Results of a Pilot Site Study Disrupters, Enablers and Variability Impacting Construction Productivity: Key Findings from Timber Square frame installation.

This study reviews the productivity of the superstructure installation at Timber Square, a major London development. It focuses on how structural materials were delivered and assembled, how the team measured on site performance and identifies key disrupters which impacted productivity. The study highlights what worked well and offers suggestions for improving productivity on future projects.

Overview

Timber Square is a part new build; part refurbishment and extension project which comprises two buildings providing a total of c.362,000 sq ft of office accommodation and 14,500 sq ft of retail and leisure space. The development located in Lavington Street, Southwark, London, will be net zero-carbon and highly sustainable.

The East Building (Print Building) is part refurbishment and extension project. It retains its basement and four floors of existing structure and is extended using a hybrid structure of steel frame with trusses and CLT (Cross Laminate Timber) to 10 stories in height.

The West Building (Ink Building) is a new building comprising two basement levels and 15 office floors. It uses a hybrid superstructure of steel (castellated beams) and CLT arranged around two exposed concrete cores.

Figure 1 Timber Square site plan

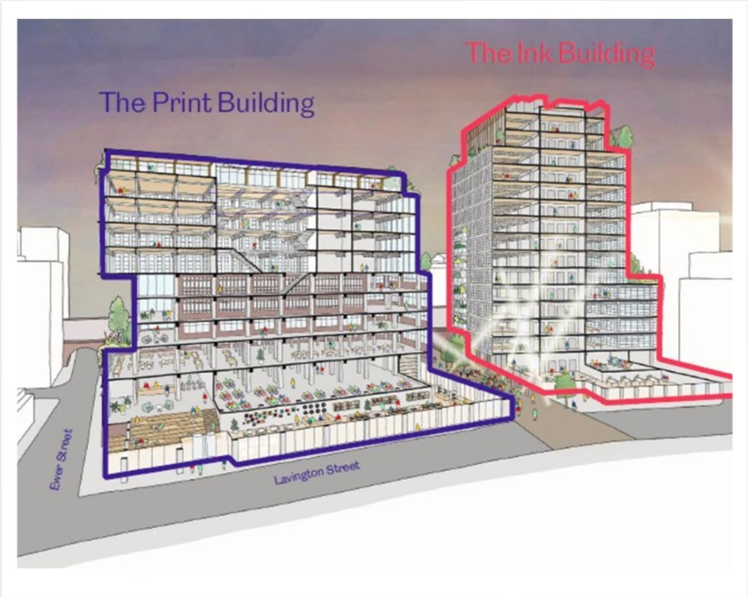


Figure 2 Cross section of Ink and Print

The key stake holders involved in the project are:

Client – Landsec

Construction Manager (CM) – Mace

Project team – Opera (PM), Bennett Associates (Arch), HTS (Struct Eng), Hoare Lea (MEP, lifts and supporting disciplines) Turner Townsend Alinea (Cost)

Key Contractors – William Hare (Hybrid Steel and CLT), J. Coffey (Concrete), Sipral (Cladding), T. Clarke (Electrical), SES (Mechanical), Otis (Lifts), Modular (Toilets).

Data Analytics – University of Cambridge

The study commenced in January 2024 as the enabling works contractor The Erith Group was completing demolition/enabling works and basement construction and had commenced the jump cores in the Ink building. The enabling works were procured under a traditional contract with the Client. The main construction works were procured under a Construction Management form of contract with Mace appointed as construction managers.

This work study specifically relates to the installation of steel frame and cross laminated timber (CLT) floor plates across both buildings (noting that the project is currently studying a number of other work fronts). Mace and the Timber Square team were excited to be part of Phase 2 of the CPT's Pilot Sites workstream. The study has reviewed and analysed the installation methodologies and construction challenges of the hybrid structure.

The project used the following digital technologies to assist collecting data for the study in accordance with the CPT Measurement Framework.

Technology	Purpose
Lobster Cameras	Mounted on the Tower crane and adjacent building to provide view of the new works being installed
OpenSpace	Weekly video captures inside the building recording progress / output
1 Guava	Crane utilisation data
DataScope	Turnstile records advising of number of operatives and types of trade
Autodesk Construction Cloud (ACC)	Quality handover trackers
MatMan	Data output for steelwork status (William Hare tracking system

The following productivity metrics were used for steelwork and CLT elements:

- Production rate (m² of GIA / day)
- Labour productivity (m² of GIA / worker-hour)
- Production rate (pieces / day)
- Labour productivity (pieces / worker hour).

The GIA related measures create metrics which effectively define the rate of value creation from a developer perspective and enables comparisons of the overall superstructure rate of installation and productivity level between floors, between the two buildings and wider industry benchmarks.

The piece count metrics capture performance at a more granular data enabling analysis at the component level.

Key Findings

Background

The works on the two buildings were completed utilising three tower cranes. Each building had one dedicated crane with the third crane shared between the buildings. For the initial 6 months of the superstructure construction the hook time allocation was shared between the structural frame and the concrete core construction. The works to both buildings were programmed to work in tandem and sequenced so that the shared crane could facilitate the needs of both buildings.

Steelwork and CLT elements were installed in double floor increments with a double height column and the lower level of steel installed as a first pass. The CLT floor panels were then placed on the lower level followed by the steelwork and CLT for the upper level.

Topping which celebrated the completion of the superstructure was achieved in January 2025.

Wherever possible production rate and labour resource data was collected from multiple sources (for example manual checking of site cameras and downloads of the MatMan data to determine the number of steel pieces installed per day). This enabled the Cambridge University team to triangulate data for analysis and verify the results.

The study reviews the disruptors impacting productivity and the varying production outputs.

