with the client as our core focus. We started discussions with a client in the pharmaceutical industry and they highlighted an issue with our dayworks process, namely that it was prolonged and occasionally contained errors. The existing dayworks process was based on a manual daily worksheet requiring a Suir Engineering foreperson to record time and materials used for the works completed, and then for the client to sign the daily worksheet to confirm works were completed (see Figure 1). Once signed, the quantity surveyor would then scan and update values to the client's computerised account. This case study details the examination and improvement of this process in eliminating waste via the application of the core Lean principles: identify value, map the value stream, create flow, establish pull, and seek perfection.

Suir Engineering had no conclusive records of how long the dayworks process actually took. The improvement initiative entailed us connecting several site teams working across different sites in Ireland for the same client, to become a "Suir Engineering Network Team". Firstly, we set out to make visible the entire process for the daily worksheet journey, and the initial step was to map our current state, identify waste, improve efficiency, and adopt Lean problem solving and thinking.

SUIR

DAILY WORK SHEET

Form No

Rev.

SUIR ENGINEERING LIMITED

Unit 9A, Cleaboy Business Park, Old Kilmeaden Road, Waterford

Telephone: 051-339503 Fax: 051-305509

No. 137552

CLIENT NAME: DATE:

ADDRESS: ACTUAL DAY:

PROJECT No P: WEEK ENDING:

DESCRIPTION OF WORK	MATERIAL AND PLANT		
	Quantity	Description	Value €

LABOUR COST DETAIL — MATERIAL TOTAL €

NAME	GRADE	BASIC HOURS		O/T HOURS X 1.50		O/T HOURS X 2		
		HOURS	RATE	HOURS	RATE	HOURS	RATE	VALUE €

CLIENT ORDER No:

Signed on behalf of above named client

LABOUR TOTAL €

GRAND TOTAL €

PRINT NAME: DATE:

Figure 1. (Then) Manual Daily Worksheet (extracted sheet from dayworks book)

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

A consensus within Suir Engineering was that the dayworks process had worked for 35 years and it didn't need changing. Our challenge was to identify the lead time for the dayworks process and eliminate errors. Across several sites, we carried out quantitative surveys to establish the lead time and waiting times, and then added a layer for suggestions to identify improvements. The creation of the Suir Engineering Network Team provided the difference. Later in the project, we could prove that the data was not just restricted to the pharmaceutical sector, but rather the data came from various sectors. We wanted to improve the dayworks process not just on pharmaceutical sites but across the organisation. The dayworks survey reflected the exact timings of the process, and we used the data for our value

stream calculations. As shown in Figure 2, the current state had 10 steps in the process, consisting of a lead time (start to finish) of 17 hours 55 minutes and a process time (time spent working on task) of 34 minutes. We identified 17 hours 20 minutes of waiting time which involved waiting for signatures or looking for people.

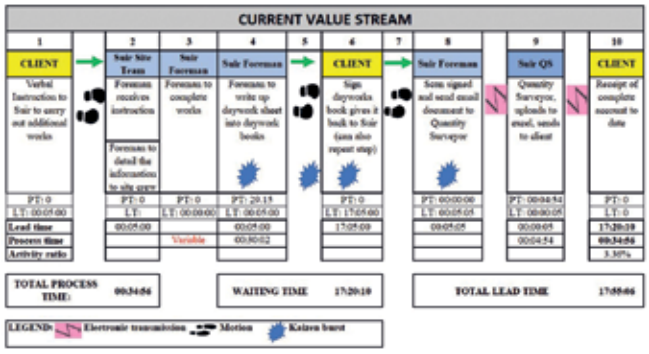


Figure 2. (Then) Current State Value Stream

Now, we could visually see the process steps and we had the data for the actual times involved. In steps four, five, six, and seven, we could target improvements and opportunities identified as Kaizen bursts (Figure 2).

Identifying Lean Waste

We highlighted areas in red under the headings: transport, inventory, motion, waiting, over-processing, over-production, defects, and skills. We used the associated acronym of TIMWOODS, and it was a great way to get the team to use it as the identification tool for waste in the processes. The team enjoyed this process and it enhanced engagement as we teased out the different types of waste. As shown in Figure 3, we defined whether the steps were value-add, necessary non-value-add, or non-value-add items.

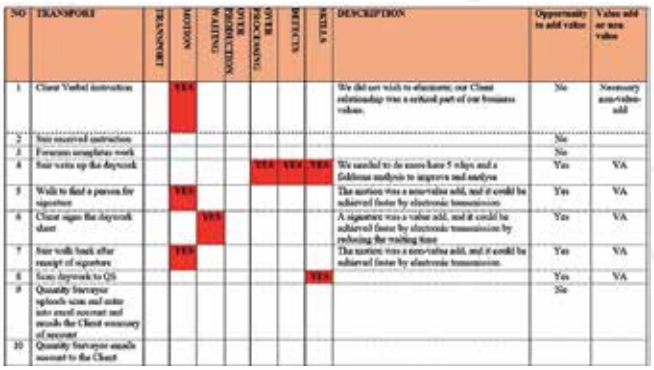


Figure 3. Identification of Waste

We crucially ensured that waste was labelled as a process and not a person, thus eliminating any finger-pointing or blame culture (see Figure 3). Physically writing up the dayworks was labour intensive and involved over-processing, defects, and non-utilisation of skills as it was later retyped. Defects were mistakes in calculations and illegible writing. Skills not utilised were using a computer to do up the calculations, the use of drop-down menus for repetitive information, and the lack of copy and paste in the manual process. The motion identified in three steps was the walking around on site trying to find the person for signatures – noting that this live site was a 33-hectare site which accumulated to a significant number of wasted miles of motion. Furthermore, specific sites are hazardous environments wherein mobile phones are not allowed and only specific personnel carry walkie-talkies. Once you leave the compound you must wear complete safety attire, and thus if you were looking for a personal signature in a cleanroom environment you had to gown up to do so. We needed to establish what we do, how long it takes, where the inefficiencies were occurring, and how could we get to our root cause. Again, with emphasis importantly placed on it being about the process and not about the person.

5 Why Analysis

The 5 Why analysis questioned why the dayworks took so long and why it happened again (see Figure 4). Following on from the standard answer of "there was no other way", we focused on the cause and effect of the problem.

Figure 4. 5 Why Analysis

Fishbone Analysis

The fishbone analysis established that we could only complete the dayworks process manually as no other method was available, thus prompting us to identify another level of the problem, namely that we had no other method available. Did we look at our environment? The project was a hazardous site. We asked if we had correct staffing and were we using the correct machinery. We always did the process the same way as there was no other method present in Suir Engineering. The analysis showed that only site and commercial staff were part of the existing process.

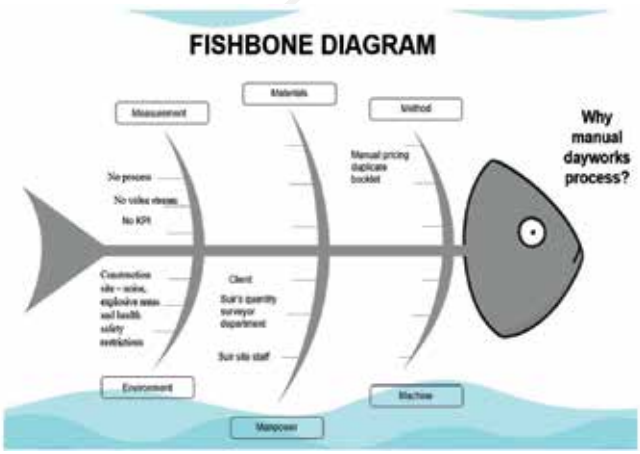


Figure 5. Fishbone Analysis

Step one was where the client initiated the contact; we did not want this step to move to an electronic request as this was instrumental

to building our client relationships. We moved to steps two and three, not identifying any improvements. In steps four to eight, we saw waste in the form of motion and over-processing. Our proposed value stream incorporated the improvement targets to eliminate waste, but we could not identify the projected lead times.

After discussions, we decided to upload an electronic dayworks sheet into Excel for a trial period of one month on numerous sites. The results would give us the data for the proposed value stream calculations. Our colleagues gave additional suggestions in the trial and research period, like, for example, identifying electronic calculations, copy facilities, and drop-down menus. This research was hugely beneficial as it provided a holistic view, and we made several adaptations following on from the suggested improvements. Our research also highlighted a significant risk to our project: could our clients view and action the electronic version? We had overlooked this initially, but the added layer of research in the trial period picked this up, which proved beneficial. We proceeded to ask this of all our clients, and they confirmed they could receive and action this through the proposed route of Adobe.

In our project charter, we had defined our project controls to eliminate scope creep. Change management was a prominent aspect of this project, and the team's knowledge of change management was an area identified for improvement. The dayworks project change from manual to electronic was a significant undertaking as the existing manual process has been in existence for over 35 years. We identified that we would likely encounter some resistance to this new way, and thus change management became critical for adapting the process improvements along the way, and we maintained this through use of the Change Kaleidoscope. Additionally, training was a significant element of this project and Management committed extra system support analysts, which proved critical for the success of this project.

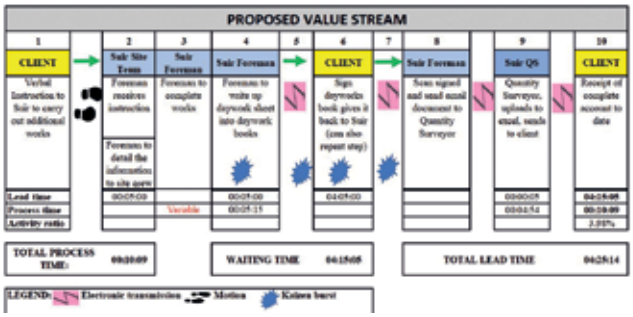


Figure 6. Proposed Value Stream

Lean Initiative Improvements & Impact

In March 2021, discussions and meetings took place over the projected metrics in this project. We projected a 70% reduction in the lead time and a 67% reduction in the process times. Management saw the potential savings for the company if reproduced on all sites. In April 2021, our proposal went to the Board of Management where it secured successful sign-off along with the budget and support to continuously improve and implement across the company.

Lessons learned included the need to present an A3 early-on in the project to highlight the potential improvements. Presenting early had a significant impact on our project as all the team members worked full-time and the project was taking too long to implement. We explained this to Management, and it became a critical turning point for us. Management assigned two system analysts to us to test, implement, and train teams quicker. We informed Management how the Suir Engineering Network Team approach had contributed to the project's success. The team focused on the Suir Way, had a diverse background, mutual respect for each other, and had fun in the process. The plan is to build more projects together as a team. Sending the presentation to Management in week six rather than week sixteen accelerated this project. Feedback from clients has been fantastic, and we have since trained two external clients personally on the system as they want to adopt this on other sites themselves.

We have already adjusted for future improvements as this is an ongoing project. Suir Engineering currently runs a system called a "T2 APP" dashboard which compiles a site's information. Management thus have a collective view of the project labour, quality, health and safety, commercial, continuous improvement, operations, and planning. With this in mind, we have since begun to move the electronic dayworks from Excel into the T2 APP dashboard. We have developed the same structure to implement this move into the T2 APP platform. At the initial meeting for the T2 APP, we were presented with several different screens to add information, and we reverted to the process which states one-screen-one-click and no multiple screens were allowed.

We also applied the 5S technique when discussing this new process: sort it, eliminate waste, standardise for company-wide use, perfect it and make it sustainable. Trials are currently running on the T2 APP dashboard, with presentations to the entire workforce planned for the end of November 2021. In preparations to roll this out across the company, we encountered an issue regarding colleagues who are not literate with computers. This issue highlighted an additional requirement for two types of training: one computerised, and one computer-aided – and our timelines on training were accordingly adjusted.

Knowing what we do, how long it takes, identifying waste, adding value, creating a pull system, improving efficiency, perfection, and problem-solving will be part of all future projects. The results for the downtime project are a significant improvement in lead times and process times, thus strengthening the Suir Way culture of the business. There has been elimination of bottlenecks in the department, flow introduced to the process, KPIs and measurements in place, waste eliminated, and risk identified. Lean tools and techniques are applied and normalised, and value-add has been achieved with the dayworks process. This is a tribute to the collegiality amongst Suir Engineering colleagues seeking to enhance value-add for the company and its clients, and is a further example of the purpose and impact of the Suir Way.

Company Overview | MODUBUILD | modubuild.net

Headquartered in Kilkenny, with regional offices across Europe, Modubuild is an engineering, design, and construction company. Modubuild provide volumetric, turnkey modular construction, to Life Science & Data Storage customers across EMEA. The company employs 400 people. Operations are underpinned by Lean, using analytics, CI, and ISO to create a positive and collaborative environment for excellence. In recognition for its commitment to excellence, Modubuild was named in Deloitte's Best Managed Companies for 2021, and in 2020 Large Pharma Project of the Year at the Pharma Industry Awards. In 2019, the company won Kilkenny employer of the year, and in 2021, MD, Kevin Brennan, was nominated for EY Entrepreneur of the Year.

Author

James Blanchfield

Overview & Background to the Lean Initiative

Change and continuous improvement (CI) can be difficult to achieve, particularly in fast-paced environments like Modubuild. This coupled with company growth can make implementation of tangible CI even more difficult to achieve. Modubuild has pivoted in recent years and is leading the way in Turnkey, Off-Site Manufacturing, and 3D Volumetric Construction. However, behind the scenes and through a successful CI campaign, Modubuild is endeavouring to improve and continue to improve its support system and processes to reflect both the company's future growth plan but also the demands of today's construction sector.

As a fast-growth company, one of the issues was that systems and process became static. As the company grew, its SOPs remained the same and in many cases did not reflect the current state; and in other cases the SOPs were essentially a redundant document that was no longer followed.

Recognising the issues and the need for CI, the team began to strip down operations to create a clear understanding of the issues. It was key that analysis was obtained of the then current state and that this was used to create an environment focused on collaborative and tangible change. The analysis needed to tell the story of the current state and highlight where the issues lay. It was prudent that data did the talking and not assumption. To achieve the required outcome, the company recruited Data Analytics Lead, Alanas Jakonis, to drive the analytic stage of the investigation.

The objective was to gather data and to graph operational performance of each department. We measured input, pinch points, failure points, communication and collaboration flow, dates, and more. A set of KPI dashboards were introduced, and the team sought to use the data to become unstuck, improve efficiency, increase collaboration, increase decision making, and improve the overall company business cycle.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

From the beginning, the team took a hybrid approach of both quantitative and qualitative data collection. To obtain a clear understanding, it was essential that the quantitative elements were underpinned by narrative that was accumulated directly from the users or inputters into the applicable process. To understand the numbers, it was imperative to understand the how and why behind them.

To begin, the Operations & Analytics team focused their attention on Modubuild's design department. This was a purposeful move as the design team had experienced significant increase in demand and personnel. Additionally, it had become apparent that the design process was an area where the company was beginning to get most stuck. Efficient and accurate design, happening in close collaboration with programming, is the first step to enable successful project procurement, mobilisation, and completion.

Overall		Total	Submitted (total)	Submitted (%)	Planned	Planned (%)	Overdue	Overdue Client	Awaiting Client	Status A (total)	Status A (%)	Status B (total)	Status B (%)	Status C (total)	Status C (%)
Overall	PAR	154	154	100.00%	153	99.35%	0	3	5	134	87.01%	3	1.95%	0	0.00%
	CAR	570	559	98.07%	432	75.79%	6	23	44	377	66.14%	13	2.28%	0	0.00%
	COCR	351	277	78.92%	350	99.72%	0	12	12	259	73.79%	10	2.85%	0	0.00%
	As-Built	452	97	21.46%	386	85.40%	290	0	0	0	0	0	0	0	0
	100's	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retrofitting	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 1. Design Workload Forecast

To tackle this, the team used various methods and techniques to obtain usable and tangible information that could be used to measure incremental improvements that could be continuously measured. Firstly, it was important that the non-design personnel understood the true process. To do this, the operations team placed themselves at the Gemba, where, using direct observation and dialogue, the design process and input was observed. Throughout this process, the operations team recorded observations and challenged, in a constructive fashion, any deviations from the SOP and any apparent wastes that were observed. Furthermore, questioning the causation for the deviation or waste created collaboration and discussion that enabled people to understand the reasoning behind the task. Direct observation has been maintained through the improvement process, and this allowed for the change process and its improvements to be noticed, celebrated, made to stick, and be further improved within the CI cycle. To categorise this stage of the data collection, it was considered as a qualitative stage.

