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Cambridge Framework for Construction Productivity

Measure · Benchmark · Improve

Dr Danny Murguia, Dr Ashan Asmone,
Dr Asitha Rathnayake and
Professor Campbell Middleton†

In memory of Professor Campbell Middleton,
Laing O'Rourke Professor of Construction Engineering,
University of Cambridge

Please cite this publication as:

Murguia, D., Asmone, A. S., Rathnayake, A. and Middleton, C. (2026). *Cambridge Framework for Construction Productivity: Measure, Benchmark, Improve*. Cambridge: Department of Engineering, University of Cambridge.

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Preface

Improving productivity has been one of the construction industry's most persistent challenges. Yet a fundamental barrier remains: the lack of an industry-wide method to consistently measure and benchmark productivity within and across projects. Without a common approach to measurement, it is difficult to determine what good performance looks like, understand why productivity varies, learn systematically from previous projects, or translate those lessons into better planning and delivery.

This publication presents our journey at the University of Cambridge to develop, test, and embed a practical method for measuring construction productivity on live projects in the UK and, increasingly, internationally. Our ambition has been to establish a consistent framework that can be applied across projects, work packages, and activities, revealing meaningful insight at every level.

Central to this journey has been a unique academia-industry collaboration, led by the University of Cambridge and built on trusted relationships with our industry partners. Their willingness to share real project data has enabled the Cambridge research team to develop the framework through evidence. Over several years, we have processed and analysed these data, tested the method through live demonstrator projects, built empirical benchmarks, and investigated the factors associated with productivity variability and underperformance. The UK Construction Productivity Taskforce and members of the World Construction Leadership Forum (founded in Cambridge) have supported this collaboration.

The result is not simply another set of productivity metrics. This publication provides a step-by-step guide for implementation during project delivery. It shows how to structure data to measure and benchmark construction speed and efficiency within and across projects, and how pooled datasets can generate further insights through data analytics. In turn, this creates a foundation for future applications of machine learning and AI-enabled predictive analytics.

The next challenge is for industry: moving from demonstrators and individual projects towards systematic adoption. As the late Professor Campbell Middleton stated:

"To really shift the dial, we believe that this framework should be embedded within the procurement process, with clients requiring the collection of productivity data as a matter of course during project delivery. This could be one of the most consequential shifts the industry can make."

By sharing our methods and case studies openly, we hope others will adopt, challenge, refine, and extend the framework. Our aspiration is to help move construction towards a more consistent, data-centric approach to understanding and improving productivity.

Dr Danny Murguia
Assistant Research Professor, University of Cambridge
September 2026

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Executive summary

The University of Cambridge Laing O'Rourke Centre is leading a major research programme to develop new, practical and scalable methods for measuring, benchmarking and improving productivity in construction through digitalisation and automation.

Motivated by long-standing concerns about low productivity in the sector, the fundamental challenge is this: construction projects generate large volumes of data, yet these datasets are typically fragmented across systems and archived after project completion, with limited mechanisms to systematically extract value and generate actionable insights that inform productivity and project outcomes. In addition, current methods for evaluating productivity are primarily reactive, using data collected to look back and reflect on project progress and deviations from plans, but not necessarily looking ahead. Furthermore, metrics for understanding labour productivity are fragmented and inconsistent and do not provide a granular perspective on opportunities for improvement.

Existing high-level productivity evaluations, such as national sector-level measures or overall Gross Value Added (GVA) per hour worked, offer very little insight to project managers, contractors, and decision-makers seeking to improve project delivery on construction sites. Unlike other industries, there is no widely adopted method for measuring and benchmarking productivity. This results in a lack of robust, evidence-based benchmarks for predicting and comparing project performance.

To support the industry in improving productivity, practical, scalable methods are needed to measure, benchmark, and improve project performance. The key is to explore how to use existing data from project planning and execution to provide actionable insights across project delivery. Advances in digitalisation and automation can be used to collect and analyse data, feeding back into live project control systems and providing the right information at the right time to the right people to make decisions.

The research programme began in 2021 with a first wave of pilot projects, followed by a second wave starting in 2023. Through close collaboration with industry partners, the Cambridge research team has collected and analysed data from more than 25 UK-based construction projects, leveraging digital technologies, data analytics, and automation to understand how construction work is planned and executed in practice. Successive pilot projects have enabled the research team to iteratively test and refine the method under live project conditions.

This collaboration has enabled the development of the *"Cambridge Framework for Construction Productivity"*, a multi-level framework that provides a structure to consistently measure productivity at different levels of granularity within a project. The framework integrates key productivity metrics, location-based visualisations, and digital dashboards to enhance transparency, situational awareness, and operational control on live projects. An essential part of this work has been the development of software based on the Cambridge Framework, translating the method into a practical

tool that can be deployed on live construction projects and support wider implementation.