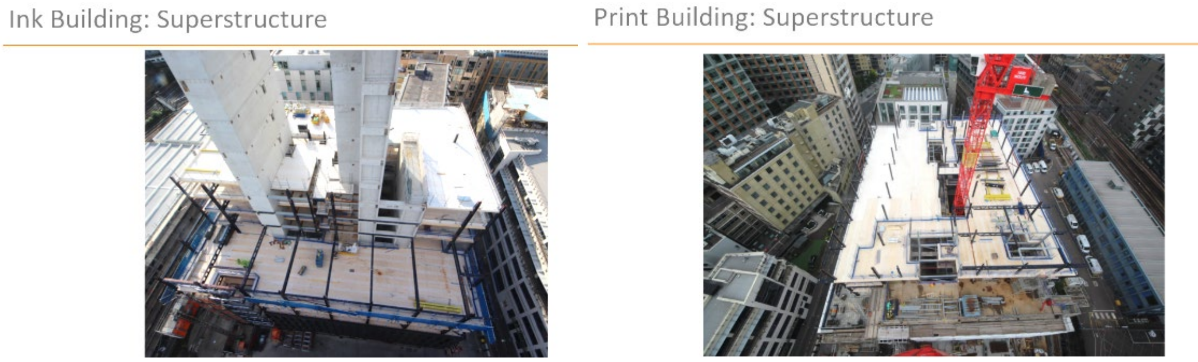


Figure 3 Images of Ink and Print superstructure installation

As can be seen from *Figure 3 Images of Ink and Print superstructure installation*, the floor plates of the two buildings are quite different. The new-build Ink building is square in form and is based around two new concrete cores. The area between the cores is used to accommodate services risers.

The Print Building has a long rectangular floor plate with three steel cores punching up through the frame. The new floors are founded from levels 3 and 5 of the original retained building structure.

Production Variability

The rate of progress of the structure was captured and recorded in measured with the use of site diaries, MatMan data provided by William Hare and the Lobster cameras mounted on the tower cranes. The diagrams below use flow lines, which plot planned versus actual progress on site to clearly show how the installation progressed. Initially the project team compared the performance for complete floor plates. However, it soon became clear that there was significant difference in productivity between the zones (allocated for crane allocation), within the Ink building. This is reflected in the different formatting of the flowline diagrams for the two buildings.

Figure 4 Ink and Print - Flowlines (plan v actual) across levels and zones

In summary, analysis of the flowlines in *Figure 4* shows that progress on the Ink Building, whilst fluctuating between construction zones, progressed well to level 6-7 where output dropped off. This can be seen from the shallow flow line gradient, with a corresponding increase in the programme time to complete the floors. The flow lines regain their verticality in the upper floors but in overall terms the performance on site did not achieve the planned output. From level 13 upwards in the Ink Building the team decided to focus efforts to get to the roof level as quickly as possible so that concrete pours could be completed prior to the Christmas break, allowing the slab to cure during the holiday period and protecting the critical path programme.

Out of hours working, originally factored into the target programme for both buildings, was not possible between June and September due to local authority restrictions - losing one day of production per week over this period.

Progress in the Print Building was more consistent. However, the planned intention to complete levels 6-7 and 8-9 in tandem was not possible due to crane availability and allocation which was complicated by the delays to, and phasing of, the Ink Building. Plant is situated at level 8, so priority was given to completing this level for hand over to following trades (concrete and waterproofing). The levels above this were progressed at a slower rate, with priority allocation of the shared crane being given to the Ink Building.

In the final condition the two buildings are linked and share critical services. It was important to ensure both buildings progressed together to reach completion with a similar time lag to the planned completion date. This was important to allow both buildings to be commissioned and handed over to the client team at the same time as planned. In this regard allocation of craneage, to each building, was reviewed and reprioritised by the site management team on a weekly basis, and did not always follow the planned phasing, hence the production rate variability between levels and zones.

As previously described the site is served by three cranes with one dedicated to each building and one centrally positioned which can serve both buildings. The dynamically varying requirements of each building added complexity to the logistics planning and management process on site and made it difficult to optimise the utilisation of the craneage resource.

As the structure was progressed with two floors at a time the analysis below has been based on the double floor cycle and examines the production rate achieved.