In a further bid to gather quantitative data, the Design & Operations team collaborated with the Quality Department to undertake a root and branch review of the documentation and standard forms that were in place to support the design process. This provided a clear understanding of which documents added value and which documents did not. It also enabled the realisation that some documents created an element of duplication within the process. For instance, similar information was being inputted into separate documents for issue to different stakeholders. This enabled the creation of a streamlined design checklist and an appended folder of value-adding documentation and standard forms used to support the design process.

In an unexpected stage, and stemming from the successful outcome of the documentation review, the team completed a gap analysis on existing documentation and standard forms for completion that were contained within the process. It was noticed that some documents added value and others did not, whilst there was an opinion that some documents needed to be added. In terms of Lean, to some it may be considered wasteful or cumbersome to add more documents or forms for completion to a process; however, the introduction of the additional forms and documentation created an environment where more robust checklists, supporting documentation, and responsibility matrix dictated the process. This created less reworks, improved decision making, and subsequently enabled faster completion of the design stage.

In 2020, Modubuild introduced a new HRM system called "Timepoint". This HRM system provides a fast and automated system for management of staff lifecycle. Critically, in the context of the improvement, Timepoint gives access to useful and insightful data, dashboards, and reports regarding every aspect of a department's running costs and performance. Essentially, through measurement and recording of the workforce, Modubuild is able to monitor performance against KPIs and gather data whilst also providing greater management of budgets.

Through logging project tasks, durations, and inputs into the system, Modubuild is able to see the duration of time taken to complete each task and the design input into each task. This provides a platform for various improvements and offers many wider impacts.

It allows the finance department to monitor project staff costs accurately based on actual hours allocated as opposed to a previously used estimation of hours. It also enhances risk management and autonomous decision making as it allows the tendering team to accurately cost projects and make accurate design allowances at estimating stage. With a clear understanding of the actual input or baseline, the tendering team are empowered to accurately make assessments and decisions on design allowances for the next job. This allows for less ambiguity and commercial risk, and removes various wastes, particularly waiting in the tendering process.

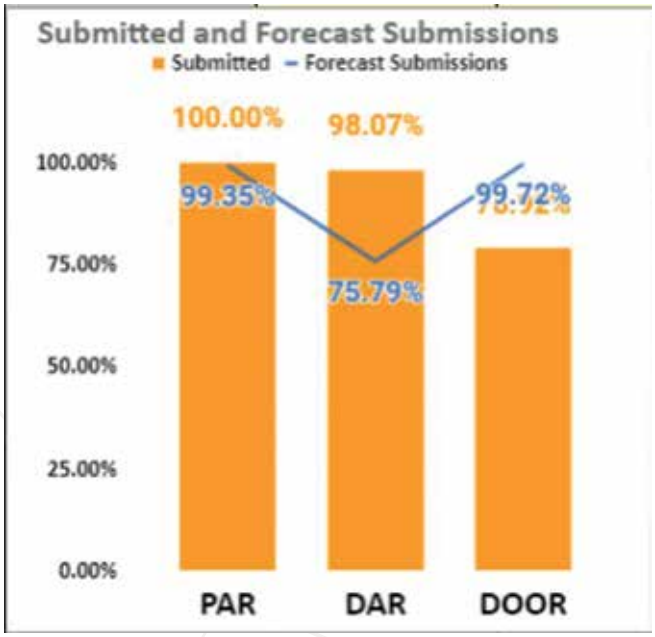


Figure 2. Submitted v Forecast

With the data collected through Timepoint, Alanis created a project design dashboard where the design and operations teams populated the dashboard with a set of key milestones, project drivers, productivity metrics, time productivity gauges, and KPIs. This included dates for specific tasks, anticipated input, typical design deliverables, estimated input hours versus actual input hours, and more. A dashboard was created for each project which ensured that the design, planning, and construction teams all had visibility of progress and a clear understanding of the key project drivers and integration into the critical path.

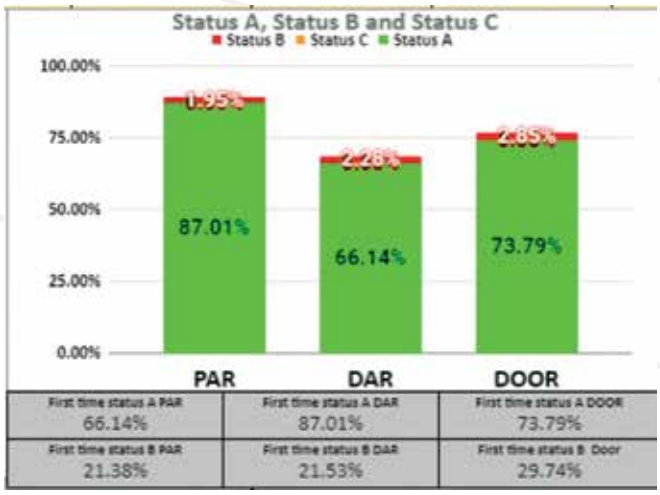


Figure 3. Submittal Right First Time Tracker

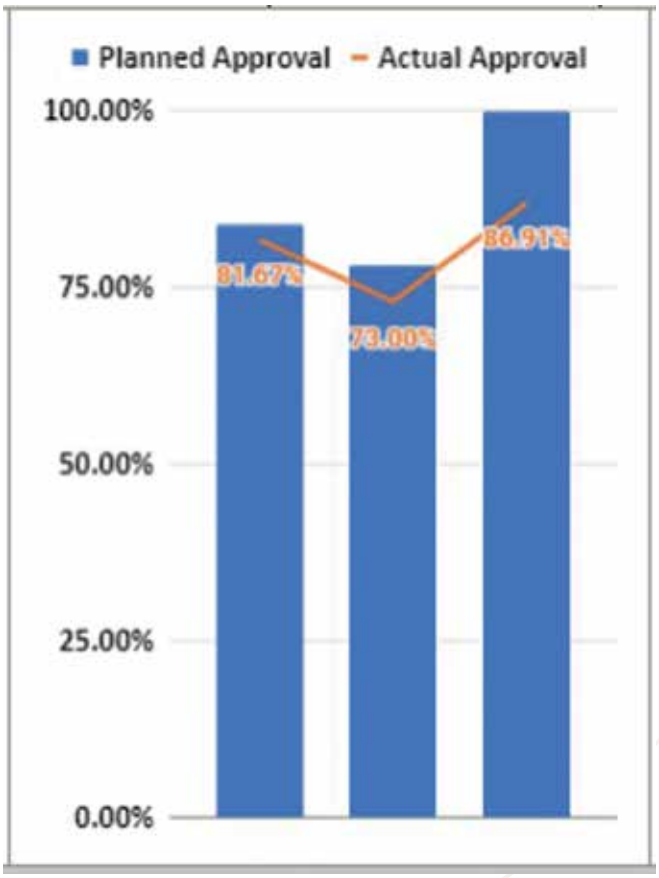


Figure 4. Forecast Approval v Actual Approvals

The next step was the integration of the dashboard into the overall project master schedule. By having a data-based metric for design, the planning team was empowered to accurately plan the design stage and subsequently provide clients with certainty and confirmation that their hand-over would not be affected by inefficient activities. Integration of the dashboard into the schedule provided a compressed overview of the project, intended and actual performance, and brought up red flags, potential pinch points, and other issues at an early stage. This allowed for energies to be focused on the right areas to find solutions to issues before they became insurmountable problems. It also provided a platform for successes, wins, and outstanding items to be recognised and celebrated.

Though the initiative is still developing, and with improvements and trial and error being applied, in the context of change management success the initiative is proving to be a success as it brings an amount of waste avoidance measures to the surface.

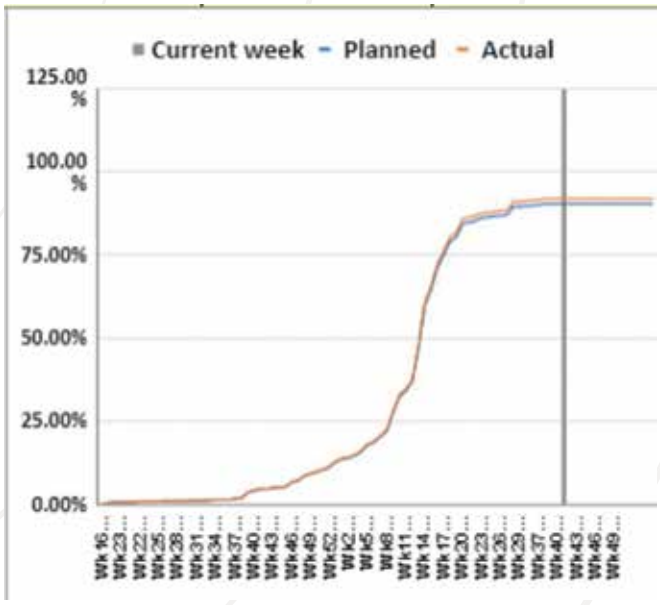


Figure 5. Overall Capacity Planned Vs. Actual

Lean Initiative Improvements & Impact

This initiative formed the basis for all tasks within the design department to be measured and tracked, with the intended outcome of enabling efficient design execution and removal of waste. As expected, it provided efficiency and accuracy within the design process, but also for the subsequent procurement stage and whilst also removing and surfacing various wastes from within the project cycle. Linking design priority and completion to key procurement dates ensured Modubuild could prioritise the design of specific design elements to integrate procurement and ensure material delivery did not affect the critical path of a project.

In an unexpected result, the big value-add for the clients was financial as it allowed Modubuild to provide accurate payment forecasting from the outset and empowered the client with certainty in cost planning.

Internally, the initiative offered significant benefit and waste reduction. Firstly, it created an environment for accurate planning and integration of the total project cycle. It helped remove siloed work patterns and isolated department planning, subsequently enabling the internal customers to be confident that each other was performing and not having any significant or negative impact on one another's activities, and thus not impacting on time milestones and project delivery. It allowed the design team to support the planning department with accurate metrics that could be used to plan and give clients full information and certainty.

It ensured that materials could only be purchased when actually needed, whilst ensuring long lead-time materials could be prioritised early. Through pull planning, the design department could prioritise design release and enable the commercial and procurement teams to order what was needed in line with lead times and schedule demand. This removed significant waste in inventory staging, thus allowing for JIT deliveries and further allowing the client to manage costs.

Additionally, it created an underpinning for the creation of a department resource planner, or resource forecaster, where future design workload could be planned months in advance based on tendered packages at a weighted probability of success. This gave the talent acquisition team latitude for forward recruitment and thus remove reactive recruitment. This was another unexpected impact as allowing for forward recruitment and on-boarding ensured that new personnel were embedded into the company culture and design process early, thus being able to understand the deliverables and expectations and not be thrown into the deep end. The success

of this in the design team has seen the data-based forward-forecast recruitment strategy be utilised across the wider business.

As a whole, the initiative is successful and it is hoped that future advances will allow for the development of further improvements within the business. Furthermore, the data being generated has created new data-based KPIs and targets for the company, with the end game of using the data to drive growth and create autonomous decision making, whilst helping to reduce waste through optimisation of inputs to maximise outputs.

MODUBUILD
LEADING THE WAY IN MODULAR CONSTRUCTION

Company Overview | CFIELD CONSTRUCTION | 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 €80m in 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.

Author

Seán O'Sullivan

Overview & Background to the Lean Initiative

CField had targeted the pharmaceutical sector as an area of the construction sector that we wanted to increase our presence in and to grow and develop our business whilst adding diversity to the company at the same time. CField had successfully completed several small-scale pharmaceutical projects in the past, and in May 2019 CField was successful in the tender process and awarded the contract for a new production building for a Multinational Pharmaceutical Company within their existing live plant. This was the first large-scale contract for us that included the full Civil Structural & Architectural (CSA), Mechanical, Electrical and Process (MEP) scope of works as project supervisor construction stage (PSCS). This project is circa €40m capital investment for the client, and a huge stepping-stone opportunity for CField to progress within the pharmaceutical sector.

We have significant CSA experience, and there was a strong degree of confidence with that scope of work; however, the project management and execution of the MEP scope were risk areas that needed to be mitigated. Awareness of these risks to the project is where our Lean initiative began.

Problem Statement
CField have not previously delivered and project managed a full CSA and MEP scope for a pharmaceutical project of this scale.

Goal Statement
Deliver the project on time, budget and Quality

S	M	A	R	T
Specific	Measurable	Attainable	Realistic	Timely
Development project mgt tools and techniques to successfully deliver the project	Programme planned v actual Cash flow planned v actual Voice of the customer	Within our power to achieve this. Personnel experience, knowledge and commitment	CField team buy in and sub-contractor engagement	During the course of the project

Figure 1. Problem Statement, Goal Statement, SMART Goals

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Within our team, we had identified the key personnel with individual knowledge and experiences to execute the project on time, on budget, and deliver quality. The task to be undertaken was to capture the experience and knowledge to create the end-to-end process to successfully deliver this project. Whilst we had a very comprehensive quality management system (QMS), this project required a high level of project management tools and techniques to be developed and incorporated into our QMS. The success of the project largely depended on these project management tools and team buy-in and ability to implement them during the different stages of the project. The following is a list of the primary project management processes we developed and implemented.

Master Programme – MS Project

This is now a common tool in the construction industry, but for this project the challenge was to create an integrated master programme to incorporate the CSA and MEP contractor scopes of work in the desired timeframe. The MEP contractors were novated and developed separate programmes at tender stage based on unencumbered access to the building from which they built their man-hours and preliminaries. We facilitated workshops between key personnel from CSA and MEP contractors to coordinate a fully integrated programme to deliver the project within the agreed contracted timeframe for all parties. The initial stage was to build trust and start to work together as a team. By creating the programme together, all disciplines were fully bought-into the delivery sequence and had a high-level view of the delivery plan, resource requirements, and the interdependencies of other trades.

Last Planner System (LPS)

LPS was tailored to suit our project and client requirements. This was where we mapped out the day-to-day and room-by-room work activities for site works. All sub-contractors populated the LPS spreadsheet to identify their proposed tasks, number of resources, location, and duration. All sub-contractor plans were then compiled into one document and reviewed collectively to ensure

that tasks could proceed and that work was aligned with the master programme. The combined plan was then reviewed with the sub-contractors and shared with them for full transparency. Our weekly traffic management plan was generated from the agreed last planner and shared with the site-wide team for the following week. As part of this planning process, we conducted weekly 6-week look-ahead master programme reviews so as to plan ahead for upcoming work and to trigger the requirement for any information or long lead-time equipment and materials, like, for example, drawings, specifications, samples, and queries.

Daily Coordination Meeting

Every morning we held a work coordination meeting to review planned work from the previous day and to resolve any roadblocks that might cause a delay going forward. This is aligned with the LPS planned progress, and it proved to be the essential communication platform to quickly update progress. This was a short meeting lasting approx. 15 minutes, and all sub-contractors, the design team, and the client attended and worked together to maintain progress.

