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Formed in 2006, Modubuild specialises in the delivery of internal modular fitout and high-tech, turnkey, modular off-site buildings. With significant year-on-year growth, the company has focused its business model towards high-tech manufacturing, biopharma, pharmaceutical, and data centres. Headquartered from Kilkenny, the company operates on an international basis with offices in Manchester, Brussels, Amsterdam, and Helsinki.

Lean thinking is part of the DNA at Modubuild and has been central to the company's growth and success. Operations are not framed within the business as Lean, but more as an unconscious part of daily activities within a learning enterprise.

With Lean thinking central to the company's operations, Modubuild has constantly evolved and applied CI and VSM to its operations. Across the business, Modubuild strive for Operational Excellence (OpEx), using Kaizen and CI as a key business focus. The company's approach is that everything must add value and operations and processes can always be improved. Data is collected across all business departments and collated to develop thematic trends and provide pertinent data towards how operations function. This data can then be developed to provide clients with the most efficient, professional, and comprehensive service possible.

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Figure 1. Modubuild Off-Site Fabrication Facility

Overview & Background to the Lean Initiative

In September 2019, Modubuild was approached by this case study's client – a large international biopharma company – that is developing a multi-phase manufacturing facility and it challenged Modubuild to develop and deliver a turnkey fast-track 900m² BSL3 twin-storey laboratory for the propagation of cell cultures used in the manufacturing of vaccines.

Setting a complex and challenging set of parameters and deliverables, the client required the project to be designed, procured, and constructed in a 20-week period.

During this 20-week period, Modubuild was required to deliver a complete turnkey building, including CSA and MEP packages, fitted furniture, finishes, FAT, transport to site, and module installation.

By applying Lean strategy to this project, Modubuild used its extensive modular experience and learnings to harness a hybrid construction approach of traditional stick-build methods and incorporated those into a modular volumetric off-site concept and design. By providing a structural steel frame, flexible concrete floor screeds, architectural cladding and roofing, coupled with internal CSA package and a complex MEP scope, Modubuild delivered this complex project to 92% completeness within the 20-week period.



Figure 2. Module Loading at the Modubuild Off-Site Fabrication Facility

Lean Initiative Undertaken – Lean Thinking, Tools, Techniques

Taking an OpEx approach, Modubuild adopted various Lean tools and techniques to deliver this off-site project. Though the project was being constructed using traditional construction methods and sequencing, its success in delivery was based on contemporary Lean strategy. Reduction and elimination of all 8 Wastes was prevalent throughout. Resources were allocated and directed based on demand, thus ensuring each person involved was adding value and increasing input and guaranteeing that output was managed and optimised against the project schedule. End-to-end collaboration succeeded in the endeavours to eliminate waste and maximise value-add, thus delivering a challenging and complex volumetric project at rapid speed. Furthermore, the Lean approach ensured that the client was provided with a finished building with zero defects.

Standardisation in design and module assembly allowed for a linear manufacturing process. A Lean production line was used for fabrication of modules. Steel fabrication occurred first, followed by painting, then floor insulation and concrete screeds. Following completion of these stages, modules were moved to the building assembly zone of the factory where units were connected, and MEP and internal finishes installation took place. By taking intrinsic control of the extrinsic factors, Modubuild could sequence works to ensure weather conditions did not affect progress, therefore external cladding and roofing were some of the final packages to be fitted. Success in rapidly completing these steps in a phased and linear method formed the foundation for successful off-site completion.

Without having to wait for completion of groundworks, concrete pours, and slab curing, the project proceeded in the controlled factory environment. To ensure consistency, each stage of the fabrication line went through digital BIM 360 field quality assurance checks. By creating a Lean standardised manufacturing environment, Modubuild achieved many meaningful and tangible wins on the project, most notably right first time, and achieving zero defects or EHS breaches at project completion – all of which contributed to Modubuild succeeding in delivering the project within the 20-week period. By accurately sequencing all works and applying LPS, Modubuild optimised the value chain and created pull throughout the project, thus allowing it to effectively and successfully practice JIT and prudent inventory management on the project.

Throughout the project life cycle, Modubuild's team strived for excellence in planning and work execution, but most importantly demanded and delivered exceptional quality standards. The first and most critical task for Modubuild was to appoint a collaborative team of specialists and trade partners. Working in an efficient manner, Modubuild appointed a value stream including Jones Engineering as MEP trade partner, Asgard Cleanroom Solutions as cleanroom provider, and McElroy & Associates as engineering design consultancy and BCAR specialists.