The framework illustrates how commonly available project data, such as programmes, BIM models, progress records, labour, and blocker logs, can be structured and integrated to support meaningful analysis, both during live projects and in bidding and planning new projects. Notably, the framework enables productivity to be evaluated at increasing levels of granularity, moving from the overall project level to the work package level (such as the superstructure frame) and the activity level (such as installing structural steel, placing reinforcement, or installing cladding panels).

The two main phases during which the framework can be applied are during project delivery and during bidding and project planning:

- During project delivery – live project controls: using flowlines, production rates, labour productivity, and blockers to productivity to diagnose deviations, support corrective action, and stabilise production flow. Upon project completion, data analytics can support the creation of benchmarks and facilitate knowledge transfer about key challenges to achieving expected productivity rates.
- During bidding and planning: ability to create robust and defensible project programmes based on a clear understanding of tasks, sequencing, and interfaces. This relies on pooled datasets across projects, work packages, and activities to establish empirical benchmarks for production rate, labour productivity and cost efficiency while emphasising the importance of like-for-like comparison and sufficient analytical granularity.

Case studies used in developing the framework illustrate the value of structured use of existing data to measure productivity, explain variability, identify root causes of inefficiency, and provide evidence-based guidance for improvement. The granular analysis of project data at different levels provides actionable insights into productivity variation, workflow, and interface challenges that impact overall productivity.

To date, the framework has been developed and tested primarily with developers and their delivery teams on commercial and residential projects. While these sectors provide the empirical foundation presented in this publication, the underlying method is designed to be transferable. Future applications are expected to extend the framework to other building and infrastructure sectors, including hospitals, data centres, schools, and linear infrastructure such as roads and bridges

Overall, this publication argues that by treating data as a strategic asset and embedding productivity measurement into everyday project controls, construction organisations can move from reactive progress reporting to proactive, learning-oriented delivery. The “Cambridge Framework” provides a practical foundation for this transition and sets out a pathway toward more reliable, productive, and data-driven construction engineering, both in the UK and internationally.

Implementing the Cambridge Framework

Drawing on the evidence presented, industry leaders, clients, and policymakers are encouraged to adopt a structured approach to measuring, benchmarking, and improving productivity by implementing the "Cambridge Framework". Achieving sustained improvement requires coordinated action across the construction value chain. Asset owners should mandate productivity measurement and standardised data sharing across projects, define minimum data requirements at each stage, and establish portfolio-level productivity databases to enable benchmarking and continuous improvement. Designers should use productivity metrics to inform design decisions, considering constructability, standardisation, and opportunities for off-site production. Contractors should implement systems and technologies to capture activity-, work package-, and project-level data and use the resulting metrics to support planning, control, and productivity improvement. Product and material suppliers should contribute fabrication, delivery, and installation data linked to project information and digital models.

As a practical next step, industry partners are invited to implement the framework and participate in pilot projects using the software solution developed by the University of Cambridge, helping to test and refine its application on live construction projects. Through these collective actions, organisations can systematically convert project data into actionable insights that support continuous improvement and more predictable project outcomes.



Reading this publication

This publication presents the development and application of the Cambridge Framework for Construction Productivity**.** It moves from the challenge of consistently measuring productivity through implementation and project control to benchmarking and advanced data analytics. While you can read the publication from beginning to end, each chapter provides value on its own, depending on the reader's role and objectives.

Chapters 1–2 | UNDERSTAND THE CHALLENGE

These chapters introduce the construction productivity challenge and explain how the University of Cambridge developed the framework through a multi-year collaboration with industry partners. They describe the research journey from initial pilot studies to testing and refinement using data from live construction projects.

Useful for: all readers seeking to understand the framework's motivation, evidence base, and development.

Chapter 3 | IMPLEMENT THE FRAMEWORK

Chapter 3 presents the Cambridge Framework for Construction Productivity. It defines the metrics, datasets, levels of analysis, and data requirements needed to turn raw project data into actionable insights. A six-step implementation process provides practical guidance for embedding the framework within project delivery.

Useful for: organisations and project teams seeking to establish a consistent approach to productivity measurement and data collection.

Chapter 4 | PRODUCTIVITY MONITORING AND CONTROL

Chapter 4 demonstrates how the framework can support live project controls. It combines planned and actual flowlines, production rates, labour productivity, and productivity blockers to identify variability, diagnose emerging problems, and inform corrective action.

Useful for: project managers, project controls teams, planners, and construction engineers responsible for managing trades and work packages.

Chapter 5 | BENCHMARK PRODUCTIVITY

Chapter 5 demonstrates how structured historical data can establish benchmarks at project, work-package, and activity levels. It provides reference distributions for production rate, labour productivity, and cost-effectiveness that can be used to interrogate planning and comparisons of future projects.