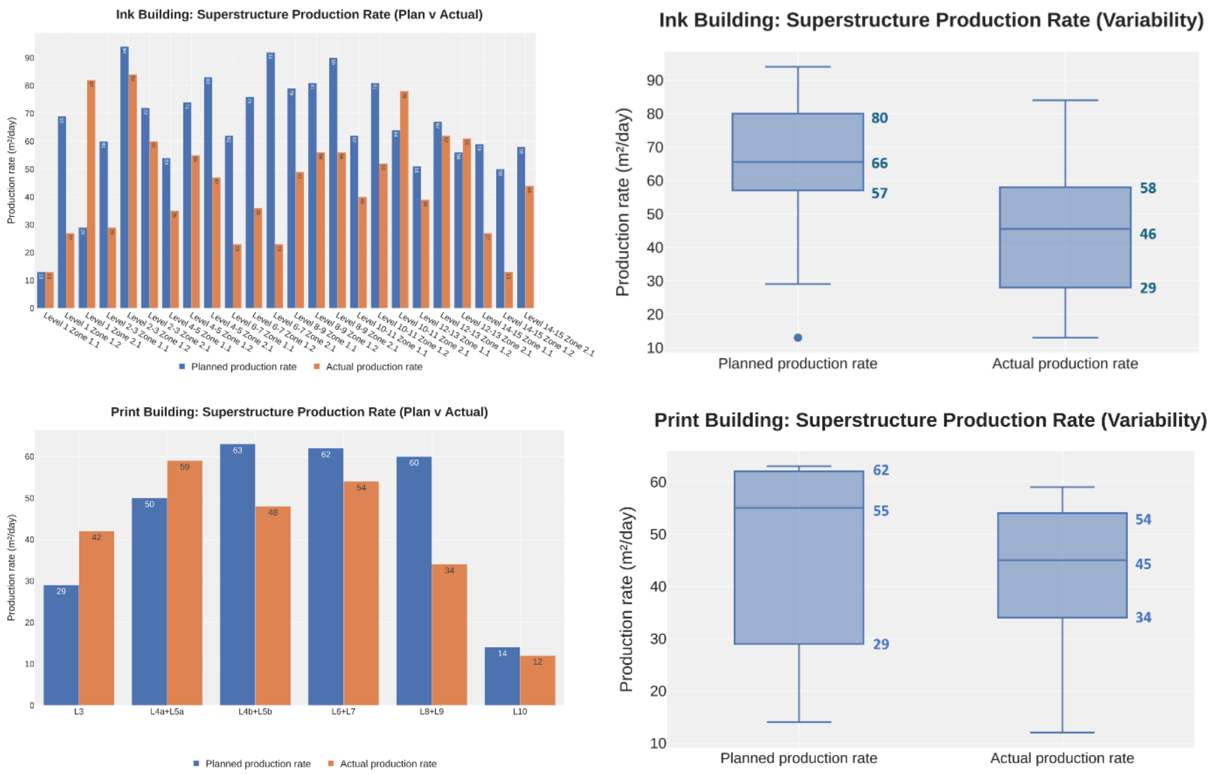


Figure 5 Production rate results for Ink and Print

Whilst the Ink Building had planned for a more aggressive programme time, based on a target of 80 m²/day, the rate actually achieved on each building was almost identical. The reasons why Ink failed to meet the higher target production rate include:

- restricted access to the crane due to works to the core over running to late July;
- reduced hours of working;
- and various other progress disrupters.

The average production rate achieved for Ink was 45.5 m²/day.

The Print Building was impacted less by progress disrupters, managing to achieve an output of 45 m²/day against the original planned rate of 55 m²/day.

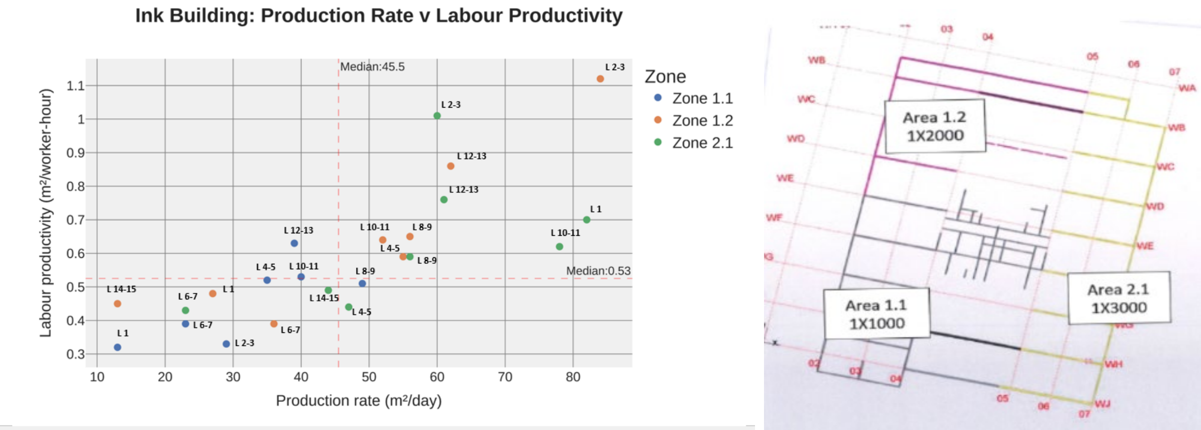


Figure 6 Production rate v labour productivity and construction zone designation for the Ink Building

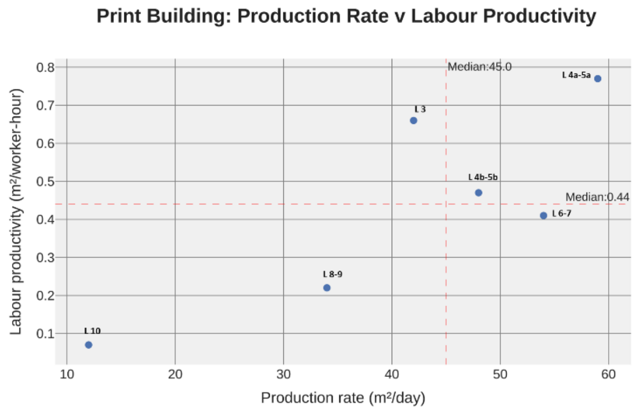


Figure 7 Production rate v labour productivity and construction zone designation for the Print Building

Within the Ink Building, construction zones 1.2 and 2.1 performed better than Zone 1.1. Zone 1.1 was less productive due to the complexity of the structure between the two cores, and the impact of the jump-form core shadowing this area. Once the cores were free of platforms, clear and unobstructed access became available enabling the installation team to focus on this area. The chart in *Figure 7 Production rate v labour productivity and construction zone designation for the Print Building* plots production rate against labour productivity. The labour resource is an overall measure of the team employed to deliver the frame and includes all roles from fixers and painters to fire watch personnel. The actual gang size per crane was 4 to 5 people.

The University of Cambridge team has collected data from over twenty-five projects commercial and residential projects in London (most of the buildings in this data set used a concrete superstructure design). The average superstructure production rate for these buildings is 57 m²/day (with a third quartile performance of 76 m²/day) whilst the average labour productivity is 0.21 m²/worker-hour (with a third quartile performance of 0.27 m²/worker-hour). The average production rate achieved for Ink and Print is around 20% below the Cambridge benchmark figure.