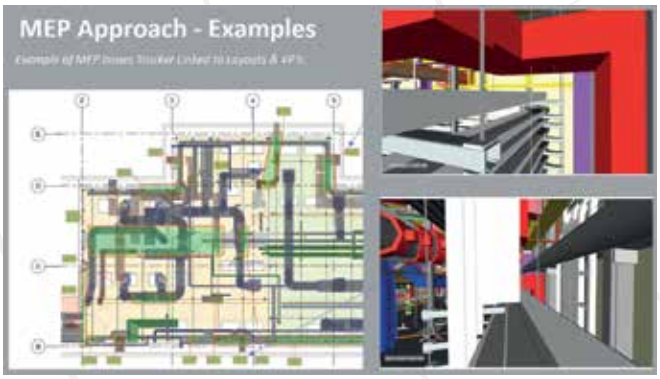


Figure 2. MEP Approach to Clash Detection

Model Review & Clash Detection

For the MEP works, the BIM model was used as the primary source for all details, setting-out, and general construction. Pre-commencement, and during the MEP works, we facilitated model reviews and clash detection workshops to further develop the model and identify clashes on the model before they became an issue on site. All clashes were recorded on a tracker sheet, and assigned owners and close-out dates. This process also involved the client, design team, and all contractors.

Commissioning, Qualification, Validation (CQV) – White Tag, Green Tag, Blue Tag

This process was developed to track progress from start to finish, and to get MEP systems available (turned-over) for the client within the planned timeframe, meet quality requirements, and guarantee minimum punches for the final client walk-down.

Systems Completion Schedule

Upon completion of mechanical and electrical first fix (bulk

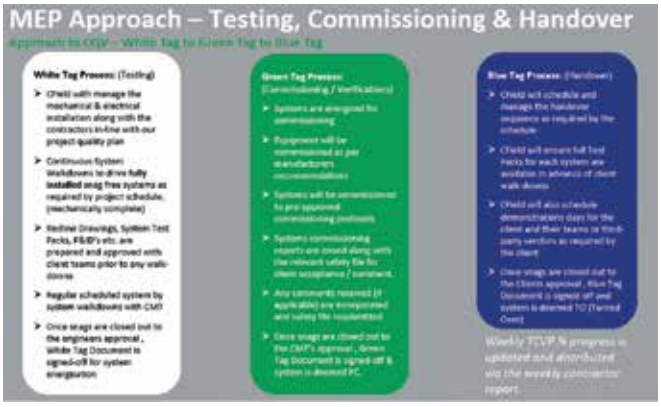


Figure 3. MEP Approach to CQV

install), the programme changed focus from meters of pipe and valves installed to systems percentage complete. This was driven by the client's requirements and the need to prioritise certain systems. This was developed in the master programme and further broken down in the systems completion schedule to plan walk-downs and punches. It includes scheduling each of the following for every system from each trade:

- White tag system walk-down between Sub-Contractor and Main Contractor.
- Generate, issue, and close punches.
- Green tag system walk-down between Main Contractor and M&E Consultant.
- Generate, issue, and close punches.
- Blue tag system walk-down between Main Contractor and M&E Consultant and Client.
- Generate, issue, and close punches.

Note that all punches are given an owner and planned close-out date that are tracked to completion.

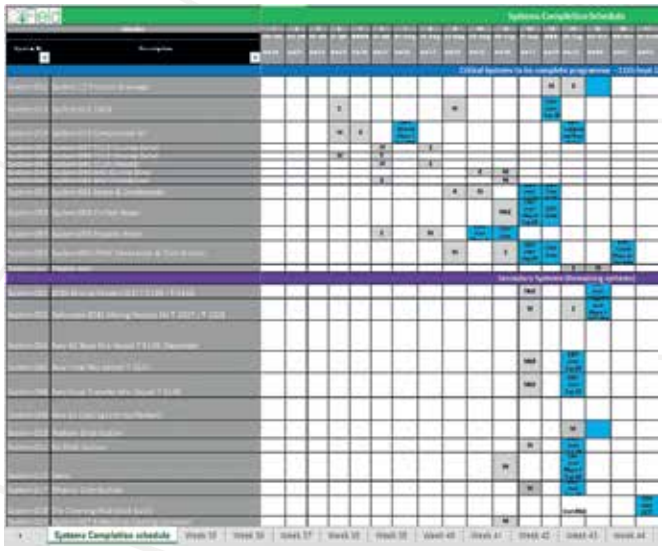


Figure 4. Systems Completion Schedule

Lean Initiative Improvements & Impact

Time

This project was time critical as we were constructing a production facility and the key driver was our commitment to our client to facilitate their product to market. We delivered on that commitment and that was largely due to the Lean tools and processes we developed and implemented. In this case study, our newly-developed

project management techniques enabled us collect and collate data on MEP project work. This empowers us to set KPIs and norms for similar future projects. The impact is that this gives greater assurance and confidence in our capability as CField PSCS team to deliver MEP projects on time. We have also developed a new suite of Lean project management tools that can be shared across the business to better manage complex projects. It is worth noting that this project implemented all CIF Covid-19 requirements as they were rolled out and as we collaborated with the client to meet their key programme milestones.

Quality

Our trackers and punch list were able to identify trends in quality issues at an early stage. This allowed us to further develop our inspection test plans (ITPs) and hand-over packs to quickly reduce punches and get the work right first time. The following processes were introduced on site:

- Project quality plan.
- Product samples for approval.
- Workmanship samples for approval.
- Drawings submittals for approval.
- First of kind samples submitted for approval.
- Material data sheets for approval.
- BCAR ancillary certs for quality workmanship.
- BCAR hand-over file.

These provided the client with enhanced transparency and understanding of what the product would look like, as well as clarity for our team that we were proceeding with approval.

Costs

Managing cost is a critical component of the project delivery, and in particular during the Covid pandemic which was unprecedented for everyone involved in the project. We worked closely with the client and design team to mitigate and design-out problems that presented by following the sequence below which was developed through Lean thinking:

- Using our 6-week look-ahead programme to identify needs and wants in a timely manner.
- Offer value engineering solutions to mitigate scope changes.
- Issue cost estimates for early warning on variations.
- Open book approach for additional cost.
- Weekly cost review meeting.
- No additional work proceeded without client instruction.

Health and Safety

Health and Safety is always a key deliverable for CField on every project, and this project was no exception. Our target as PSCS was to deliver the project with no lost time incident and work to CField's motto of "Plan Safe, Work Safe, Home Safe". As the project progressed, we collaborated with all the design team, sub-contractors, and client to implement a safe and practical workplace with a particular focus on the option of the trades in the field. Coordination and information sharing was key as we discovered early on, and we categorised areas, identified problems, and developed solutions to lead to Lean improvements (see Figure 5).

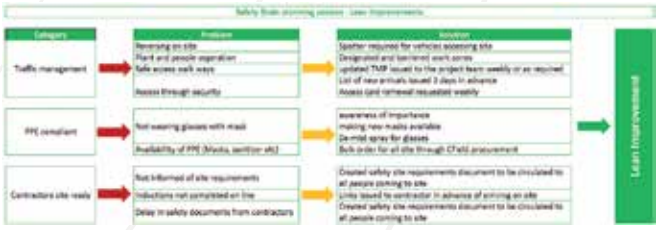


Figure 5. Safety Brainstorming Session – Lean Improvements

During the project, we held daily site briefings with safety input, weekly site safety meetings with sub-contractors and stakeholders, monthly meetings with the client steering group, and put in place an effective and actionable SOR system to listen to the voice of the workforce. Everyone on site was impowered to stop un-safe work activity.

Whilst on the face of it one might think that all these safety processes would cost time, the reality is that they greatly assisted in having no downtime due to incidents or accidents, and they facilitated good planning and provided clear understanding of site requirements.

Company Overview | DPS ATG | 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. Our sector expertise spans many markets, including Biotechnology, Pharmaceutical, Medical Technologies, Oil and Gas, Advanced Technology, Food & Beverage, Energy, Science & Education. 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 1,800 people worldwide.

Author

Richard Casey

Overview & Background to the Lean Initiative

This case study examines how process and value stream mapping can be utilised to optimise the hand-offs and quality checks required for an Off-Site Manufacturing (OSM) workflow. DPS Applied Technology Group (ATG) was engaged to design and develop the required structure to manage the OSM of a portion of a large client program. While the client wished to move to an OSM process, the changes required and the implications of the transition were not fully understood. DPS ATG worked closely with the client to determine the steps involved and the changes required to the client's existing systems and structures to implement the OSM process.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Whilst OSM is a move towards the implementation of a manufacturing-based system to improve construction productivity, the change in project infrastructures required to enable OSM can also be optimised by the implementation of Lean principles.

DPS utilised a number of key Lean techniques to enable the development of an OSM structure for a large client. This case study outlines the main principles considered in developing the program and the Lean thinking and techniques utilised for its optimisation.

Development of an OSM Framework

In the initial stages of developing an OSM framework, a number of considerations must be taken into account when setting up an OSM process for construction projects, including:

- Identification of OSM opportunities.
- Ability for trades to meet the OSM requirements.
- The establishment of a new framework for the project.
- Establishment of new standard operating procedures (SOPs).

It was determined that the DMAIC process could be utilised as the best methodology for the development of the OSM framework.

Define

While OSM can be applied in many stages across a project, one of the first determinations needs to be the establishment of what sections of the projects can be moved off-site, how much of the project can realistically be manufactured in a OSM environment, and what are the most value-adding OSM activities for the client.

It was decided to complete an OSM review with the client, coupled with a brainstorming session to determine the most value-add opportunities. A number of standard industry-recognised OSM definitions were drawn up, and the following categories were identified:

- Pre-Assembled Unit (PAU) – Unit fully designed and delivered to site for hook up.
- Supplier Package Unit (SPU) – An SPU designed and supplied by a supplier and delivered pre-assembled to the maximum extent possible. This often includes on-board automation allowing off-site FAT.
- Supplier Assembled Unit (SAU) – An SAU is a unit in which a supplier's normal scope of work is extended.
- Pre-Assembled Rack (PAR) – A PAR would be designed by the design contractor and comprise a pipe rack complete with piping, valves, cable trays, access walkways, tracing, insulation, and painting where applicable.
- Pre-Assembled Structure (PAS) – A complex structural assembly with a high weight-to-volume ratio and a large number of connections is designed, and it can often be more economically fabricated away from the project site.
- Rooms Module Unit (RMU) – An RMU is where rooms or suites of rooms are modularised as Pods. Typically, they should include all Mechanical & Electrical and Life Safety Systems that can be tied in at the site.

- Specialist Unit Design (SUDs) – The off-site fabrication of singular or specialist units for installation on site.
- Speciality Installation Designs (SIDs) – Repeatable units of multiple designs that can be fabricated elsewhere and provided to the trades-clients for installation.

Utilising these definitions as a guide, DPS completed a brainstorming session with the client and established a number of areas where OSM opportunities lay and the ease of implementation. A road-map of opportunities was identified (see Figure 1 blurred for confidentiality reasons).

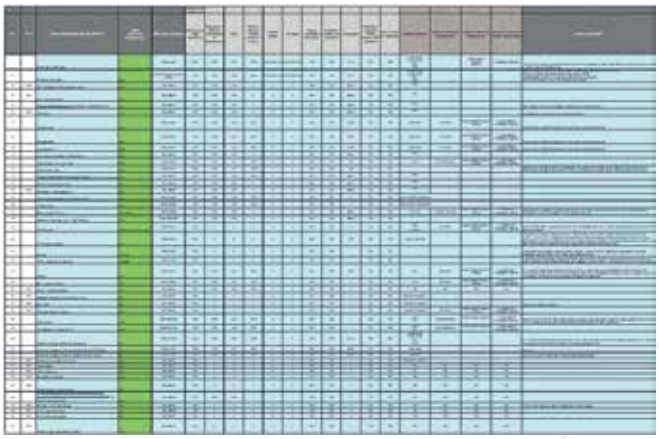


Figure 1. OSM Opportunities

The highest areas of return for the upcoming projects were identified as:

- Pre-Assembled Racks – A significant meterage of piping could be assembled off-site and installed en-masse in a matter of days.
- Pre-Assembled Culvert – For pipe transfer across the public roadway.
- MCC/CSR Rooms – These could be assembled internationally, shipped to Ireland, and road transferred to a local panel builder.
- Utility Panels – Pre-manufactured and consisted of assembled utility and service connections (piping and valves), sockets, and data.
- Mobile Vessels – Assembled off-site as complete skids, including panels.
- CIP Skids – Assembled off-site as complete skids, including panels.
- Waste Skid – Assembled off-site as a complete skid, including pumps, panels, and valves.
- LPHW Skid – Assembled off-site as a complete skid.

A current state analysis was carried out and it was determined that up to 22% of overhead could be transferred to OSM facilities and up to 42,000 hours of productivity could be gained. The first stage-gate of the framework development was passed as OSM was deemed to be viable and had an achievable return on investment.

Measure

The second stage-gate was to determine if the client's existing supply chain had the manufacturing capability to provide this service to the client. DPS compiled a CBA process to measure the capability of a number of trades within the local and international market. A total of 50 suppliers were measured against the CBA process, with five domestic trades and 15 international trades meeting or exceeding the criteria. DPS worked closely with the client's preferred suppliers to assess their capability and develop improvement plans for the preferred supplier listing.

Analyse

The next stage was to establish a new framework to allow the supply chain to understand how and where they fitted into the new OSM process. This was a significant change to the existing and established processes used historically on the projects. DPS developed a high-level value stream map (VSM) with the client and suppliers to determine the main hand-offs and pinch points.

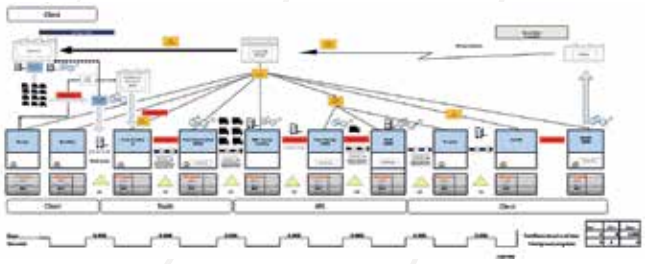


Figure 2. High-Level Value Stream Map

The VSM was utilised to establish the main owners, hand-overs, QAQC requirements, lead times, and integration points. This process was completed with all opportunities identified during the define stage and with all suppliers within the value chain.

The output of the VSM project was the generation of a RACI document to ensure clear and concise ownership of each hand-off with the corresponding deliverables and metric for success. A list of areas where new processes and procedures were required were identified by the team and summarised under the following headings:

- Schedule Integration.
- Design and BIM Optimisation.
- Materials Management.
- 4PL and Rigging.
- Trade Facility Optimisation.
- Storage Requirements.
- Transfer and Hand-offs.
- Site Installation.
- Quality Management.
- Performance Management.
- Continuous Improvement.

At this stage, teams were identified to determine if there were areas within the OSM VSM that could be improved.

Improve

The OSM implementation team utilised the VSM findings to determine areas for improvement for the overall process. All areas outlined in the Analyse phase required improvement projects to establish best known method (BKM) for OSM implementation. Sub-teams were formed to determine the best methods for the development of the OSM capability.

One example was the analysis of the existing design process to determine what items could be transferred into SIDs. The design

sub-team established a roadmap of items to focus on a developed process for the incremental development of design changes.

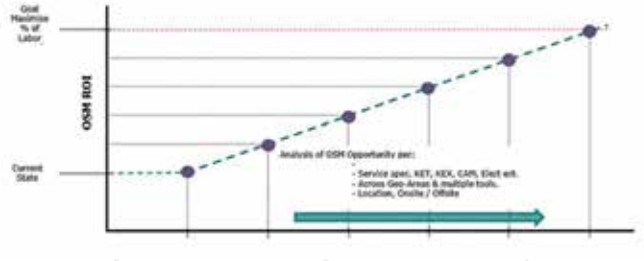


Figure 3. OSM M&E Progression Roadmap

Another example of a high-risk area identified by the process was the delivery and management of multiple specialist materials to the trades manufacturing facilities.

A sub-team was also formed to optimise the 4PL process and to establish the:

- Implementation of a singular 4PL process for management and transport of material.
- Optimisation of a singular QAQC process for traceability of issues.
- Implementation of a singular storage facility establishment of a Supermarket and JIT delivery system.

Similar improvement processes were established for all other key areas identified for the VSM process.