To ensure efficient collaboration and effective communication across the value stream, both client representatives and the conglomerate of trade partners were based at Modubuild's 145,000 sq-ft off-site construction facility located on a 1.5-acre site in Castlecomer, County Kilkenny. This ensured that key decision-makers were present at the requisite gemba, thus allowing for complex issues that could have affected project delivery to be dealt with and closed-out without detriment to the overall schedule. A key fundamental for the team was to adopt the 3C approach: Collaborate, Confirm, Construct. Having the key stakeholders present at the gemba enabled efficient and effective execution of the 3Cs. Throughout the life cycle of the project, all stakeholders were committed to the philosophy and thus enabling waste reduction in terms of time and rework. This created a speedy level of responsiveness from client representatives and the Modubuild design team and trade partners.

By using the 3C strategy, Modubuild and its trade partners achieved significant waste reduction across various waste categories. For instance, having the key decision-makers present at the place of construction enabled efficient and decisive decision-making which resulted in the removal of waiting. Within construction generally, waiting for key decisions is a common waste and cause of frustration for construction teams and it can negatively impact project timelines and schedule. In turn, this enabled project operations and fabrication to progress efficiently in line with the LPS and project schedule. Subsequently, the removal of time-associated waste enabled the construction programme to progress as planned.



Figure 3. On-Site Module Installation, & Assembled Building

Accurate end-to-end project planning was a critical element in project delivery. Modubuild used a 20-week LPS system to manage and plan all off-site activities across the various packages and trade partner elements. The LPS board was erected in the project office in clear view of all personnel. It was updated weekly, or more frequently if needed, with

valued input from the respective trade partners to ensure all milestones were achieved and look-ahead was accurately planned. From the LPS, a detailed schedule of design, procurement, and construction deliverables were developed. This ensured technical submittals were approved quickly and efficiently – to optimise decision-making, the client always returned tech sub-approvals within 48-hours or less – that design was completed, and materials procured on a JIT basis.

The accuracy of the LPS enabled the procurement team to develop a tiered procurement schedule. With critical client input, procurement tiers were categorised based on lead time, critical importance to the project, and priority of requirements. For instance, cladding and roofing were long lead elements, with a 15-week lead time. In traditional on-site construction, this would have been detrimental to project delivery. However, by constructing off-site within a controlled environment, Modubuild could progress with all the internal packages on the project, thus ensuring that the 20-week schedule was optimised and progressed on a daily basis.

By accurately scheduling procurement deliverables and using JIT, the team successfully reduced more common wastes, including excess inventory, transportation, and motion/material handling. The frontend planning and LPS process allowed the project team to slow down to speed up. Furthermore, by critically planning and prioritising product selection, design, and procurement, it allowed all stakeholders across the value chain to focus and prioritise their energies to the elements that were most important. Furthermore, it empowered key decision-makers to rapidly find effective solutions and progress complex issues.

BIM Modelling and effective design management and execution were key factors in the successful delivery of this off-site 3D volumetric modular project. From the point of order through to project delivery, the entire design team, specialist trade partners, and the client were based at the single design office within Modubuild's factory. This allowed for detailed and efficient collaboration throughout the lifecycle of the project, thus ensuring efficiency and tangible milestones were achieved throughout. Additionally, it ensured elements were designed at the place of construction, thus enabling a high level of right first time and further reducing wastes such as reworks and over-processing which enabling expedited completion of design and BIM completion.

The evidence certainly suggests that collaboration had a significant and positive impact on the project – the importance of which cannot be overstated. Throughout, the client challenged Modubuild to deliver and respond with effective and SMART problem solving. This challenge empowered Modubuild and its team to be proactive and have solutions ready. By challenging Modubuild, the client forced the value stream into an efficient and highly-effective cycle of receiving questions, answering questions, and receiving approval. Essentially, challenging the value stream and its key stakeholders enabled a collaborative and integrated delivery of the project. Modubuild was very clear at the outset of the project that all submittals had to

be reviewed by the client within 48 hours in order for the schedule to be maintained. This proved to be very successful as it greatly increased the efficiency of the procurement process in comparison to traditional build projects.



Figure 4. Module Internal Finishes – completed off-site

From an end-user perspective, exceptionally sensitive and critical activities and operations would occur in the completed modular building. The primary function of a BSL3 laboratory building is for the propagation of life-saving vaccines against dangerous and highly infectious diseases and viruses. This meant that it was essential that quality of build and system installation were to exceptional quality levels – any breach or defect could potentially lead to catastrophic outcomes for the client and its employees. Furthermore, selection of building elements and components needed to be onerous but efficient, and not negatively impact the 20-week project schedule.