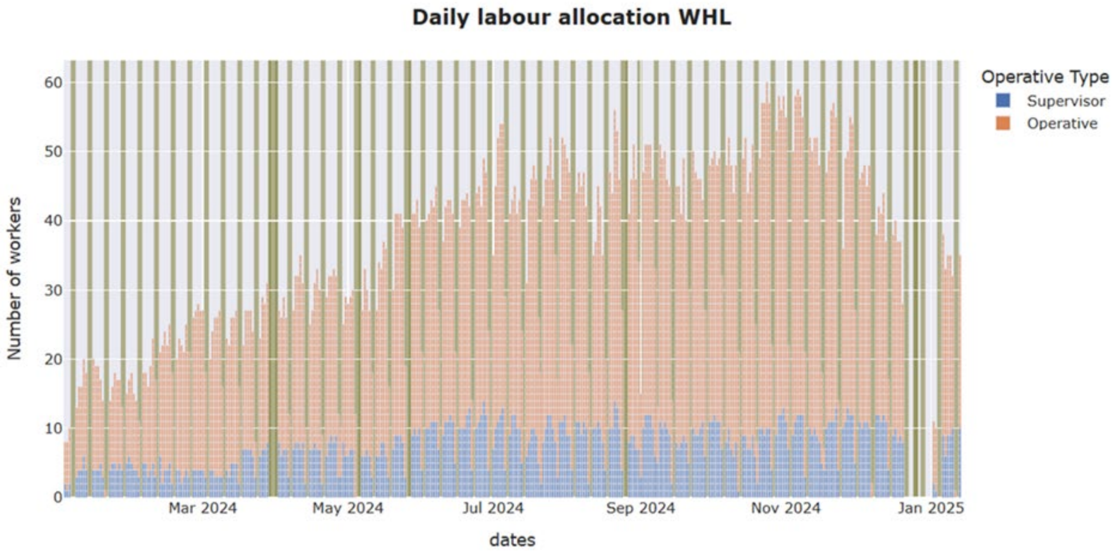


Figure 8 William Hare labour resource levels

Although the average production rate for both buildings was below the data set benchmark, the productivity levels at Timber Square of 0.53 m²/worker-hour (Ink) and 0.44 m²/worker-hour (Print) were significantly higher than the 0.21 m²/worker-hour productivity average.

The latest analysis of the Cambridge team's pooled dataset of 25+ projects shows that production rates and labour productivity are a function of the size of the install gangs. The number of workers able to work on the superstructure build varies based on the structural system employed. For example, the P-DfMA structure used on another Landsec project, The Forge (a Phase 1 case study project), only required a team of 10 workers per building to install the superstructure and was able to achieve very high productivity levels (up to 0.9 m²/worker-hour). Some precast concrete buildings can engage up to 25-30 workers using 2 or more cranes to install the superstructure, achieving higher production rates (third quartile performance of up to 80 m²/day) but at the expense of lower labour productivity (around 0.26 m²/worker-hour).

The consolidated Cambridge data set also shows that concrete structural frames with 11-15 workers (mostly projects with high levels of off-site prefabrication) achieve a third quartile performance of 44 m²/day with the highest value of 70 m²/day; and for labour productivity a third quartile performance of 0.28 m²/worker-hour with the highest value of 0.43 m²/worker-hour.

Timber Square had on average 11-15 workers in the superstructure install team per building. Ink had a third quartile performance of 58 m²/day and three instances above 70 m²/day. In terms of labour productivity, both Ink and Print exceeded the current benchmarks for the 11-15 workers group. This higher labour efficiency is likely due to the stell/CLT hybrid structural design, which did not require slab steel fixers or concrete gangs to create the floor slabs.

Steel & CLT pieces across both buildings and 3 cranes

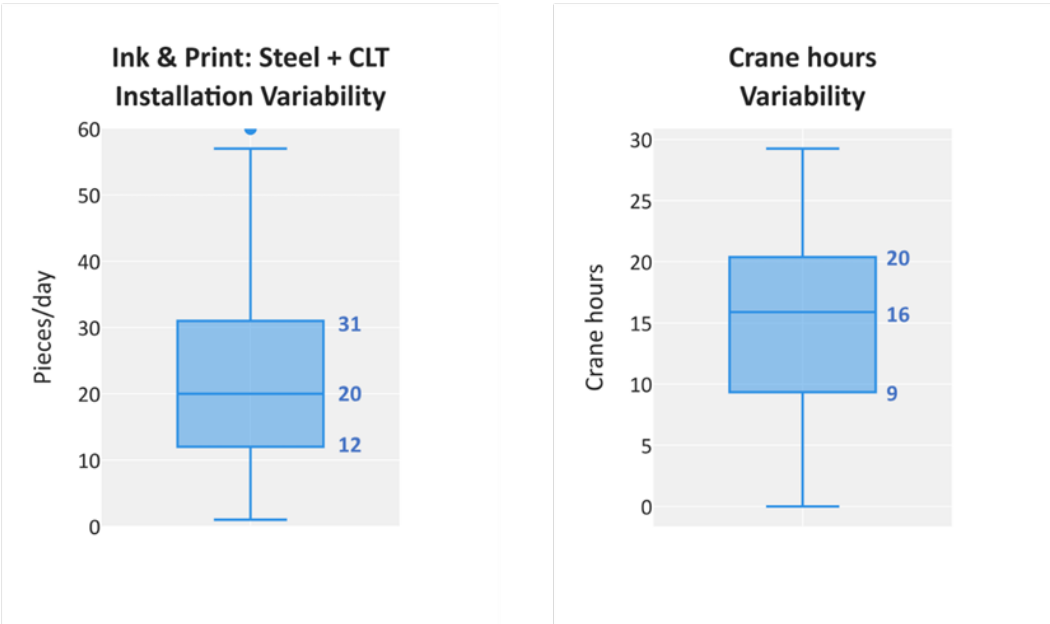


Figure 9 Variability of steel and CLT component installation rate and crane availability

Following a close out review with the superstructure package contractor the following factors impacting on production and productivity variability were identified:

- Days with high crane use but low installation rates are linked with unloading materials, or out-of-sequence/late deliveries.
- Average crane utilisation was 65% - lower usage/allocation is associated with lower productivity.
- There were cases of crane time being booked but not used due to deliveries not running to schedule.

1. Steel and CLT installation

The median across the two buildings was found to be 20 pieces/day with an upper quartile (which represents the best 25% production rate) of 31 pieces/day. The data illustrates the wide variability of the production rate achieved in terms of the amount of pieces/day.

The study uses the total number of operatives numbers deployed by the superstructure contractor across the project (including fixers, welders, fire watch individuals etc). The data has been obtained from the DataScope turnstile records.