Control

DPS compiled a number of improvement standardisation workshops to ensure roles and responsibilities, deliverables, and work methods could be aligned between the trade capability, the client's

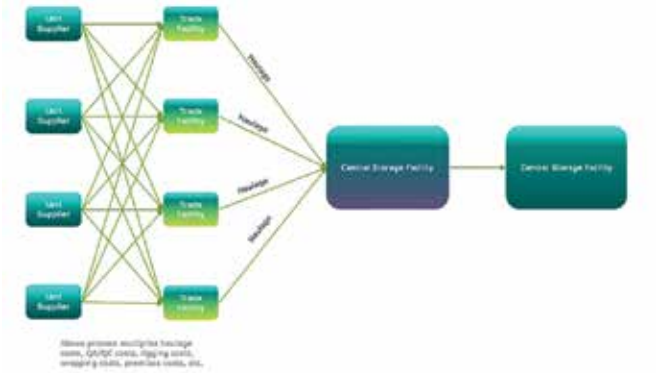


Figure 4. OSM Material Supermarket

requirements, and the project needs.

This resulted in the development of OSM-specific documentation consisting of:

- Standard Work Documentation: Containing detailed definition of the current best practices for performing an activity or process.
- Standard Operating Procedures: Step-by-step instructions compiled by the team to ensure the repeatability of the OSM module builds.
- Visual Management Processes: The implementation of a tracking system to indicate where in the process flow the OSM module was.
- Huddle Meetings: To track progress and correct issues as they arose.
- Kanban: For the delivery of the completed items to the site.

Approximately 150 documents were generated (not Lean in itself and DPS continues to work on improving this) for the establishment of the baseline requirements for the OSM framework.

Lean Initiative Improvements & Impact

Summary

In construction, the transfer of works to OSM is itself considered an implementation of Lean practices into the construction industry. While this is a step in the right direction, to improve construction productivity it must be comprehended that this is a significant change in some sectors of the construction industry.

What this case study has shown is that Lean processes and systems can be used in the development of an OSM framework for the client and their supply chain that can help with a transition from historical practices to more productive processes that can improve the overall delivery of projects.

The initial target on the project was to identify OSM opportunities to remove 22% of overhead from the project site that could be transferred from the project site to the OSM facilities with the corresponding productivity gain of up to 42,000 hours of productivity. The actual gains were 31% of OH moved to OSM activities while >60,000 hours of productivity were gained. As a consequence of developing the OSM framework for one project, DPS ATG was able to apply a similar process to a second project focusing on the OSM of a singular scope of work. This project is now in flow and results will be published in Q1 of 2022.

The significant Lean improvement and impact of this case study was the successful demonstration of Lean thinking and techniques in the establishment of a framework for change. While many Lean initiatives in construction focus on tactical solutions of issues occurring during the project, this case study showed how VSM could be utilised in a strategic development process to optimise a flow before the project begins.

The utilisation of the VSM process led to the identification of many bottlenecks within the new OSM supply chain. Supply chain logistics, QAQC checks, and the throughput of the Trade Manufacturing facilities needed to be added as KPIs to the delivery of the project. This also identified many areas where continuous improvements could be made. The manufacturing structure and capability of the supply chain now needed to be considered, the hand-offs between stakeholders needed to be optimised, the material supply chain needed to be reviewed, and the roles and responsibilities of each of the stakeholders agreed – and whilst the framework is established,

there is always room for ongoing improvement.

Next Steps

As projects become more complex, and time to market puts additional pressure on schedules, OSM will transition the construction industry closer and closer to a manufacturing industry. DPS believe that many opportunities exist within all sectors of construction to transition towards OSM and therefore reduce traditional site-based impacts such as weather and quality delays.

As an industry, the transition to OSM in construction will require the implementation of Lean processes and systems, and this can lay the foundation of a sustainable industry where modules can be manufactured and transferred globally from facilities in Ireland.

DPS is currently in the process of reviewing its OSM implementation framework to enable organisations to complete a current state analysis review to determine where they need to focus on and make changes before their next project starts. The key takeaway is that proactive planning utilising Lean thinking and techniques can lead to significant improvement on projects.

DPS Better Engineered Solutions

Company Overview | CLANCY | clancy.ie

Our origins date back to 1947, and with history comes experience. We use this 70+ years and over 1400 projects completed to date to deliver a service that truly reflects our clients' particular needs. We have 5 core values which we believe are critical to our success and every decision we make is based on our core values, which are: Safety, Professionalism, Quality, Commitment, and Teamwork/ Collaboration. We carry out a variety of project types, including: Residential, Industrial & Commercial, Healthcare, Conservation & Restoration, Fit-Out, Education, and Fast Track/Off Site Construction.

We currently have an extensive portfolio of projects with our most recent projects for the HSE an example of where we used our experience and our own design and build model to construct two 24 bed isolation wards in a 14 week period to assist with the country's fight against Covid. Investment and implementation in areas such as staff training, technology, and Lean Construction have propelled Clancy forward and given the company the platform to be one of the leading contractors in the country.

Author

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Overview & Background to the Lean Initiative

Lean thinking, tools, and techniques have been introduced to the Clancy team over the last number of years. This transformation happened gradually at first, with waste reduction the key focus initially, and it has now expanded to where it is generating its own momentum.

This case study looks at the refinement of Lean practices within Clancy and the current journey being undertaken as a strategic project to standardise the Clancy Last Planner® System (LPS) across the company. LPS is a system for planning and production control designed to deliver highly reliable work flow and rapid learning. It is a system that encourages collaboration on projects, versus the traditional method of working in silos, and it results in improved project delivery to meet client requirements.

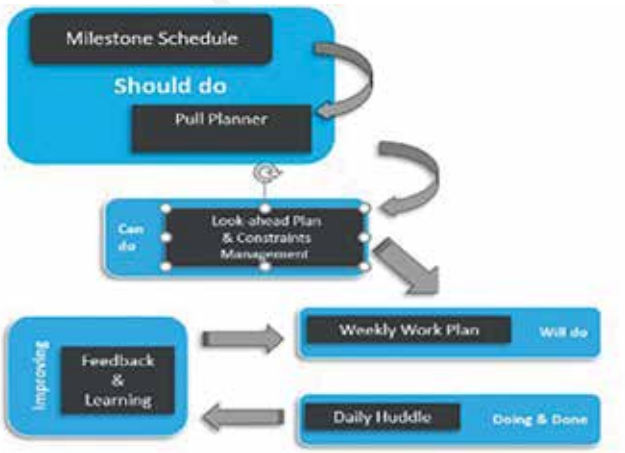

Figure 1. Key LPS Processes

There are six key processes in the LPS:

1. Master (Milestone) Scheduling.
2. Phase (Pull) Planning.
3. Look-Ahead Planning and Constraint Management.
4. Weekly Work Planning.
5. Daily Huddle.
6. Continuous Improvement.

This study outlines Clancy's strategic change management approach to the systematic deployment of LPS across the company. Recognising that standard work is foundational in Lean deployment, this LPS standardisation was undertaken as a strategic initiative by senior leaders who invested time and funding for: (a) training by an external Lean service provider on the six key LPS processes; (b) workshops to create agreed standards of execution that best suit the company's needs; and (c) execution of trials at project level to enable the senior team to coach the process in the future and before full deployment.

Aim

The overarching aim was to ensure our client requirements were met in collaboration with our stakeholders by reducing the variability within project delivery. At a more detailed level, the following aims were in scope:

- Client: Assist our teams with meeting project KPIs and company goals.
- Project Delivery: Create a more predictable construction programme and successful hand-over with a reduction in defects and snags.
- Standard: Implement the Clancy LPS universally across all project teams.
- Metrics: Improve analysis of the weekly work plan to gain valuable trends and data.
- Efficiency: Improve efficiencies for implementing the system and efficiencies for our site teams such as time management, removal of firefighting techniques, and reductions in waste.
- Education: Educate and improve the leadership buy-in and implementation via training and workshops.
- Collaboration: Enable a collaborative working team on each project.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

LPS was first introduced to Clancy personnel in 2016 whilst working on a large-scale project. Being very much engaged with the process being implemented on this project, our people could see the real benefits resulting from using the system for project delivery. Those early adopters have continued to utilise LPS principles on various projects since then, yielding many benefits such as improved schedule adherence, improved communication, and collaboration across project teams. Mainly due to this success, these practices have been spread informally to pockets of the organisation since that initial experience.

Clancy senior management identified a strategic opportunity to standardise LPS deployment across the company to further reap the benefits of a uniformly-applied system on all projects. This will result in improved competitiveness through more reliable programs, improved team collaboration, and enhanced communication, thus enabling further growth in the business. Furthermore, as communication and collaboration are core values for the company, any improvements in these behaviours are viewed as vital to the success of all projects.

Strategic Team and Objectives

The company appointed two Directors as program sponsors and a Contracts Manager as leader of the initiative with responsibility to guide the development to a successful conclusion. This team recognised early on that key to the LPS development strategy was sourcing an industry-recognised consultancy to provide clear and expert direction, not just on the tools but also on the approach for effective change management. Crystal Lean Solutions (CLS) were identified as the best fit to work with the Clancy team, and the deliverables set out in partnership with CLS were to:

i. Develop an LPS standard to meet the company's construction requirements through collaboration with all the Contracts Managers.
ii. Complete LPS training with Contracts Managers.
iii. Develop a roll-out plan for deployment across the company, including engagement with Project Managers and Site Managers.

Potential risks were identified in both engagement with the change, and having time to work on the change. These were viewed as medium risk as there was a high level of communication and engagement with the senior team built into the plan, including:

- Explaining the why and following up to ensure the messaging landed well. Utilising the Kotter Model for communication and feedback, including quick wins (complete external audits to see if baseline is maintained).
- Focus on the Kotter Model and monthly follow up meetings with CLS and the Steering Group (monthly communication to all staff).

Baseline of Current Process

So as to create a baseline for LPS maturity within our organisation, one of our leading LPS project processes was assessed by CLS against the LCI LPS Maturity Model, which resulted in a score of 2.9 out of 5. Both Pull Planning and Weekly Planning were identified as good, and there were opportunities for the project team to improve around look-ahead planning, constraints management, and using metrics to improve project performance. This could be achieved through additional training and tweaks to the existing system.

The assessment highlighted that, albeit the project team was performing very well and implementing the system to the best of their ability, as a company there was an opportunity to improve our techniques and also educate our teams further to instil LPS best practices both on this project and across the company.

Key Milestones

Following on from that initial baseline assessment, actions and milestones were agreed in order to achieve the target deliverables, including:

- Complete program charter and change management plan.
- Lean Construction training (namely "LCi Lean Pass") with Management completing this introductory course, including Value to Customer, 8 Wastes, and 5S housekeeping.
- Communication and Engagement. A workshop was run involving the program team and the contracts managers in the proposed approach and soliciting feedback on same.
- Complete LPS introductory training with the core team. This was a high-level overview putting the system in context and explaining the overall intent of the system. This set up a series of training workshops for the individual processes.
- Complete pull plan training with the core team and run a workshop to agree a pull plan standard.
- Complete look-ahead and constraints management training with the core team and run a workshop to agree a look-ahead and constraints standard.
- Complete WWP and daily huddle training and run a workshop to agree a WWP and daily huddle standard.
- Complete two standardisation workshops with contracts managers.
- Trial on site.
- Final workshop with senior management to agree the LPS standard.
- Agree roll-out plan of the standard.
- Implement a process to sustain LPS into the future.

Lean Initiative Improvements & Impact

The undertaking of this Lean initiative has been of great value to date for the company as we now have an agreed LPS benchmark that suits our company's core values. The process has yielded many advancements to the processes we had begun to roll out. Moreover, the process has generated consensus amongst the leadership team about how the system should be deployed and has increased the overall knowledge of Lean practices within the business. The workshops to date with senior management, project sponsors, and CLS have generated an overall agreed LPS system which will ensure the following areas are met.

LPS Standard for Clancy

- The LPS standard will be universal across all project teams going forward.
- There is a training manual to support new employees using the standard in the future.
- A company champion is in place to ensure engagement with, and education about, LPS is upheld going forward.

Sustaining the LPS Standard

- LPS maturity will be audited externally to monitor and continually benchmark the approach used. This will enable sharing of best practices going forward.

Project Performance Metrics to Drive Continuous Improvement

- Improved analysis of the executed fortnightly programme which can now gather PPC, reasons for variance, and constraints to aid project teams manage their sites.
- An agreed company constraints log which will aid senior management review live projects and the constraints that site teams are finding. This is invaluable to the successful running of the business.
- Data collection and analysis of information managed on our projects has furthermore been developed with an investment in Procore. Gaining real time analytics from inspections, checklists, and snags is again an enhancement to our LPS journey. This can be used to review across all projects and help senior management identify trends.

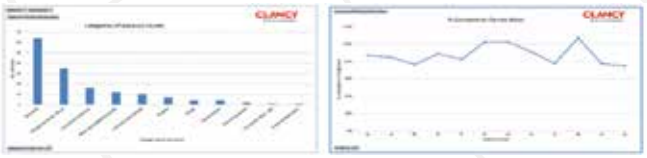

Figure 2. Analysis from our Clancy Weekly Work Plans

Daily and Weekly Visual Management of Project Delivery

- Improvements to our site LPS constraints board will aid our site teams work through common constraints and allow them to look-ahead in a more systematic way that is universal to all sites.
- Improvements to our daily white board will ensure we get the maximum value from this daily activity and ensure site teams are completing the tasks as set out in the weekly work plan.

Figure 3. Clancy Last Planner Constraints Board

Leadership Coaching Capability

- Education of senior management in order to guide site team implementation of the LPS standard within the company. This will be backed up by the LPS champion within Clancy, along with CLS as required.
- Roadmap for training of middle management now that the benchmark Clancy LPS has been set, and using CLS to ensure that dedicated training is completed.

Improved Efficiencies

- Improved time efficiencies in carrying out the fortnightly programme for our last planners with an estimated time reduction of over 1.5 hours each week per site manager.
- The removal of additional meetings from site team agendas to free up more time within each working week.

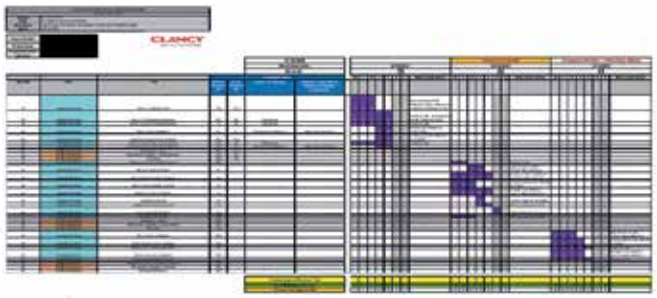

Figure 4. Clancy Fortnightly Programme (including look back)

Overall Senior Team Feedback

During the workshop process over recent months, the LPS standards were trialled across all sites to agree the benchmark. From feedback, this process showed each site team that collaboration between site teams and the last planners was a very successful way to manage projects and instil a strong team working environment. Below are some of the comments received back from the senior team to describe the work completed to date and looking forward to the implementation and continuous improvement stages that lay ahead:

- "The workshops and training to date have greatly enhanced the level and consistency of our service offering across all spectrums and is at the core of our pursuit of a better way."
- "The LPS is transforming Clancy's approach on how we engage, collaborate, and deliver projects."
- "It will enable us to form an inspired, harmonious team early in the initiation stage across all disciplines, and set the expectations, demands, and responsibilities transparently from the outset."
- "These workshop sessions have helped to mould the process into a common operating environment that can be used throughout the organisation, on any of our worksites, by any of our construction management teams. I'm really looking forward to the next steps."

This feedback was furthermore confirmed by means of external audits carried out during the implementation trial period by CLS who noted considerable uptake with the benchmark LPS and were confident that the system implementation would be a success overall.

Company Overview | COLLEN CONSTRUCTION | collen.com

Collen Construction is a family-owned company, with a history dating back over 200 years and a reputation for building quality and excellence. The firm is an international construction company with operations in Ireland, Germany, and Sweden. Collen is currently ranked in the top 5 main building contractors in Ireland, and has experience in private and public-sector projects, as design and build contractor, management contractor, and joint venture partner. The company's portfolio includes commercial office fit-outs, data centres, life sciences, industrial warehousing, retail, and conservation and refurbishment projects, ranging in value from under €1 million up to €700 million.