Useful for: clients and contractors during tendering and pre-construction, particularly planners and cost estimators seeking evidence-based assumptions for programme, resources, productivity and cost.

Chapter 6 | ANALYSE AND PREDICT

Chapter 6 moves beyond benchmarking to interrogate the factors associated with productivity. Examples cover off-site construction, batching strategy, cycle time, and crane allocation, showing the additional insights you can extract from structured historical datasets.

Useful for: data managers, analysts, and digital teams seeking to assess risk and develop predictive analytics, including future machine-learning and AI applications.

1. Introduction

Despite advancements in digital technology, off-site manufacturing, and improved safety and quality standards, the construction industry continues to face a long-standing challenge: stagnant or declining productivity, as measured by national statistics (Office for National Statistics, 2021). While the manufacturing sector has seen steady gains, national statistics and industry reports show that construction's economic output per hour worked has barely improved over the years. However, these national statistics (macro-level) do not reflect what is happening within individual projects (micro-level), where new methods and innovations should, in theory, drive productivity improvements.

The problem lies in how productivity is measured. Current national statistics focus on economic indicators such as Gross Value Added (GVA) per hour worked, which offer little insight to project managers, contractors, and decision-makers seeking to improve productivity on construction sites. Unlike manufacturing, where methodologies such as lean production or overall equipment effectiveness (OEE) provide standardised productivity benchmarks, no equivalent method has been widely adopted in construction. Without this, it is nearly impossible to identify inefficiencies, compare project performance, or make informed decisions to drive improvement. A closer look at major construction projects reveals three common issues in current project controls:

- **Heavy reliance on Gantt Charts for planning and tracking progress -** while effective for simple projects, Gantt charts become unwieldy on complex programmes, obscuring interdependencies and offering limited insights into flow or resource constraints, limiting their practical use in productivity improvement
- **Basic productivity metrics that do not tell the full story -** many projects assess productivity using metrics such as activity count or cumulative actual v planned progress (Rathnayake et al., 2024), but while these help track delays, they fail to capture flow efficiency, process bottlenecks, or interactions among activities
- **Reactive, lagging indicators that delay corrective action -** most project controls report on what has already happened rather than providing forward-looking insight, and by the time issues are visible in the data, the window for effective intervention has often passed

As a result, project teams often lack a clear picture of current productivity levels or where improvement opportunities lie. To address this challenge, this publication introduces a **multi-level, three-dimensional productivity measurement framework that provides greater clarity and transparency into** construction productivity (Murguia et al., 2024). Developed in collaboration with major developers and Tier 1 and Tier 2 contractors in the UK, this framework provides a structured approach to measuring productivity at three key levels: **project, work package and activity**. It lays out clear methodologies for data collection and analysis, helping construction professionals understand productivity variability, benchmark against other projects, and leverage data analytics for decision-making.

By consistently applying this framework, industry practitioners can gain a more accurate view of construction productivity, interrogate the root causes of underperformance, and improve visibility into project controls. However, success requires active engagement with the supply chain, particularly with Tier 2 contractors, and a commitment to systematic data collection. Clients also have a role to play by setting productivity data requirements and fostering greater transparency in cost and time benchmarks. While automation technologies can support data collection and analysis, human oversight remains critical.

Key applications of this framework include:

- **Visualising productivity data** and understanding its variability
- **Benchmarking productivity** within and between projects and organisations
- **Identifying cause-and-effect relationships** to pinpoint factors impacting productivity
- **Integrating insights into planning** with planners and quantity surveyors
- **Using machine learning (ML) models** for simulation and predictive analysis

As the industry builds large datasets using this approach, we can finally answer critical questions that have long shaped construction policy and strategy. For example, how do digital technologies, off-site construction, and procurement models impact project performance? How do clients use productivity benchmarks to encourage collaboration across the supply chain? And how do contractors implement data-driven insights to improve programme and cost reliability whilst maintaining competitiveness in the market? Answering these questions, and acting on the answers, is how a structured, data-driven approach, such as our framework, can drive a genuine step-change in construction productivity.

2. How this framework was developed

The “Cambridge Framework” presented in this publication aims to develop a robust and standardised method for consistently measuring project-level productivity. The framework was developed iteratively, with continuous refinement based on real-world testing, extensive collaboration with industry partners and ongoing stakeholder feedback. This approach ensured that the framework was theoretically sound and practically viable, addressing the complexities and dynamic nature of construction projects while maintaining a clear focus on the key productivity indicators that matter most.