The project schedule could not afford delay through reworks due to delayed approval of systems, or benchmarks, or quality of installation. As mentioned previously, the construction team operated proactively using the 3Cs which enabled efficient decision-making and progress. It was also important that the quality of construction met client requirements and was right first time, and so it was prudent that all elements were benchmarked and approved, and consistency was achieved. Therefore, the team and installation operatives strived for excellence. Having the client present at the gamba resulted in quality at source, therefore expediting construction to unparalleled speeds whilst achieving best-in-class quality across all elements of the project.

As a facility-ready, plug-and-play, off-site constructed building that contained various and intricate electrical, HVAC, process, security, active fire protection, and BMS systems, it was essential that exceptional quality testing was completed. Modubuild and its team designed the project to ensure that all these systems were entirely installed in the off-site environment. This subsequently required that Factory Acceptance Testing (FAT) be completed on all systems within the 20-week off-site construction programme, subsequently shortening the allowed installation time. Taking the construction and installation into the controlled off-site environment ensured right first time, reduced reworks, and allowed for pre-FATs to be completed sequentially and successfully – thus for final FATs to pass on the first effort each time. Finally, upon completion of all off-site works, the entire modular building was powered-up and put into fully operational mode. This allowed the client and others to carry out actual walk-throughs of the complete facility and assess any alterations or comment on any final quality topics prior

any alterations or comment on any final quality topics prior to site delivery. Importantly, this stage provided the client with certainty and comfort that the building operated to fully meet their deliverables and expectations.

With design and construction having commenced in September 2019, the completed building was in position and ready for module delivery from Modubuild's off-site facility in Kilkenny during the first week of February 2020. The separation and weather wrapping of individual modules coincided with the commencement of groundworks at the final building location on site. Just five months after placing its order with Modubuild, the client received delivery of 18 11m long x 4.5m wide x 4.5m high mega-modules.

The transport of the mega-modules was coordinated with oversized load experts, Aylward Haulage, and relevant local authorities and councils. The first mega-modules arrived on site on 14 February 2020, and, following 9 days of module installation, a two-storey weather-tight building was fully in situ. This was the point where extrinsic factors affected progress as severe weather conditions impacted installation progress – without having encountered two significant storms, installation would have been achieved in just 5 days.

Onsite activities continued, including reconnecting and commissioning of electrical, HVAC, process, owner-furnished and contractor-installed equipment. The building consisted of 65 CSA and MEP systems. There were a number of these systems commissioned during a short period and as they became available. The remaining systems were completed over an expedited period after returning to site following the Covid-19 restrictions. Critically for the client, they were considered to be essential workers. As the laboratory was facility-ready with systems operational and owner equipment in place, end-user staff could move into the building to commence placebo operations within the building during the Covid-19 lockdown.

Lean Initiative Improvements & Impact

For the client, the BSL3 laboratory is considered to be a mission-critical element of infrastructure essential for successful manufacturing of life-saving drug vaccines within its main production facility. Without a functional and high-quality BSL3 laboratory, the manufacturing processes could not commence. Failure or delayed delivery would have resulted in serious impact on the functions of the client organisation. For these reasons, it was of critical importance that the completed building was constructed and delivered in a fully scalable, replicable, facility-ready, plug-and-play condition within the 20-week time parameter.

By approaching this fast-track and complex project with volumetric off-site construction, and by applying contemporary Lean thinking, Modubuild delivered, and in many cases exceeded, client expectations, deliverables, and requirements. From concept design through to project completion, the key

focus was to optimise, manage, efficiently plan, coordinate, and execute all intrinsic elements. Through developing an accurate LPS, Modubuild created its basis for successful completion of the intrinsic elements of scope, including design, procurement, off-site construction, module delivery, and site installation.

Waste removal and addition of value was a key priority. By ensuring detailed and efficient collaboration across the entire value stream, the project team created an environment for swift and effective decision-making. Importantly, resources were accurately planned and this ensured that all personnel were always adding value. Interestingly, through planning resources and workload, data shows that the project was completed with approximately 45% less personnel than would have been otherwise required on a traditional on-site build equivalent.



Figure 5. Plant Room & FAT Testing Station completed off-site

Success in delivery of quality was a significant achievement on the project. All punch-list items were closed-out at the off-site facility prior to delivery. This ensured that the client received a completed facility-ready building and did not need to wait for extended periods for close-out of any snags or punch-list items. Following installation of modules and connection of systems, the building was ready with zero defects reported. This copper fastened Modubuild's pre-requisite of waste elimination. Using Lean thinking and practices to provide a completed volumetric modular off-site building on time and with zero defects allowed the client to move into operations approximately 12 months earlier than would have been possible through traditional construction. Essentially, this empowered the client to produce its life-saving vaccines 1-year earlier than planned – the ultimate definition of value-add for such a client.