Privately owned by seven generations of the Collen family, and founded over 200 years ago, Collen Construction is supported on a firm foundation of experience, knowledge, commitment, and pride in its achievements. The company's success and expansion over the last decade is due to committed team members and highly-qualified management and technical staff. The management teams operate in partnership with client representatives, design consultants, and subcontractors to ensure delivery of projects to the highest standards on time and within budget.

Author

Willie Loughnane

Overview & Background to the Lean Initiative

The culture of continuous improvement within our day-to-day operations at Collen Construction means that our organisation continuously strives to exceed our clients' expectations through the adoption of new and innovative Lean practices. The successful delivery of large, complex builds depends largely on the rigorous and systematic approach to scheduling – a tactic that Collen embraces from project initiation stage right through to project hand-over. This culture empowers our project delivery teams to challenge the status quo and make the best plans even better.

At Collen, we believe that collaboration is a fundamental tool for problem solving, and the partnership approach that we adopt with our subcontractors supports a working environment of trust and transparency to get to the right solutions fast. Our decision in Q4 of 2020 to invest heavily in Snychro 4D meant we could make further enhancements to our planning processes, taking us and our supply chain to the next step with immediate improvements across safety, quality, productivity, and efficiency. The 4D planning allows us to combine our 3D models with the project schedule, thus enhancing the way we visualise project information in comparison to Gantt charts that, for certain types of projects, cannot provide a complete view of all interactions and sequences of activities.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Over the past five-year period, Collen has successfully completed a number of fast-track, hyperscale data centres across Europe. These projects are complex in nature and require an exceptional level of detailed planning across multiple engineering disciplines. The schedules associated with these projects have become more and more demanding, forcing us as an organisation to look beyond the traditional methods of construction scheduling and leverage the latest software and digital tools to support a leaner and more efficient way of planning our projects. Furthermore, our clients' business needs often hinge around schedule certainty, thus pushing us to find an effective solution to creating more accurate programmes that ultimately minimise the risk of delays to the typical mission-critical milestones associated with data centre delivery.

Over the years, Collen has embedded a very effective platform for collaborative planning across all projects in the form of weekly last planner sessions. Our commitment to the Kaizen philosophy means that we are constantly in pursuit of operational excellence, striving to find possible areas of improvement to further enhance our Lean Construction tools and techniques. As useful as these sessions are for validating and enhancing the project schedule, we found it increasingly difficult to get a complete view of all subcontractor interactions and sequence of activities. We also needed a tool that could enable better communication between the various parties and therefore reduce any misunderstandings from the start. Progress monitoring too in terms of schedule and cost can oftentimes become extremely challenging on these hyperscale projects; and truly understanding our actual progress versus our planned progress on site involves a significant amount of administrative work across multiple team members on a weekly basis. Furthermore, creating an environment of certainty and transparency underpinned our partnership approach to project delivery and any improvement in schedule reporting was fully supported by all stakeholders. Also, the proper coordination of multiple contractors in the field is a critical factor in site safety and the implementation of 4D scheduling for logistics planning was going to be a convincing step forward to a safer work site.

In Autumn 2020, Collen took the decision to strategically invest in Synchro, a 4D software platform that would ultimately deliver a more consistent and concise means of scheduling on our projects.

During this period, we worked closely with our clients to develop a 4D Scheduling specification that would meet the needs of all stakeholders, from our subcontractor partners right through to the end user. After some market analysis, it quickly became apparent that the Synchro software had the following critical capabilities to meet our needs.

Model to Schedule Linkage

- The Software had to be able to establish links between the modelled elements and the scheduled tasks.
- The links between the modelled elements and their associated scheduled tasks had to be persistent over the course of the model, schedule updates, and revisions.
- The methods of updating and linking had to be incorporated into the overall workflow to minimise the resources required and maximise throughput and transparency to authorised stakeholders.

Model Imports and Updates

- The 4D software had to be able to read, store, coordinate, and update multiple files from the various design teams and GC models.

Free Viewer Application

- Access to the 4D model had to be available to all stakeholders without the need for additional licencing. A freely-available viewer that could easily be downloaded and installed was the preferred choice.
- This application had to have review and mark-up as well as reporting functions available, including the ability to save, print, and export as required.

Figure 1. Benefits of 4D

During these early stages of evaluation, we could immediately anticipate the benefits that 4D could bring to multiple facets of project delivery, from design development right through to the project hand-over phase.

Lean Initiative Improvements & Impact

Once the decision to adopt 4D was made, we immediately set about an implementation plan to ensure a smooth on-boarding of the software and upskilling the members of our BIM and Planning departments over a three-month target period. At this particular time, we had just secured the contract for a 50MW Data Centre in the Nordics region, which proved to be an ideal opportunity to fully leverage the benefits of 4D planning.

Logistics Planning

During the initial phases of this project, it became clear that a number of logistical challenges existed between the extensive underground infrastructure scope and the parallel task of steel frame installation works. The nature of these fast-track projects involves the mobilisation of large quantities of plant and materials to specific work zones and laydown areas which cause significant congestion and workflow delays if not planned ahead in detail. The implementation of 4D scheduling allowed us to look ahead in great detail and visualise the work fronts weeks in advance in order to optimise and streamline the workflows between the groundworks contractor and the steel and cladding contractors. Laydown areas for steel and crane set-up locations, for example, were agreed weeks in advance at our weekly last planner sessions where our 4D planner stepped through the various scenarios and options available in the field with the relevant subcontractors. Rather than presenting the construction teams with lengthy schedules and detailed Gantt charts, we could now present an immersive 4D model that could be navigated and manipulated on demand. Within these collaborative settings, we could see the natural tendency for the subcontractor supervisors to rely on these visual outputs, prompting a more active involvement in schedule development and coordination resolution. From the outset, we were laying the foundations of successful project delivery and providing the support to all project members to get it right first time.

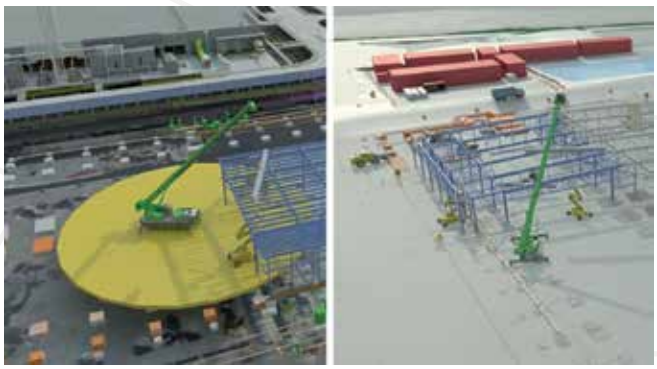

Figure 2. Logistics Planning in Steelwork & Groundworks Coordination

Most importantly, we found that our 4D planning initiative has helped improve project safety performance by instilling a collaborative approach to problem solving amongst all stakeholders. On a weekly basis, we were actively identifying high risk activities (HRAs) prior to and throughout the construction process. Teams are now equipped to implement preventative measures to avoid incidents and accidents well in advance. Fundamentally, we can now further support our supply chain partners in carrying out more detailed risk assessments and ensure that all tasks can be fully executed in the safest possible manner.

Planned Vs Actual

As part of our weekly reporting mandate, we have now incorporated a Planned Vs Actual Visualisation procedure whereby our 4D Planner along with the Project Manager produces a graphical representation of actual construction progress versus the progress that should have been achieved in accordance with the baseline schedule. All stakeholders can quickly assess if the project is on schedule or not. Critical areas can also be filtered in isolation to truly evaluate the schedule performance of the critical path tasks. During the construction phase of data centres, early access to critical white space areas is often a key milestone for our clients and progress monitoring of these specific areas can be enhanced through 4D modelling. This offers real-time transparency as the traditional methods of progress reporting through detailed Gantt charts can sometimes be confusing and misinterpreted. If required, mitigation measures are easier to develop as 4D offers a platform that can promote collective problem solving and helps unlock the range of experience and expertise within our delivery teams to drive more predictability into the schedule.

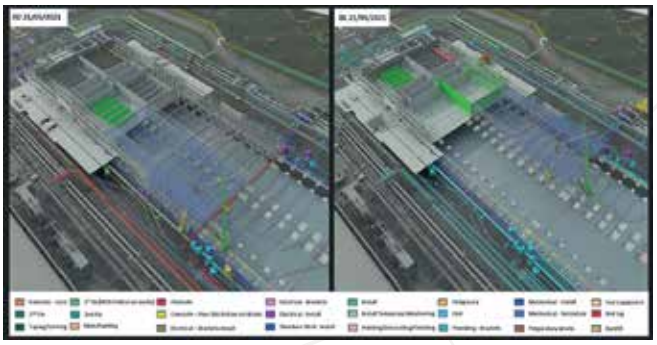

Figure 3. Planned Vs Actual Progress

Scenario Planning & Clash Detection

Fast-track scheduling can bring enormous challenges, especially at the CSA and MEP fit-out interfaces where an over-reliance on field coordination can lead to costly rework and schedule delays. On our data centre projects, the plant yards typically consist of multiple AHUs and generators that are accessed and serviced via extensive steel gantries and walkways. At the project initiation stage, we ran several scenario animations using the Synchro software to determine the most suitable means and sequence for the equipment, steel, and cabling installation in these critical work zones. This rigorous front-end planning proved to be extremely beneficial in the long-run, leading to a schedule performance improvement of 30% within these critical work fronts. This right first time approach has led to less fire-fighting in the field, thus increasing morale and confidence for those at the coalface. Validation of access routes for the mobilisation of AHUs to their final position also proved to be an extremely useful exercise. Taking the time to animate such construction activities allowed us to highlight the potential clashes in advance and determine the optimum amount of containment and cabling that could be installed before the AHUs were guided through a maze of pre-installed equipment and associated infrastructure.

At Collen, the implementation of 4D allows our project teams to create more realistic programmes and break down any miscommunication between what is planned and what is actually executed. We believe that high-quality BIM-based design and staff training is a worthwhile investment that will provide significant benefits throughout the project lifecycle. BIM and 4D planning is not a trend, but a way of working that is here to stay.

Company Overview | MODUBUILD | modubuild.net

Headquartered in Kilkenny, with regional offices across Europe, Modubuild is an engineering, design, and construction company. Modubuild provide volumetric, turnkey modular construction, to Life Science & Data Storage customers across EMEA. The company employs 400 people. Operations are underpinned by Lean, using analytics, CI, and ISO to create a positive and collaborative environment for excellence. In recognition for its commitment to excellence, Modubuild was named in Deloitte's Best Managed Companies for 2021, and in 2020 Large Pharma Project of the Year at the Pharma Industry Awards. In 2019, the company won Kilkenny employer of the year, and in 2021, MD, Kevin Brennan, was nominated for EY Entrepreneur of the Year.

Author

Drené Venter

Overview & Background to the Lean Initiative

In smaller companies, rapid business growth and the increased demand in services often results in the company being outgrown by their systems and the number of trained experts available to deliver the same quality of work over all business areas. As part of Modubuild's Continuous Improvement campaign, we implemented a new Continuous Learning and Development division under Human Resources. The main objective of this division is to ensure that employees are kept to industry standards, grow along with the company, and realise the benefit of investing in themselves. Implementing continuous learning systems within your company equips employees to confidently deliver fast-paced and qualitative work, provides the ability to adapt to change and ensure readily trained staff across all business areas.

To kick-off this initiative, Modubuild's Talent Experience Specialist, Ciara O'Dwyer, initiated a training gap-analysis. An anonymous individual survey was conducted throughout the entire team, followed by departmental discussions with line-managers and some employees. The survey identified critical training areas which should be prioritised, whereafter the Continuous Learning System will be implemented.

It is important to note that continuous learning and development is not only limited to tangible knowledge, but also includes mental, emotional, and soft skill training programs. We believe that training the mind and wellbeing of our employees will bear the fruit of intrinsically motivated, confident personnel who convey a contagious positive atmosphere, again leading to a constructive working environment.

Ultimately, the continuous improvement campaign coupled with the learning and development initiative, strive to create a team that subconsciously function on the Lean thinking principles. We want to optimise Modubuild as a whole by eliminating internal waste, develop knowledgeable employees, build quality into our systems, be able to deliver fast-paced work while managing flow, defer responsibilities with confidence, and, finally, be able to create a culture of mutual respect throughout the whole business.

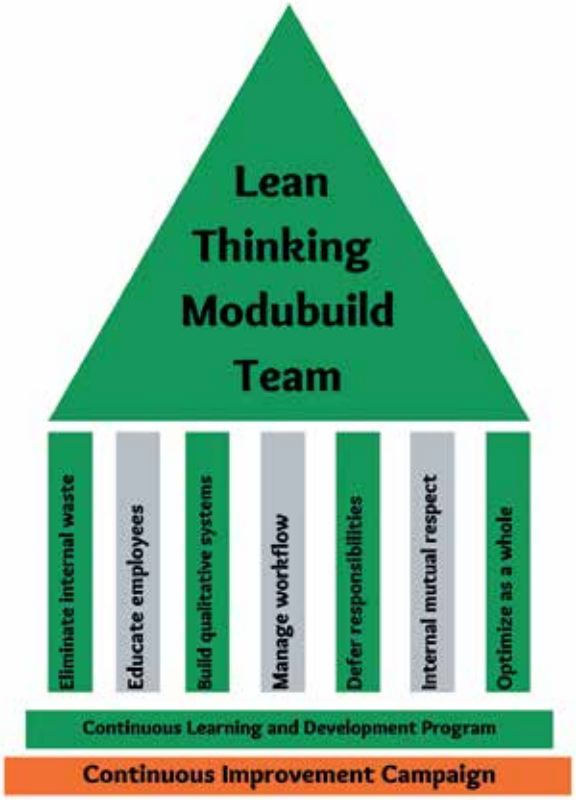

Figure 1. Learning and Development Program within the CI Campaign

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

In a rapidly growing company striving to keep up with demand and systems, employee training is often overlooked as a means to maintain a healthy and stable company culture. As part of Modubuild's continuous improvement campaign, we are in the early

stages of implementing a continuous learning and development program. Given that we are presently (as at October 2021) between the Plan and Do stages of the PDCA cycle, and some advantages can already be seen within the team, we look forward to seeing future advancements.

As with any new strategic approach, proper analysis and planning are key attributes to effective implementation thereof. During our employee feedback survey, the training gaps identified within the different departments will enable us to implement a continuous learning system, and paramount to this is to first address the current critical training needs within each department. Within the departmental meetings with the line-managers and their teams, these critical training needs were identified and are currently being addressed. Table 1 captures the key training themes and sub-themes identified within the company.

Key Themes	Sub Themes
HSE	First aid, defibrillator training, mental health first aid, stress management
Project/Construction Management	Project management & construction management courses, Planning (P6)
IT Skills	Excel, cyber security, troubleshooting, G Suite
Communication	All areas of communication training
Design	REVIT, BIM, Dynamo, Navisworks
Leadership and Management Skills	Change Management
Site skills/tickets	Setting out, Forklift license, MEWP training, appointed person training, telehandler
Commercial Awareness	Contractual knowledge, dispute resolution, managing project budgets

Table 1. Key Training Themes & Sub-Themes

Following more feedback from the employee survey, together with the high number of newly employed staff, a proper in-house induction program is indispensable as well as the surety that all new employees have the proper basic training to complete their new role. For example, a Safe Pass course is done by personnel that would be required to work on/visit a construction site. Operatives are equipped with the required abrasive wheels or slinger training, or forklift training, for example, and those who will be using Navisworks (design software), undergo the necessary training to enable them to properly navigate the software. Whilst good, Figures 2 and 3 illustrate that there remain opportunities for improvement within our induction program.