The labour data has been combined and analysed across both buildings as it was not possible to obtain a fully verified breakdown of how the operatives were allocated across the two buildings. Operatives were able to easily pass between the buildings due to their proximity with no security line between them. Having two buildings on the site but only one set of entry and exit turnstiles prevented the use of the DataScope data to automatically track labour resources deployed on each individual building.

The above scatterplot presents actual crane hours working on the structure per day across three cranes. The data was recorded and taken from Wolffkrans 1Guava tracking system. The average daily crane hours are 16 hours across the three cranes, with the third quartile benchmark of 20 hours. The data shows the importance of maximising crane use to achieve high installation rates.

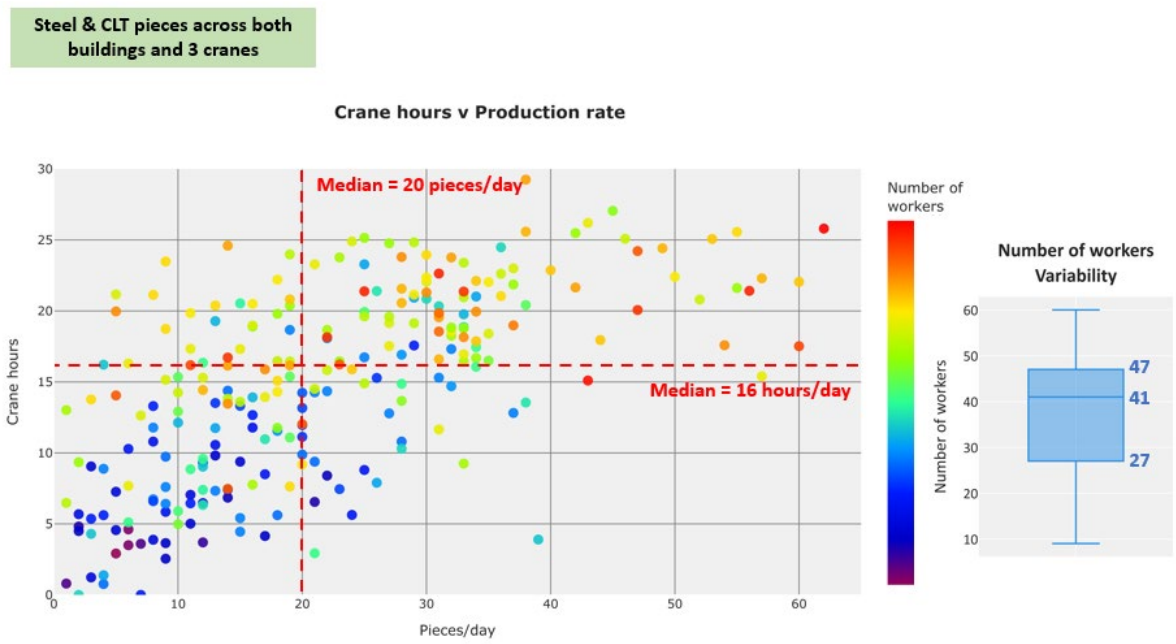


Figure 10 Timber square crane utilisation and production rates against number of workers deployed

The chart in *Figure 10 Timber square crane utilisation and production rates against number of workers deployed* shows that a greater number of site workers does not always result in increased output. However, the highest piece counts have been achieved when the resource is at its maximum.

An optimum level of resource is needed to get areas ready to install and close out the follow-on completion items allowing the next phase to commence on time. For example fixing the CLT to the steel allowing the Mobile Elevating Platforms (MEWPs) to be loaded onto the top CLT level to start the next cycle of steel clearly makes an impact.

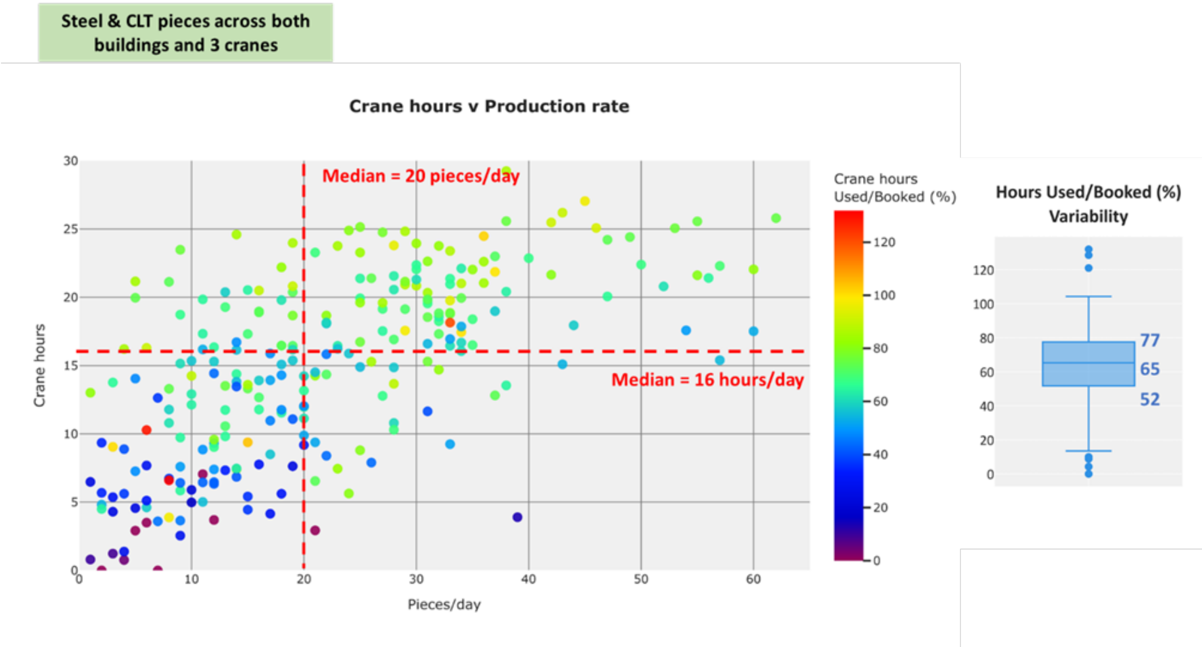
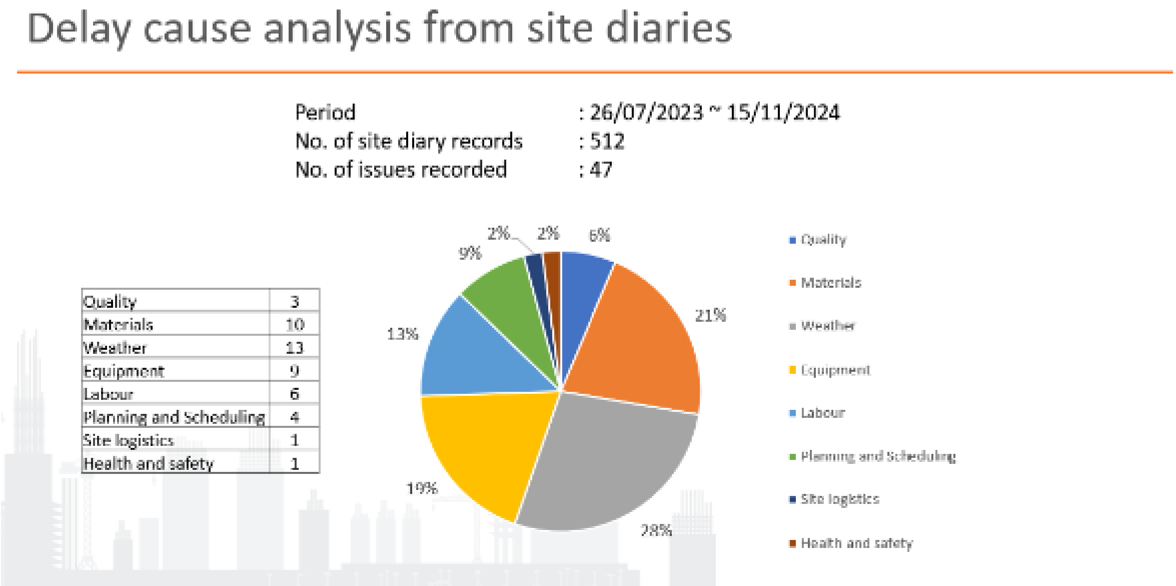