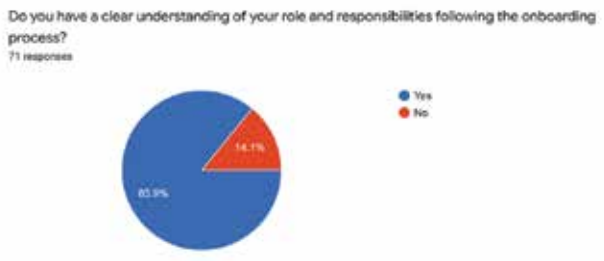

Figure 2. Results of Employee Responsibility Comprehension Post-Induction

Our immediate action plan is the implementation of a comprehensive interactive induction program which covers the essential training required within the departments. This will familiarise the employee with the standard operating procedures (SOPs) as well as the documentation and policies that will be used within their day-

Figure 3. Results of Employee Comprehension of Organisational Objectives Post-Induction

to-day duties. The current critical training will be scheduled, including those employees whose competency certificates are due to expire and this will then be followed by the initialisation of our continuous learning program.

Due to the diverse nature of our geographical locations, some of our new employees will start remotely and thus the induction consists of either an office-based or web-based session with our Learning and Development Coordinator guiding the employees through the key operating procedures. The second part consists of an interactive slideshow taking employees through a series of slides, video tutorials, policy documentation, and safety training to complete in their own time. This removes additional labour hours from the program and ensures all new employees understand the business operating model whilst remaining knowledgeable about their new environment. A "Quality Time Session" is also arranged with the new employees and their line-managers to conduct an informal conversation, which would allow them to feel welcome and comfortable in the department. This session is also used to review and understand their specific job description and confirm their exact roles and responsibilities on which the essential training will be based. Implementation of this revised induction plan ensures that all new employees are equipped with the required training for their role, are knowledgeable about their environment, and fully understand what is expected of them.

Starting November 2021, we are kicking off our continuous learning and development initiative with a series of lunchtime learning in which daily short informative lessons are screened online across the company. The topics covered will include the areas identified in the training needs analysis, most of which include one of the major organisational categories of Kaizen. This way we show employees that we listen and act on their needs and gain trust in the learning initiative whilst motivating them to invest time in their own development, coupled with embedding Lean thinking principles without imposing. The learning month's primary objective is to inspire employees to broaden their general knowledge of their field of expertise in their own time. We will follow that month with more internal training on company culture, leadership, processes implementation, productivity, quality, safety, and technology.

As with any new initiative, some concerns surfaced, including that often some employees are resistant to change or new initiatives and can only be motivated after some trust is won. Another concern identified is the amount of talent we have within departments that is not directly linked to their role description and which is not being fully utilised. Keeping in mind that we want to ultimately achieve all Lean principles through our organisation, an opportunity was identified to work with departments to improve systems and processes

within the departments, together with enhancing interactions and communications between departments. That way, trust is gained between employees in different departments by means of open communication lines within the workplace, building relationships outside of the formal work-based environment, and by building a culture of working not only for the company, but for one another as well.

During the process of working with the departments, an additional focus point will be to identify talent which employees have beyond their day-to-day scope of work that might be valuable to the company, combined with the opportunity to identify learning requirements and aspirations of the employees. Although we have only started this process with one department, the possibility of what we will be able to do within departments by extracting non- or under-utilised skills is exciting for the future of Modubuild's internal systems and teamwork across the different departments.

Modubuild also started a Manufacturing Technician Apprenticeship Program this year with two apprentices, and we hope to take in 20 apprentices by the end of 2022. Once again, this program strives to deliver graduates that are already familiar with Modubuild's company culture in addition to being readily trained in the manufacturing roles we will require them to step into.

These are just some of the current strategies being actioned. While most are only at the initiation stage, we are hoping that these will lead to a whole new way of approaching the implementation of Lean within Modubuild.

Lean Initiative Improvements & Impact

As stated, this initiative is only at the beginning stages and we hope to have it fully up and running at the beginning of 2022. The impact cannot yet be determined; however, going back to our main objective, we want to embed Lean thinking into all new and existing employees. When you have properly trained staff who are confident in their work, the outcome is low risk and high-quality work being delivered at a fast pace.

Our foundation phase will be branched by a few other strategies in early-2022. A different area of concern we identified is that, with the growing number of projects we now run simultaneously, we are often stuck with a single person with the required expert knowledge to complete a specific task/job. To address this, we will set up a Mentorship Program within the company wherein senior staff will be shadowed once a week for an hour, along with sessions in which they will sit down and carry over some of their knowledge and skills to someone else within their department. Reverting to the fact that a lot of employees are not currently being used to their full potential, we trust that this again will aid in utilising our internal resources and skillsets more effectively. We also aim to partner with further education and training providers to host/attend group training sessions as a company/department, contributing to the overall company culture throughout all departments.

With the number of employees currently employed by Modubuild, we are still managing to capture training and keep track of expiration dates manually; however, with employee numbers growing exponentially, we are looking to automate our training system by means of software called "Mango". Implementing Mango will reduce both the labour hours and human risk factor of capturing and inducting training. Mango will also help us to further automate our Induction Program as well as other in-house training initiatives that we may wish to undertake.

Finally, Modubuild plan to implement a Chartership Support Program, where we support our personnel with the paperwork and training they require to obtain the correct amount of CPD (Continuing Professional Development) points to ultimately register and maintain chartership at the different professional bodies.

Although having different departments is an important aspect for a company, we have found ourselves operating in departmental silos the last while. However, we are hopeful that by working through these strategies, we will also create better internal communication channels between the departments, leading to operating more as a team rather than several different departmental teams.

Figure 4. Team Modubuild Operations

In conclusion, we expect that the effective implementation of continuous learning and development programs will result in a leaner and more streamlined workforce. We are hopeful to create employees who operate Lean thinking principles daily, and we as a team look forward to operating under one umbrella with improved internal systems and communications achieved by implementing these strategies.

MODUBUILD
LEADING THE WAY IN MODULAR CONSTRUCTION

Company Overview | JOHN PAUL CONSTRUCTION | johnpaul.ie

John Paul Construction is a leading international construction specialist with expertise across all sectors, including Data Centres, Pharma/Life Sciences, Industrial, Healthcare, Commercial & Retail, Fit-out, Residential & Student Accommodation, Tourism & Leisure, Public, Transport, Energy/Renewables, and Civil Infrastructure.

We are more than just Contractors. We make things happen for the right reasons in the right way and pride ourselves on being good people to do business with. We make a point of understanding our Clients' business requirements and applying our considerable expertise to satisfy their needs effectively and efficiently. The pursuit of excellence is the heartbeat of our organisation and our people are constantly looking at ways to improve our performance. We believe in collaboration and all-party alignment as the best way of achieving maximum results for our Clients, and this approach to project delivery is built around our core ethos of teamwork, respect, and trust. With more than 70 years' experience across all sectors of the construction industry, our success is built on an uncompromising dedication to quality and service. We put our Clients' interests first, providing a level of service that enables them to concentrate on their business in the knowledge that their project is in safe hands. One of our key strengths is our ability to forge strong partnerships and long-lasting relationships across clients, professionals, and supply chain. We are owner-driven and passionate about our work, with a hands-on collaborative approach and genuine commitment to delivering value and excellence in everything we do. Construction is all about people and performance, and our people are skilled and highly trained with the experience and ability to deliver the most complex and challenging projects within demanding project deadlines and meticulous quality standards.

Author

Michael Kelly

Author

Eamon Walsh

Overview & Background to the Lean Initiative

As John Paul Construction continues to grow and expand as a business, how we deliver our projects continues to evolve and improve, and we continuously seek new and innovative ways to deliver our Clients' projects. As the pressure on project timelines continues, the need for effective and efficient initiatives for managing programmes and short-term planning is ever greater. With this need in mind, John Paul Construction has continued to expand on its Lean initiatives developed over the last number of years.

Our initial Lean initiative was introduced in 2017 with the use of the Last Planner® System (LPS) across several projects. This proved hugely successful and aided in the delivery of some key projects for the company. On the back of this success, the increased use of LPS was promoted and adopted with additional training for site personnel and LPS champions were appointed across the company to drive the process into all our projects. Over the course of 2020 and 2021, we have expanded the use of LPS to over 75% of our current live projects, with all new projects utilising the system from the outset.

In addition to the expanded use of LPS, other Lean initiatives were introduced across the company such as 5S and Overall Equipment Effectiveness (OEE). These were not just used on projects but across all departments of the business such as accounts, HR, safety, quality, IT, and tendering. These areas implemented the 5S model aiming to continuously improve how departments are run, with OEE looking at the effectiveness of not just the equipment but the personnel also. This worked well in line with the adjustment phase that Covid-19 was already creating and led to significant reduction in waste and improvement in standards across each department.

Figure 1. Lean Initiative Planning

On the project side, this case study focuses on how our Lean Initiatives, and LPS in particular, led to the successful delivery of a high-capacity and fast-track Data Centre to the Client's requirements.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Project Overview

The project involved the construction of a new 2-Storey, 28,000m2, 36 MW data centre, along with a full M&E fit-out delivered to a fast-track programme over12 phases. The initial phase of the project was delivered with zero defects and handed-off at IST with zero commissioning tickets.

Key Features

- Full M&E fit-out including top-down construction of all critical M&E elements using a racking system. Combination of hard wire and busduct power distribution system with back-up diesel generators and UPS 10 min battery autonomy.
- Full BMS & EPMS system.
- CRAC and AHU installations with humidified water system (adiabatic cooling) and complex diesel fuel distribution system.
- Traditional concrete pad foundation with structural steel columns and beams along with the installation of FM2 floors.
- Complex integration of services and utility infrastructure.
- Fit-out of highly finished administration block, along with landscaping, hard standings, roadways, and paths.
- High-specification security fencing and red wall system.

Within John Paul Construction, our Mission Critical Department heads up key projects in the industrial and data centre sectors of the business. It uses a core group of highly experienced personnel, with a track record of managing and delivering fast-track projects for some of our largest Clients. This 36MW Data Centre, with full site infrastructure, was one of the projects delivered by that Mission Critical Team. The project was completed in 43 calendar weeks from commencement on site to hand-over to the client.

From the outset, LPS was used to manage the short-term planning and ensure the flow of work on the project was maintained and unconstrained. As this system was new to several of the John Paul team, plus numerous subcontractors, introductory sessions and walkthroughs were completed, ensuring the team got up to speed quickly. There was excellent buy-in from the subcontractors to LPS as they could quickly see the benefit of having the plan in front of them and any constraints being closed-out to give them a clear flow of work.

Figure 2. Last Planner Meeting

Due to the scale of the project, LPS was implemented in a twin approach with separate pull plans prepared for the civil works and the building works. The project managers for each section worked with the subcontractors to generate the initial pull plan and agree the key milestones for each section. Crossover points between the building and civil works were managed through regular communication between the team leaders. The implementation of regular meetings and huddles to facilitate the pull plans, weekly planning sessions, and daily huddles was a challenge; however, with continued support, all members of the team ensured that the system was bedded-in over a period of time, thus enabling a successful outcome on the project.

The system was broken into a number of steps to give everyone a clear understanding of what is involved in each step.

Step 1 – Pull Plan Sessions

- Key milestones were identified for the pending 6-8 weeks and issued to the full site team to allow everyone prepare information for the Pull Plan Sessions.
- Pull Plan Sessions took place every 3-4 weeks with new trains and milestones pulled as the project progressed.
- The session involved all the relevant John Paul Construction team, including site managers, engineers, project managers, and M&E coordinators, plus all the relevant subcontractor supervisors.
- Initially, workshops were completed using virtual MS Teams meetings due to Covid-19 restrictions but were then completed in-person in a large external marquee to facilitate adequate social distancing.
- Activities were pulled from the milestone back, thus creating trains or flows of work.
- Any constraints were logged, a person assigned to close-out, and a need-by date identified.

Step 2 – Weekly Work Plans (WWP)

- Ahead of the Weekly Coordination Meeting (WCM), WWPs were submitted by the subcontractors outlining their intended work for the upcoming week.
- This would be in line with the Pull Plans, with more detail on required resources and work fronts.
- These were coordinated into a Master WWP document ahead of the WCM.

Step 3 – Weekly Coordination Meetings

- These weekly meetings took place on the same day and same time every week for 1 hour only.
- Pull Plans were reviewed along with any overdue or new constraints.
- The previous week's performance against the WWP was reviewed.
- The upcoming weeks WWPs would be reviewed, coordinated, and agreed.

Step 4 – Daily Huddle

- Daily huddles took place every day for 10-15 minutes to discuss the planned works for the day.
- Any new constraints were discussed, and, if required, recovery plans put in place.

Step 5 – Tracking Variance

- From the WCM, the performance of the week's progress was tracked.
- Regular causes of variance could then be reviewed and appropriate action taken.

Throughout the project, several risks and challenges were encountered. Early in the project, unforeseeable ground condition issues were encountered across a large portion of the building footprint. Working with the client in an open and collaborative manner, we reviewed the problems and generated a ground stabilisation solution that could be employed on the site. As part of the solution presented, a detailed pull plan had been prepared to generate a revised sequence and programme of works. This revised sequence allowed the project to hit its original project completion date, and, following approval of the solution, we utilised LPS to plan and monitor on-site progress to ensure the key milestones were achieved.

Our previous experience on the Lidl Regional Distribution Centre, where we provided an engineered D&B ground treatment solution to provide a suitable platform upon which to build the warehouse, proved invaluable to this process.

Following the initial earthworks element of the project, the next critical phase was to construct multiple reinforced concrete cores to allow the main structural steel frame tie into these cores. From initial scheduling of the works, it appeared there would be a significant out of sequence element of work to the structural steel frame. This is where the LPS became invaluable. Through our pull plan sessions and engagement with the subcontractors, the RC contractor committed to improving the programme dates. As a result, significant time was saved on the completion of the RC cores, thus allowing the structural steel frame to be completed in the correct sequence and saving significant time later in the schedule.

As the project progressed, each new subcontractor was incorporated into LPS with up to 15 different contractors involved during the peak of the project. Due to the fast-track nature of the project, communication was critical between all parties to ensure successful delivery of the project. This was evident in the pull plan sessions wherein each contractor was identifying potential constraints to the works as the plans were being developed. Constraints could take the form of missing information, open RFIs, resource issues, material issues, variations/design changes, scheduling issues, or clashes with access to areas. In certain instances, design issues were beginning to impact the progress of certain areas of the project. In this case, design team members were invited to review the constraints log from the pull plan sessions to aid in resolving constraints on the spot rather than going through the full RFI process. Eliminating the interface of an RFI and getting the designer, who normally wouldn't engage in planning sessions on the project, to assist in closing constraints which were impacting the flow of work proved invaluable at key stages during the project. In addition to logging future potential constraints, previous constraints were recorded and trends identified so that measures could be put in place to mitigate any risk of reoccurrence.

Following the WCM, updated plans were printed and displayed in the main planning meeting room along with being issued to all contractors. With the plans clearly displayed, the likes of site managers, foremen, and engineers could each review and track works on a day-to-day basis, checking off tasks that were completed or identifying tasks that were delayed.

The Master Weekly Work Plan data was collected every week and used to generate the Percent Planned Complete (PPC), which is the measure of the actual completed activities against the planned activities in a given week. Each week it became clear where constraints were impacting the PPC, which allowed the team to act and prevent further slippage. A simple example of this is where a subcontractor was underperforming on site and the follow-on trades were impacted. The PPC and the data collected would show the requirement for additional resources which could then be communicated to the subcontractor allowing them to better plan their resources and upcoming works. This type of data review and feedback was useful throughout the project, with communication between John Paul Construction, the subcontractors, and the design team key to success.