Figure 11 Timber square crane utilisation and production rates against crane hours booked

The chart shown in *Figure 11 Timber square crane utilisation and production rates against crane hours booked* is measuring actual utilisation of the crane time against booked time and pieces installed. It is clear to see that low crane utilisation reflects in low piece count as you would expect. However, it can be assessed from this analysis that the availability of the cranes was not the driver behind the lower production rates. Maximising the utilisation of the time available on the cranes and the gang's maintaining installation is key.

Productivity Disrupters



Quality	3
Materials	10
Weather	13
Equipment	9
Labour	6
Planning and Scheduling	4
Site logistics	1
Health and safety	1

Figure 12 Production blockers by category

The site team recorded blockers using a standard schedule, developed by the University of Cambridge team from previous studies. Using a standard set of coded descriptions normalises the data collected and allows for easier digitisation and analysis. It is hoped that this approach will be widely adopted to enable the consistent collection of data on future projects.

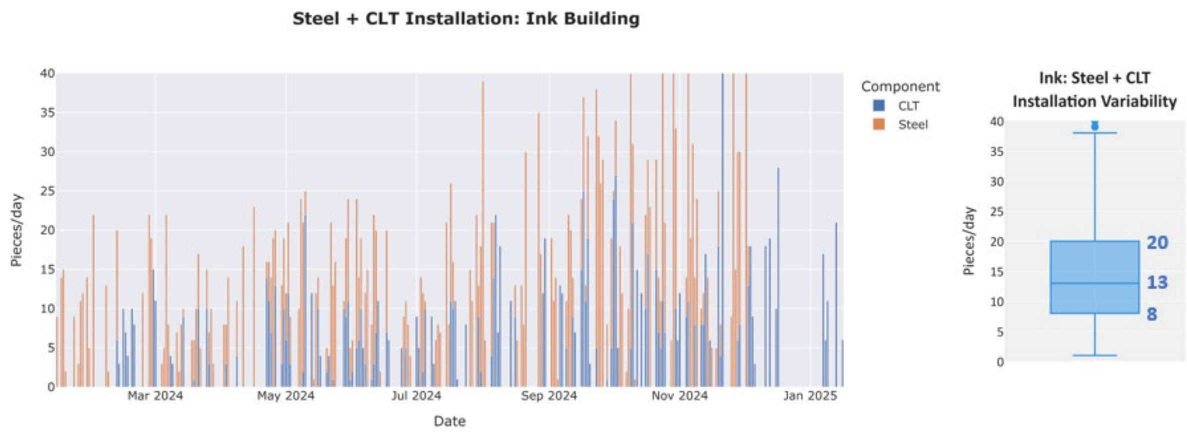
Below is a summary of the main disrupters observed in the data and the perceived reasons for their occurrence:

1. Winding off / Severe weather

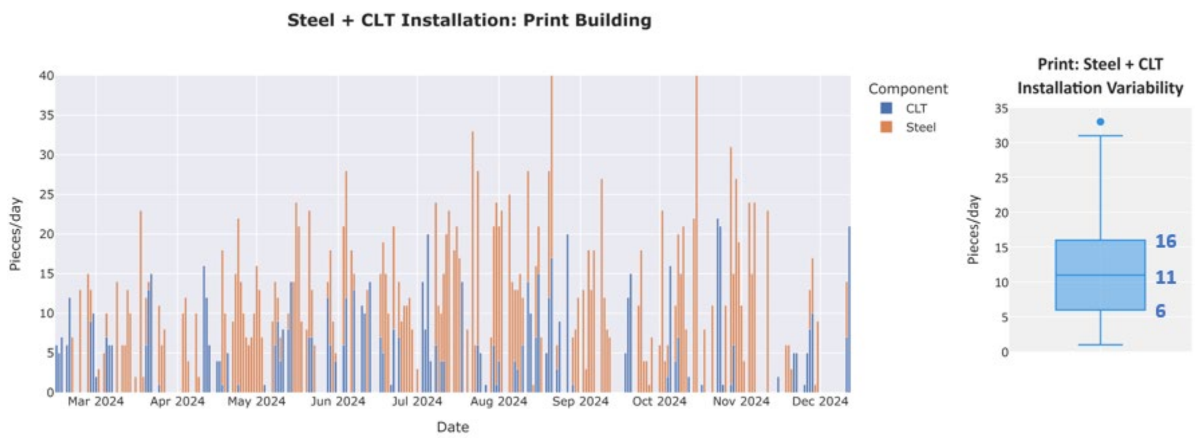
The data record shows that 23 days were winded off. Severe weather and in particular high winds can significantly impact the productivity of packages heavily dependent on craneage lifting operations and is something that we must deal with in the UK. The key is to make sure the impact is managed and follow on delay is mitigated. Ensuring the availability of material for delivery ahead of a forecasted windy day, and having material available immediately following, is key to maintaining production rates and overall productivity levels.

The off-loading waiting times from the haulier was also a factor. Loads were less likely to be called in the afternoon due to the concern of not being able to off load within the day. Qflow the automated delivery data capture software system was utilised to track deliveries digitally and ensure the correct materials were delivered in sync with the installation phase.

There is anecdotal evidence that projects on or close to the river Thames incur more winding off and downtime. Mace are collecting data from across their London projects to test this hypothesis, but the outcome of the analysis is not yet available.



Vertical blue bars: number of pieces (steel + CLT) 23 days lost due to wind. Average 13 pieces/day with a 3rd quartile 20 pieces/day (43 out of 261 days no installation)



Note: Vertical blue bars: number of pieces (steel + CLT) 23 days lost due to wind. Average 10 pieces/day with a 3rd quartile 18 pieces/day. (36 Days out of 240 no installation)

Figure 13 Superstructure component installation rate

The charts in *Figure 13 Superstructure component installation rate* show that both buildings had a similar average installation rate and were affected by wind to a similar degree, as expected for similar height cranes.

The team investigated the use of Wolffkran – Vita load navigator, witnessing it in action at Chapter Living, another Mace project, where it was being used in a trial to maintain installation rates at higher wind speeds.

Figure 14 Wolffkran Vita load navigator

The equipment was clearly useful for many lifting requirements, particularly where the load has increased windage due to the size and shape of the item and the height to which it is being lifted. Always maintaining control of the lift clearly has many benefits.

Following a review, it was concluded that the steel beams and flat heavy CLT planks being lifted at Timber Square were not ideally suited to the technology and a decision was made not to extend the trial to the project.

2. **Crane utilisation**

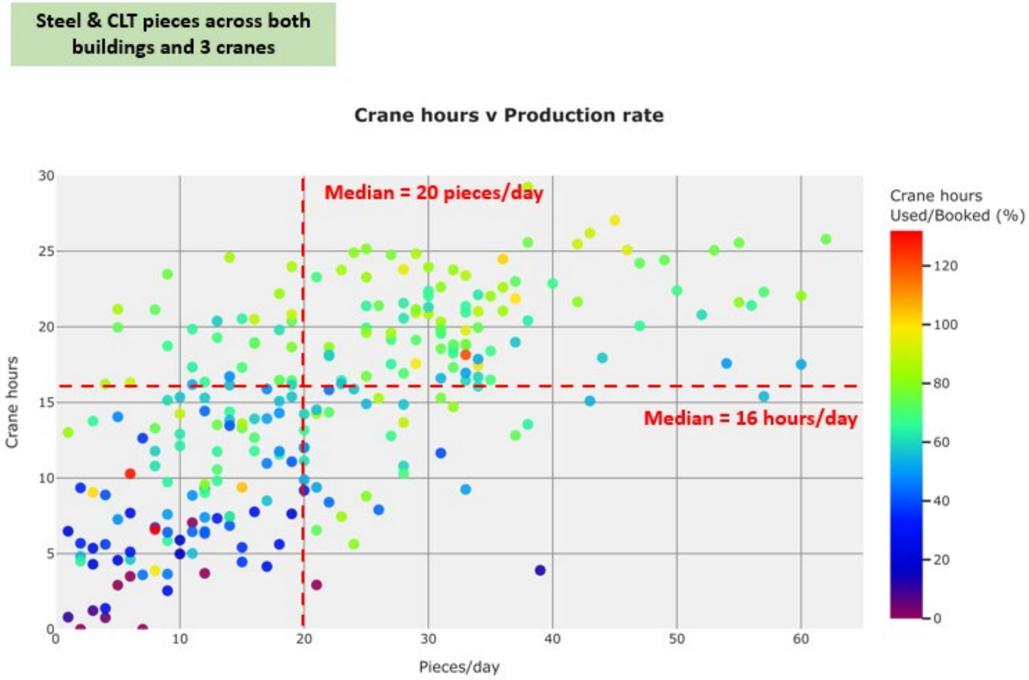


Figure 15 Timber square crane utilisation and production rates against crane hours booked

Figure 15 records actual craneage used (from 1 Gauva), of that allocated for steel and CLT erection, against crane hours and piece count. Mostly the level of crane utilisation was between 60-80% with a few occasions at 90% or more. Lower usage/allocation is associated with lower productivity. The construction team monitored the utilisation levels closely throughout the installation period. The data prompted the team to push the installation contractor for additional resource to fill extended working hours periods and increase resource at critical times to complete secondary tasks to maximise the use of the crane.

3. **Cranes clashing in work area / off-loading**

This was well managed with daily planning meetings. However, on a number of occasions when an activity was progressing ahead of schedule it might sometimes zone out another. Whilst this had limited impact on the project it highlighted that adding additional cranes, something reviewed in the early days of the project, does not always maximise lifting capacity on a site due to increased clashes and sharing of pick points.