Additional Tools Deployed to Deliver the Lean Approach

- Viewpoint – The entire project team used Viewpoint as a Common Data Environment (CDE) for the sharing and dissemination of all information and project records, with bespoke workflows established from the beginning of the project for technical submittal approval processes, benchmarking process, and the tracking of RFIs. This ensured fast-track production could proceed on a large scale with a clear understanding of acceptable standards and performance metrics.
- Fieldview – This is a cloud-based and offline mobile solution that replaces pen and paper in the field, and it was used by the entire team for inspections, including: safety inspections, quality observations (both good and bad), BCAR inspections, snagging, technical queries, benchmarking, and sample approvals to track and close-out issues as they arose. Having single portals for tracking actions and sourcing information proved vital to the delivery of such a large-scale fast-track project.
- BIM – John Paul Construction employed several digital tools to manage the different aspects of the project. The fully integrated, coordinated, and up-to-date BIM model allowed the site team to accurately set-out all elements from the model, to generate live as-built records, and to use tablet applications such as Dalux Viewer to compare virtual views of the planned installation against actual completed works.

Lean Initiative Improvements & Impact

The communication and shared team goals generated by LPS proved vital to achieving the project milestones. Setting up and implementing LPS was challenging due to the scale, fast-track nature, and the number of contractors involved. This was a large culture change for several contractors, including members of the John Paul Construction team who were used to a more traditional method

of planning works. However, it was clear to see that, once LPS was embedded into the mindset of everyone involved, it quickly became a powerful tool to drive the project in the right direction.

Not only did it improve the project programme and give certainty on delivering milestones, it improved quality, cost control, and health and safety. Feedback from the contractors involved in LPS was positive, with many mentioning that, by having detailed plans ahead of time, they were able to line up resources with certainty that they would be starting works on the dates in the plans. This ensured that everyone bought-into the plans, with contractors knowing how their element of work was going to affect the follow-on trades if not delivered on time.

LPS gave a flow to the project with synergies between civil teams, building teams, and M&E teams key to delivering the project on time and on budget. Contractors' supervisors became the schedulers, planning in detail their works and the works of their colleagues around them, thus creating predictable workflows. Communication was continuous throughout, with the many challenges of such a fast-track project overcome through proper team planning, coordination, and driving for the same shared goal.

Looking Forward

As John Paul Construction continues to grow, the use of Lean tools and techniques to improve our project delivery will be key. As mentioned, LPS will continue to be implemented on all new projects with over 75% of our live projects currently utilising LPS. As well as this, continued development of our BIM and digital departments will benefit how we deliver projects across all sectors. Continued upskilling of staff to better understand the benefits of these advanced analytic methods and technologies will be vital, as well as generating a proactive culture for quality, safety, scheduling, and cost control.

PAUL

John Paul Construction

Company Overview | BAM IRELAND | bam.com

Operating successfully for over 150 years, the bedrock of Royal BAM Group'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. 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.

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 €8 Billion and employs approx. 23,000 people worldwide. At BAM, we are building the present while creating a sustainable future for all.

Author

Simon Tritschler

Overview & Background to the Lean Initiative

Miyamoto Musashi (1584–1645), was a swordsman, philosopher, strategist, writer, rōnin and is considered a Kensei – a sword-saint of Japan. In his final years he authored The Book of Five Rings, a book on close quarter combat that has become a foundation of Japanese strategic business and manufacturing thinking. In it, Musashi advises to "… gather information from every possible source. Leave no stone unturned. Use spies, consultants, informants… Perceiving the enemy's position allows you to defeat it…".

Today, we strive to learn from what we do and how we can continuously improve, and our enemy is a lack of timely information in the decision-making process. In August 2020, the Digital Construction Department of BAM Ireland attended its subsidiary Modular Homes Ireland (MHI) for a technical visit with a view to improving the execution of their digital processes. Since then, both companies have worked together to reduce waste and add value. Our journey began by mapping out the work process, and today we are digitally tracking that work to add greater value.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

In August 2020, at an initial tour of the facility, BAM Ireland Digital Construction was introduced to MHI – a subsidiary of BAM Ireland – teams responsible for the design and production processes for the creation of steel panel modular houses and units. This was followed with a factory floor walk to get a better understanding of the entire production process, starting with the cold forming of the blank steel rolls into the modular panel wall frames, assembly of the units, and right up to the final wrapping of a completed module.

From this initial visit, it was clear that Digital Construction could bring value and remove waste from their processes through the application of Lean methodologies and the implementation of better digital technological practices.

Over the following visits, our first action was to complete a current state value steam map (VSM) so as to understand the entire production process, establish a benchmark value, and to use as a basis to build a recovery deployment plan.

VSM is a snapshot of how a process is currently executed, regardless of what the ideal or perceived process state may be – it reflects what is happening out in the real world. The VSM works to capture the entire span and duration of a process, and to identify within the process where value has been added or lost for the client. Undertaking this process gives visibility to waste or roadblocks in the overall production process and is created through direct process observations and forthright staff interviews to understand the pain points.

Over 3-4 visits we interviewed all the key personnel from each department and worked hard in the design office and on the production floor to understand the different task durations for the "first of a kind (FOK)" and "many of a kind (MOK)" events.

The MHI process begins with the client need which is translated via the design teams into a viable design. Once finalised, this FOK design is reviewed by the production team, and any lessons learned from the first production run are reapplied to the design, thus improving the outcomes for the following production units (MOKs).

Physical production starts with the cutting and forming of a flat roll of light gauge steel into a structural unit. These units are then moved to frame assembly where they are joined together to form the structural panels for the final unit being created. Panels are then combined to create the final modular structure, and these units move along the production line for slabbing, insulation, glazing 1st and 2nd fix, and so on, culminating in a fully-finished unit. Once all

quality checks have been completed, the unit is wrapped and made ready for delivery to the client's construction site.

After all the information had been gathered, a VSM was compiled and a finalised version was presented to the MHI management team for review and comment.

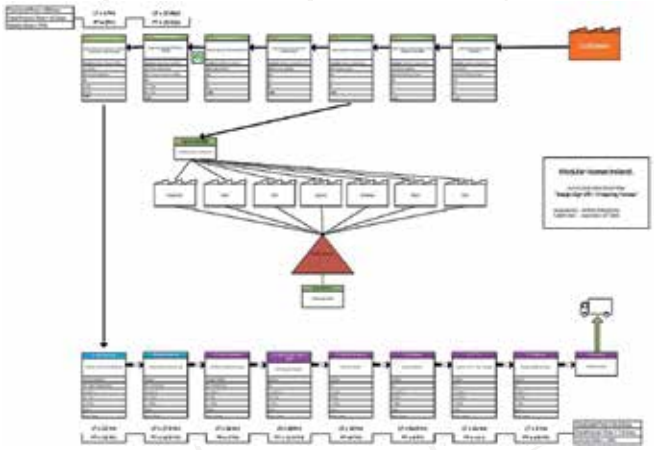

Figure 1. cVSM

The standout waste findings were:

- 20%+ non-value-add time within the internal design process.
- €100,000+ of product sitting idle on the production floor adding zero value.
- Panel team were over-producing in the range of 50%, leading to an oversupply of the assembly line and thus creating delays to production times.
- Overall production time was >4 times higher than the ideal state (albeit due to known reasons).

Responding to these findings, the digital construction team identified several opportunities for improvement:

- A digital method to track each unit through production and to dashboard the work in progress in near real-time, which would allow management to quickly identify and resolve any roadblocks in the production cycle and to better manage overall production time.
- The lack of a common data environment (CDE) was preventing the entire design team operating in a collaborative manner as well as the integration of stakeholders from design, production, and site installation on a single platform. This lack of a collaborative space was causing delays and miscommunication within the design process.

As not having enough timely information is the root cause to both of these findings, the digital team deployed two separate solutions. Both looked to reduce manual interaction with the process to address many of the 8 sources of waste identified within the opportunities.

- Unit Tracking – Digital Construction developed an in-house app to allow the different production managers track the start/stop work time for each unit. By using QR codes on each unit, the managers could open the app, scan the QR code to quickly identify the unit, and select a start/stop button to capture the time. This data was feeding a dashboard that management could access for near real-time information.
- CDE – Digital Construction deployed BIM360 from Autodesk to act as a common platform for the design process as well as the integration of the quality process, thus further enhancing the collaborative environment.

Figure 2. MHI App

Lean Initiative Improvements & Impact

Increasing Productivity and Sustainability Using Single Identity IoT

Current state mapping of MHI practices highlighted that substantial value could be added if production was accurately monitored and tracked in near real-time, thus providing MHI management with the information to take immediate action. However, the previous manual tracking and disconnected software solutions provided incomplete, inaccurate, or too outdated information to assess and action effectively. Additionally, they were finding that the in-house developed app was proving too cumbersome to implement efficiently.

MHI management recognised that there was room for improvement and executed extensive research looking for a single solution. The solution had to be flexible enough to identify units throughout their lifecycle, track processes activities around the assembly and installation, track the work completed, track equipment and stock in a production or construction environment by providing granular time-based activity, conditioning, and location data.

They found a new and innovative modular, multiprotocol, single-identity solution in Hiving Technology's "Hive OneID" product. The multiprotocol OneID building blocks enable cost-effective real-time data collection of all the components MHI set out to track Using NFC for close-range, Bluetooth for position tracking, and other radio frequency protocols for mid- and long-range tracking. The OneID has an active life of approximately three years and is passive through NFC for life, is modular, configurable, and can be equipped with sensors to suit requirements such as temperature, humidity, movement, tilt, and an accelerometer. This thus created a constant stream of granular data from connected manufacturing that construction operations used to learn and adapt to new or changing demands in near real-time.

Figure 3. Active Units & Readers

MHI deployed the OneID solution for tracking both modules and work. OneIDs transmit data on a regular configurable time interval, so installing readers in zones around the factory/sites and attaching the OneIDs to the module frames allowed tracking of the assembly and installation process until the finished module got installed on-site. In addition, the people and equipment involved in the build and installation are tracked and linked to the modules, which thus allows for the actual work to be heat-mapped in near real-time and provide data to optimise the value process.

Figure 4. Tracked Module

NFC on the module allows MHI to add value to the assembly process. For example, a building or quality process step can be acknowledged through a mobile app by simply tapping the mobile against the NFC, informing the user about the module's current status or proposing the next tasks to be completed – all specific to the users' role need. Additionally, the NFC stays active on the module for life, thus providing all the relevant lifecycle information for possible operational and circular recycling requirements.

Key to the OneID value is capturing the data in a granular format consisting of secure identification data and sensor values. The reader adds location and time information to the data that is captured. The reader infrastructure reads any OneID in range and updates the data seamlessly with BAM and other stakeholders.

This novel approach to capturing information has far-reaching consequences for how BAM approaches adding value to its digital construction. This OneID is a fundamentally simple approach that has its strength in being both modular and easily scalable. Implementing a single source system like this creates consistent and clean data, enables multiple stakeholder and system requirements, and seeds the data mining process of the BAM data lake to support the smart cities future.

Beyond the advantages to existing industrial construction practices, this solution can add value when applied to existing processes. When compared to the structured environment of a factory, the traditional construction site environment has an unstructured and often chaotic pace and flow. The challenge for the project management team is to get high-quality and timely information that will guide the decision-making process and therefore the optimisation of the value returned.

By implementing a single multifunctional modular solution, we can replace existing solutions to a single source platform. This alone addresses many sources of waste, including:

- Over-Production – We only create and collect the data we need on the item being tracked due to the modular nature of the solution.
- Over-Processing – With a modular solution that runs on a single platform, there is no need to translate the data into a common format. In addition, the fundamental nature of the data allows for multi-use analytics beyond the original need for the data.
- Inventory – A scalable modular solution can address the need to have multiple products from different vendors as this solution can replace them. For example, the same thermo module can track concrete curing or storage temperatures for modular bathrooms.

On a highly-dynamic construction site, the ability to track the resources, plant, and materials for each work task in near real-time will enable better daily management, provide metrics to support continuous improvement, and generate data to verify the value-add to both the client and the stakeholders.

Company Overview | JONES ENGINEERING GROUP | joneseng.com

Jones Engineering Group is a leading global, mechanical, electrical, and fire protection contractor operating in 14 countries across Europe and the Middle East. The original company was set up by Harry O'Neil in 1890 and, to this day, it has continued his vision of prioritising education, training, and innovation. Over the last century, Jones Engineering has grown sustainably in both size and reputation, with a turnover of approx. €700m and personnel of over 3,500 people worldwide. Jones Engineering has been applying Lean principles for many years, and recognising the benefits it brings to the firm, our clients and the industry as a whole. This commitment has fostered our dynamic, knowledge-driven, and customer-focused concentration on creating value-add and eliminating waste.

Author

Padraig McArdle

Overview & Background to the Lean Initiative

In delivering mission-critical projects across Europe and the Middle East over the past decade, we have witnessed three typical project forms, each with a major shift in the approach to building:

- The old school stick build approach.
- The OSM "we tried, we failed, now we're fixing it on-site" approach.
- The collaborative and early engagement approach.

This case study considers the importance of, and opportunities related to, MEP Off-Site Manufacturing (OSM) and Design for Manufacture and Assembly (DFMA) in enabling Lean in construction. A cautionary note is that how a DFMA project is realised could lead to a project having more waste than a typical stick build project.

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

The Old School Stick Build Approach

There will always be elements of a project that will need to be stick built, at least for the foreseeable future. However, all too often we witness systems still being installed with the stick build approach. This is primarily due to the project teams not understanding the overall project benefits that emanate from a successful OSM and Lean approach, including, for example:

- 7%-30% reduction in cost.
- 20%-60% reduction in construction programme time.
- 70% reduction in on-site labour.
- 20% reduction in pollution and site congestion.
- 90% reduction in on-site waste using volumetric construction.
- Increased Quality achieved in factory environment.
- Reduced on-site commissioning duration post-functional module testing off-site (if strategy realised and incorporated at schematic design stage).

The OSM "we tried, we failed, now we're fixing it on-site" Approach

There are numerous reasons for an OSM approach to fail. A successful OSM project is down to the project team's understanding of a few key design and working practices. Without a clear understanding of these enablers, a retrospective stick build approach is usually adopted during construction, which creates more waste than any other project.

To create a program framework (LOD100) which can work towards a typical 80% OSM target from the Basis of Design (BOD) development, the following are required:

- A complete design taking a nuts and bolts approach to stage 4 design.
- Clear understanding of the end-user requirements during BOD to eliminate retrospective change as much as possible.
- A collaborative approach with all project parties.
- A clear understanding of all interfaces to achieve OSM targets.
- Each project party understands the drop dead dates to facilitate OSM from both design and procurement viewpoints.

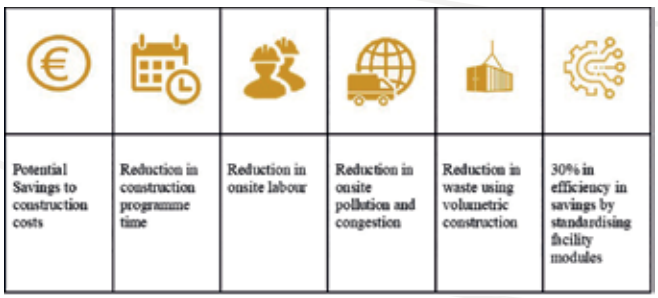

Figure 1. DFMA Benefits (Source: KPMG 2018-2020)

The Collaborative & Early Engagement Approach

The most successful projects are down to the project team completely understanding the benefits of OSM as well as the

enablers to achieve a collective OSM goal, and taking an integrated project delivery (IPD) and early engagement approach.

The early engagement of the design and construction partners provides benefits in terms of close collaboration as early as the BOD stage. This collaborative approach ensures that the design under development is based on sound construction methodology and that time is allocated to consider, identify, and advise on the best construction route based on the developing design, price, and quality.

When early engagement, and ideally an IPD structure, are implemented, the project and team approach towards OSM will directly influence the development of potential project gains and Lean efficiency per Figure 2.

Taking such an approach to early engagement, Jones Engineering was enabled to engage with all of the project stakeholders, design teams, and vendors. This case study details the M&E systems, capital plant, and supporting infrastructure that we were able to maximise via the OSM approach and benefit the project gains – a key objective to achieve from the outset.

Figure 2. Early Collaboration & Capabilities

Containerised Generator Sets

(Location: Northern Holland; Project: Confidential Data Centre.) During the development of the containerised generators, early engagement enabled us to successfully and fully detail and manufacture the following elements of a contemporary generator set up, which are typically site stick built:

- Cable entry box installed with cable gland plates installed and pre-drilled ready for cable termination.
- All FLS services within the generator container installed and FAT tested through early coordination between the Fire Alarm Contractor and Generator Manufacturer.
- BMS interfaces and network switches installed and configured.

External Sprinkler & Water Meter Buildings

(Location: Northern Holland; Project: Confidential Data Centre.) During the development of the external sprinkler buildings and water meter buildings, early engagement enables us to successfully fully detail and manufacture the following M&E systems:

- Internal containment and supports for M&E services completed and QAQC checked.
- Internal LV & ELV standalone systems installed and factory tested to L3 and QAQC vetted.
- FLS systems installed and tested.
- All mechanical pipework and pump work installed and factory tested.
- External cable entry points installed with cable seals prior to site delivery.
- All ELV wiring and BMS monitoring points installed, tested, and configured prior to site delivery.
- Drainage lines pre-installed.

Main Primary LV & MV Primary Trestles

(Location: Northern Holland; Project: Confidential Data Centre.) During the early stage 3 & 4 development, early engagement with the steel manufacturer enabled Jones Engineering to install all of its containment into the primary steel infrastructure to be delivered in 13 meter sections. The benefits of using this approach were:

- Higher quality of installation of the containment modules doing high-level work at low level in the steel manufacturing facility.
- All MV and ELV primary containment installation time greatly reduced.
- Mechanical supports in place ready for pipework installation and cladding.
- H&S risks limiting working at height durations.
- Drastic improvements on programme installation time.
- Reduced labour costs as a factory assembly attitude was adopted in the steel manufacturing facility, and as the containment install became part of the precision process.
- All earthing and bonding completed and QAQC checked.
- Enabled cable pulling to be mitigated and starting earlier on the programme.
- Reduction in access plant hire.

Figure 3. Off-Site Manufactured Primary Steel Gantry with M&E Services

CHAC – Cold & Hot Aisle Supporting Structure Modules

(Location: Northern Holland; Project: Confidential Data Centre.) Once the end-user requirements were known for the data hall white space, the team was collectively and successfully able to develop M&E modules in 13 meter sections complete with systems pre-installed. The key element to achieving this OSM element is taking a nuts and bolts approach with confidence in the stage 4 design to enable a design freeze, whilst meeting all of the client/end-user requirements:

- Lighting, emergency lighting, lighting controls, and fittings only.
- All LV & ELV containment systems.
- Fire Alarm/Vesda.
- Sprinkler system hangers and supports.
- Distribution boards and headers localised to primary routes.

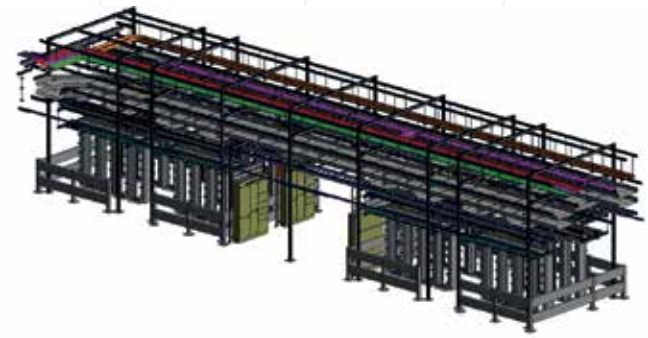

Figure 4. OSM White Space M&E Module Example

Containerised Electrical Plant Rooms

(Location: Northern Holland; Project: Confidential Data Centre.) The main objective specific to the project brief for the electrical capital plant was to maximise the OSM approach and design external electrical containerised plant rooms mounted on an external gantry.

Taking this approach greatly increases the amount of commissioning that can be achieved off-site, and all of the projects savings noted above were all achieved from reduction of off-site labour to minimising QAQC issues usually found on-site during Level 3 commissioning.

Figure 5. Containerised Electrical Plant Room Typical Example

Lean Initiative Improvements & Impact

The Jones Engineering Way

The major contributing factor in how Jones Engineering successfully delivers its OSM and DFMA approach, again and again, is down to our global in-house OSM & DFMA facilities which have an extensive DFMA portfolio listed below, being championed by Ian Davy the Jones Engineering Manufacturing General Manager & Group QA Manager.

Laboratory/Clean Rooms	Battery Charging Facilities
Chemical Treatment Building	Water Treatment Building
Acid Storage Building	AHU M&E Modules
Packaged Generators	Battery Tripping Units
Utility Corridor Modules	Fuel Oil Plant Room
Tower Makeup Pump-House	Cold & Hot Aisle Containment
PCW Side Stream Filter	Data/IT Rooms
Low Temperature Hot Water Skid	Modular Colling Units
Chilled Water Skid	Gas Purification Skids
Trestles – Mechanical & Electrical	Air-Cooled Plant Rooms
Sprinkler Pump-House	Heating/Cooling Plant Rooms
Fire & Gas Detection Systems	Central Utility Buildings
Packaged Switch Rooms	Single/Multiple Storey Plant Rooms

Table 1. Jones Engineering DFMA Portfolio

In summary, Jones Engineering recognises the responsibility to advise on best practice, efficient and economic proposals, and alternative options, as well as cost saving and value engineering suggestions during the Early Engagement Process.

We believe that both the design and construction route benefit from close collaboration as early as the BOD stage by all Project partners. This collaborative early engagement approach ensures that the design under development is based on sound construction methodology and that time is allocated to consider, identify, and advise on the best construction route based on the developing design, price, and quality.

Jones Engineering work with a number of clients in the Life Science, Data Centre, and Microelectronic sectors wherein the timescale between BOD to Facility Ready (FR) is under increasing pressure to reduce, thus increasing the need and essential requirement to maximise the utilisation of OSM and DFMA.

To accompany a global reach with state-of-the-art DFMA facilities, the real strength lies with our people and our teams. With our approach, our experience, our in-house working practices and in-house early collaboration to ensure all project DFMA goals are realised, and with our real-world belief that OSM and DFMA implementation can only benefit our projects on multiple fronts.

The unison and the inter-working relationships, collaboration, and understanding of the project benefits of DFMA between both the Jones Engineering Manufacturing Teams and the wider Jones Engineering Mechanical & Electrical delivery teams across all working sectors, is the true power house to our DFMA journey and success. We adopt the early engagement approach in-house within Jones Engineering Group, and identify our collective clients' requirements and project-specific DFMA targets. We then maximise our client targets with internal Jones Engineering Group collaboration between Jones Engineering Manufacturing Facilities and the wider Jones Engineering Technical Sectors, along with external early collaboration with all project partners, to realise the shared project goals.

To finish with a personal note and observation, I have been involved in the hyperscale data centre industry for 15 years and have seen "the good, the bad, and the ugly" across a large geographical footprint. With recent market trends, with delivery programmes becoming ever-more aggressive, with financial budgets forever tightening, and with an ever-growing emphasis and responsibility to reduce our project-specific carbon footprint and enable long-term sustainability, the need for DFMA is only going to increase. Having recently been a leading figure within Jones Engineering Group on the successful delivery of the quickest ever 64MW hyperscale data centre build, we embodied The Jones Engineering Way, and that made all the difference.

Figure 6. Jones Engineering Manufacturing Geographical Footprint

Jones Engineering

Paediatric Outpatient and Urgent Care Centre, Children's Health Ireland at Connolly opened in August 2019 (Image courtesy of New Childrens Hospital)

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Paediatric Outpatient and Emergency Care Unit, Children's Health Ireland at Tallaght opened in November 2021 (Image courtesy of New Childrens Hospital)

CHAPTER 2

Glossary of Terms & Concepts

A3
This is a one-page report prepared on a single sheet of large (A3) paper (report) that adheres to the discipline of PDCA thinking as applied to collaborative problem solving, strategy development, or reporting. The A3 entails getting the problem, the analysis, the corrective actions, and the action plan down on a single sheet of paper, often with the use of graphics. A3 reports have evolved into a standard method for summarising problem-solving exercises, status reports, and planning exercises like value-stream mapping.

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.

Agile
Is the method of project management characterised by the division of tasks into short phases of work and frequent reassessment and adaptation of plans. It is an iterative approach to project management that helps teams deliver value to their customers faster and with fewer headaches. Instead of betting everything on a "big bang" launch, an agile team delivers work in small, but consumable, increments. Requirements, plans, and results are evaluated continuously so teams have a natural mechanism for responding to change quickly.

Agility
This refers to supply chains and their management, and essentially means "readiness to change". From a business perspective, agility is defined as a strategy that is more responsive in a volatile marketplace, where this strategy is totally demand driven and the whole supply chain management changes as consumer buying patterns change at a very rapid pace. The fundamental drivers of agile supply chain are Speed, Cost, and Efficiency, and agile supply chains are based on the sensitivity to consumer demand, with sensitivity referring to the ultimate consumer demand in terms of the volatility of that demand. Agile supply chain framework is based on four major constituents: (1) Virtual Integration; (2) Process Alignment; (3) Network-Based; and (4) Market Sensitive.

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 they 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 ensure that 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 to produce a product, service, or unit of work (for example, a room, building, quadrant), or to complete a process, and as timed by actual measurement.

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.

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 thus 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.

Error-Proofing
Is a method that prevents that helps workers avoid mistakes in their work, or prevents an error or defect from happening or being passed on to the next operation.

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: Optimise 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:

1. 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.
2. Value Stream: The sequence of all processes from raw material to customer.
3. Flow: Keep value moving; avoid batches and queues; there should be few non-value-adding steps.
4. Pull: Short-term response to customer's rate of demand and no over-production.
5. Perfection: Delivering exactly what a customer wants, when they want it, at a fair price, and defect-free, with minimum waste.

5S
These terms describe workplace practices conducive to visual control and Lean production: (1) Sort; (2) Set in order; (3) Shine; (4) Standardise; (5) Sustain. The 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 Why Analysis
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 enquiry 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
This is the Japanese term for "actual place" and refers to the place where the actual work is done and where actual value is added. Lean experts encourage "going to the gemba" to see how things are really done and where there is opportunity to eliminate or reduce waste. Gemba is the practice of leaders going to the place where work is done to observe, ask questions, and show respect. Gemba walks should be done with purpose and focus on understanding and improving processes, not evaluating employee performance. After a walk is complete and the leader has the chance to reflect, action is taken regarding any opportunities for improvement that were discovered.

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.

Heijunka
This refers to levelling the type and quantity of production over a fixed period of time. This enables production to efficiently meet customer demands while avoiding batching and results in minimum inventories, capital costs, manpower, and production lead time through the whole value stream.

Hoshin Kanri
This is the Japanese term for direction management or strategy deployment – Ho means direction; Shin means Focus; Kan means Alignment; Ri means reason. Hoshin Kanri is the practice of identifying the organisation's long-term breakthrough objectives and aligning the goals and decisions of every person in the organisation. Strategy deployment is not an annual event, and success requires that it become operationalised at every level and incorporating strategy deployment into leader standard work to set a schedule for reviewing progress toward the objectives and managing KPIs on a daily basis. At any point, a leader should be able to say where their team is on the path toward its stated monthly, quarterly, and annual objectives.

Huddle Meetings
Huddle meetings give employees the opportunity to identify challenges and work on problem solving skills. They should be part of leader standard work because they give managers and supervisors early insight into potential problems and the opportunity to coach the team on how to implement positive change.

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: Organisation 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 materials to a certain quantity used in production, and is 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. It is a visual system for managing work as it moves through a process, and it visualises both the process (the workflow) and the actual work passing through that process. The goal of Kanban is to identify potential bottlenecks in your process and fix them so work can flow through it cost-effectively at an optimal speed or throughput.

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)
The complete term is "Last Planner System for Production Control". This is a system for project production planning and control that is aimed at creating a workflow that achieves reliable execution. It 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.

Leader Standard Work
This applies the concept of standard work to the task of driving Lean thinking and behaviour throughout the organisation. Leader standard work is a set of actions, tools, and behaviours that are incorporated into the daily activities of leaders at all levels. Like the standard work for any process, leader standard work must be documented, practiced consistently, and changed only with reflection and experimentation.

Lean
The concept that all processes contain waste. Lean is a value-driven and integrated 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 is underpinned and sustained by a culture of respect and continual 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. It is an alternative and transformational way to design and build capital facilities versus traditional construction design and project management.

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 to understand "Real Lean", and to design, develop, implement, manage, and sustain a Lean Enterprise and culture of proactive problem solving and continuous improvement.

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" and refers to 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/processes 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 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/Planned Percent 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 performed 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
This is a Japanese term for Error-Proofing or Mistake-Proofing developed by Shigeo Shingo that is used to prevent an error or defect from happening or being passed on to the next operation.

Perfection
This is the essence of "Continuous Improvement" and the PDCA Cycle. As value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, we must begin the process again and continue it until a state of perfection is reached in which perfect value is created with zero waste. Continually making improvements to further eliminate waste and add value is critical in order to perfect Lean Construction processes. Not only should adjustments be made throughout the individual project to identify and reduce waste, but taking learnings from project to project will enable continual innovation of new ways to add value and eliminate waste. In reality, "perfection" is never reached and it is instead about the relentless pursuit of quality and excellence.

Personal Protective Equipment (PPE)
Integral to health and safety, 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
Quality denotes an excellence in goods and services, especially to the degree they conform to requirements and satisfy customers.

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 ensuring that all activities/processes 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
Integral to Lean tools and techniques, and the essence of problem solving, this is 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.

Scrum
Linked to Agile, and initially utilised in software development, Scrum is a framework for developing, delivering, and sustaining complex products, within which people can address complex adaptive problems while productively and creatively delivering products of the highest possible value. Scrum meetings encompass the essence of Lean Huddle Meetings and Leader Standard Work.

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 amongst those that are sound in priority order, as well as sound 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 last responsible moment (LRM) in order to find by means of set intersection the best combination that solves the problem as a whole.

Shielding
Preventing the release of 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
This refers to Suppliers, Inputs, Process, Outputs, Customers. It is a tool used in process mapping to assist in documenting a process from beginning to end.

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 thinking and practice, this aims at creating standardised processes and procedures that are repeatable, reliable, and capable this being the basis for continuous improvement. It is the documented and current best way to do a particular task, procedure, or process. Workers develop the standard and follow it until an improvement process results in a new standard. Standard work ensures that results are consistent and forms the foundation upon which improvements are made.

Statistical Process Control (SPC)
This is defined as the use of statistical techniques to control a process or production method. SPC tools and procedures can help you monitor process behaviour, discover issues in internal systems, and find solutions for production issues. Statistical process control is often used interchangeably with statistical quality control (SQC).

Takt
The German word for "beat", 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 ensure 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
This is the output rate of a production process, and refers to the amount of material or items passing through a system or 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 ensure 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
This is the start, middle, and end point of Lean. Value refers to what the customer wants from the process – the customer defines value – and is captured through the "Voice of Customer (VOC)".

Value-Adding (VA)
Those activities/processes that directly add to or 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
In statistics, Variance (σ^2) is a measurement of the spread between numbers in a data set. That is, it measures how far each number in the set is from the mean (expected value/average) and therefore from every other number in the set. When an assignment is not completed as stated, it is considered a variance from the daily/weekly/monthly 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 ensures that the status of the system can be understood at a glance by everyone involved and actions taken locally in support of system objectives.

VUCA
This stands for Volatile, Uncertain, Complex, Ambiguous, and it describes the situation of constant and unpredictable change that is now the norm in certain industries and areas of the business world. VUCA demands that we avoid traditional and outdated approaches to management, leadership, and day-to-day working.

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 "Gemba Walks" and are a form of direct observation and simply entail 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 optimise 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
Part of the Hoshin Planning process, 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 is compiled from various sources, including the WIT Glossary of Terms & Concepts, the Lean Construction Institute (USA) Glossary, and the Lean Enterprise Institute Lexicon. It is recommended that plain language terms be used as much as possible.

New Children Hospital located on a shared campus at St. James's, Rialto, Dublin 8 and currently under construction (Image courtesy of New Childrens Hospital)