4. **Jump-form platforms restricting access for lifting in structural elements.**

The completion of the cores overran the expected periods and the impact from the platforms shadowing the structure below increased, resulting in reduced productivity due to the more complex lifting methods needed. In the core areas there were many small pieces of steel and connections forming the risers between the buildings. It is recommended that future projects with this type of design should plan to prefabricate the steelwork elements used in core areas at the design stage. This would have enabled assembly into integrated components which could then be manufactured and delivered in manageable sizes.

5. **Working within and attaching to the existing building.**

Early exposure of the existing steel structure in the Print Building was important together with the surrounding elements of the building. This enabled detailed surveys to be carried out on the numerous connections needed between the old and new structure within the building before construction began. The installation of the new connections was completed successfully without impact to the programme.

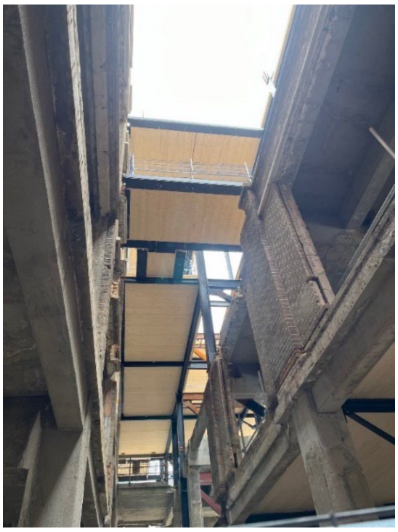


Figure 16 Image showing typical connections between old and new structure

6. Temporary support of CLT

To avoid the risk of having exposed CLT at terraces and roof areas, and to provide the same finish to the soffit on the office floor plates, the CLT was utilised as a permanent shutter for a concrete structural topping.

This required propping to be installed to support the structure in its "wet" condition. However, this added another labour-intensive activity slowing the sequence of installation. It continued to impact the following works due to curing and removal periods.

To avoid this issue, it is recommended for future projects that the CLT should be fitted as a soffit finish post the construction of the slab using a traditional metal deck / concrete installation.

Figure 17 Print Building upper floor construction

7. Resource / working hours - CLT installation by Steel erectors

Maximising the level of resource that can be used effectively is key for any project and seeking to maintain this at the optimum level was a focus throughout the structural installation of Timber Square. Having one installer for both steel and CLT components mitigated the daily co-ordination and logistical issues regarding the delivery of CLT cassettes to suit steel installation / crane utilisation. However, in order to realise the benefits, the steel fixers had to learn new skills to deal with the complexities of installing CLT.

Once CLT is landed in position it needs the requisite edge protection to be installed and completed. It has to be screw fixed from above and below to form the structural diaphragm action across the floor plate. The joints of the panels are then sealed with a breather membrane. The optimum split of labour resource and the sequence of installation requires a fixing gang working closely with the crane hook landing steel and CLT, and a secondary gang supporting closing out the floor plate.

During the project the team were able to agree extended hours with the council which then allowed working into the evening. However, it proved difficult to maximise productivity during these periods due to difficulties sourcing labour for the late shift and in achieving the target output levels when working into the night with the restrictions on noise.

Recommendations

Key recommendations for future projects to consider include:

1. Use of a crane camera linked with AI capability linked back to the design model to record daily installation activities, assess progress against programme and provide real time data to maximise productivity. This type of technology would provide detailed information for the structure and envelope installation teams. It would confirm precisely what was being lifted and to which building and location, providing a better understanding of crane utilisation particularly where a number of cranes are being utilised. Using three cranes split over two buildings at Timber Square presented a series of complex issues associated with the optimum sequencing and phasing of the works. This technology would assist in the management of this.

2. Create clear unhindered scope for crane operations – review in detail the sequence around high-level jump forms and any particularly restricted lifts. Assess opportunity of lifting off the underside of the jump form or other methods of lifting below the jump form - use of an offset lifting beam was found to be slow.

3. To maximise opportunities to accelerate where actual progress exceeded planned progress and to cover winded off periods, it would have been advantageous to secure additional site storage or local storage for steel/CLT components. (Clearly this is dependent on available space availability on site and/or budget allocation for local storage/consolidation space.)

4. Reduce the need for back propping of CLT and if required use a dedicated team for installation. Design out any requirement to use CLT to retain concrete in the temporary condition.

5. Minimise leading edges, reducing works to temporary edge protection and endeavour to complete full floor plates in sequence.

6. The secondary steel in drylined cores comprised many small components tying up crane time – need to focus on the design and planning stage on the prefabrication of modular units/assemblies and use alternative lifting methods to reduce reliance on tower crane hook time.

7. The CLT supplier Hybrid packed and shipped the panels in sequence for installation straight off the trailer. To minimise double handling the planned sequence of steel installation must be adhered to, and every effort should be made clear any blockers.

8. Identifying what labour resource was deployed in each building had to be based on supervisor/manager assessments and manually recorded information which was much less accurate than could have been obtained with digital measurement at controlled points of access to each building.

9. Although excellent data was available from the crane telematics it did not automatically capture information on the items being lifted, and where one crane served two buildings which location the crane was operating on. It would have been ideal to have the split of crane hours for different structural elements such as steel pieces and CLT panels.

Next steps

Although the data collected on the superstructure package did help to better inform the site team in their efforts to regain time on the programme, more needs to be done to get closer to real-time analysis. This will help derive insights from the data to accelerate corrective actions and plan recovery strategies based on productivity improvements. The project is currently capturing data from the cladding, lift, washroom and MEP Cat A installations. The production rate and productivity metrics achieved for these packages will be subject to further review and analysis as the works are completed during 2025.

References and acknowledgements

Measuring Construction Site Productivity: A Seven-Step Framework for Success, Construction Productivity Taskforce, 2022

Murguia, D., Rathnayake, A., Jansen van Vuuren, T., & Middleton, C. (2024). Measuring Construction Productivity across Projects: Multilevel Three-Dimensional Framework. Journal of Construction Engineering and Management, 150(11), 04024151.

Table of Figures