Phase 1 of this work originated from the CIRIA C792 report *“Methodology for quantifying the benefits of off-site construction,"* which developed a framework for measuring project performance to investigate whether off-site construction delivers the intended benefits (Jansen van Vuuren and Middleton 2021). The report proposed several performance areas depicted in Figure 1, including direct project impacts, broader project impacts, and wider societal impacts. To test the proposed method, the report used final outcomes of school projects that employed varied construction methods, ranging from traditional in-situ construction to off-site and modular components. The report revealed that performance data were inconsistent within and between construction organisations, or simply unavailable. Only some aspects of direct project impacts could be evaluated, such as cost, time, and labour. Due to inconsistent and variable data on project performance, it was not possible to robustly determine the relationship between construction method and project outcomes. Consequently, it became evident that more granular data are needed to improve the understanding of performance and productivity in construction projects more broadly and not only those employing off-site construction methods.

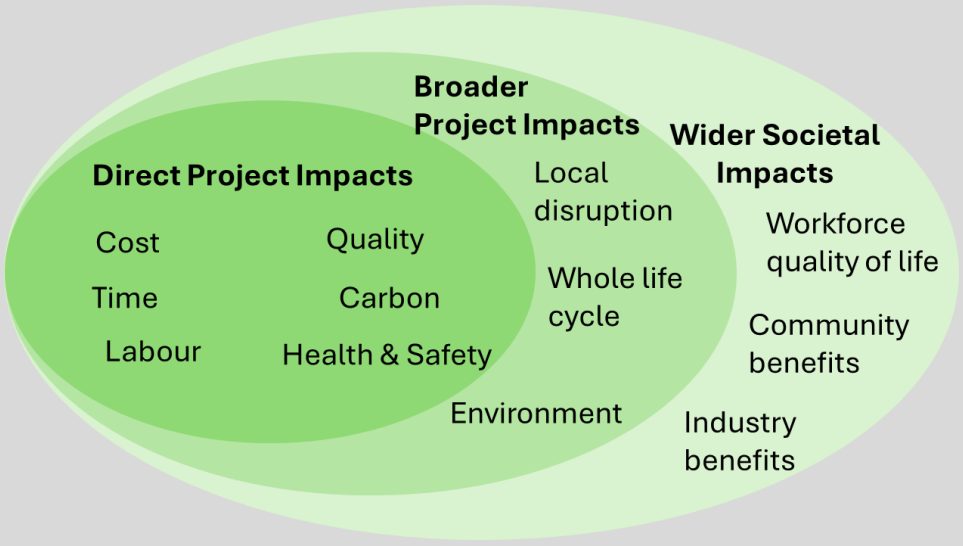


Figure 1: ‘Areas of impact’ for selecting metrics for construction projects (Source: CIRIA report C792)

Phase 2 of this work included working more closely with industry partners on live construction projects, in order to: i) understand how productivity is measured and controlled on a regular basis, ii) understand what digital data and enabling technologies are available, iii) identify the data gaps, and iv) to design, develop, test, and iterate a robust method for measuring productivity.

The framework was first developed and implemented in three pilot projects in 2021 and 2022. It was refined based on feedback from pilot projects and further tested using historical data from over 15 building projects in the UK. The framework underwent a second phase of refinement with four further live pilot projects. These pilot studies were instrumental in identifying practical challenges associated with data collection, metric definition, and measurement consistency. The research team worked closely with a diverse range of industry partners, including clients and Tier 1 and Tier 2 contractors, to capture real-world data. A structured programme of workshops, presentations, and direct consultations generated critical feedback, enabling the framework to be refined through iterative cycles. This collaborative process strengthened the technical robustness of the measurement method while ensuring alignment with industry practices, capabilities, and decision-making needs. Common challenges such as variability in data quality, inconsistencies in measurement approaches, and external influences on project outcomes were systematically addressed through standardisation, clearly defined data-collection protocols, and sustained stakeholder engagement. Continuous testing and refinement in live project environments enhanced the framework's reliability, usability, and scalability, establishing it as a practical tool for measuring site-level productivity across a range of construction contexts.

This work culminated in the development of a comprehensive *"Cambridge Framework for Construction Productivity,"* supported by a unique, structured dataset that may be among the first of its kind globally. The framework and its initial applications are presented in this publication, drawing on data from schools, residential, and commercial projects. It is anticipated that the framework is transferable to a wider range of construction sectors, including healthcare, schools, prisons, data centres, and transport infrastructure such as roads and bridges.



3. Cambridge productivity framework

3.1 Current practice

How does the sector measure productivity?

In practice, construction organisations predominantly assess productivity by tracking progress, that is, the completion of planned outputs over defined time intervals (e.g., daily, weekly, or monthly) and cumulatively against baseline plans. This metric is typically called "activity count," "percentage of plan complete" or "schedule performance index (SPI)" as per the earned value management thinking[1]. While progress-based metrics are effective for indicating whether a project is broadly "on track" against the programme, they provide limited insight into how efficiently work is being executed. Specifically, they do not capture the variability, continuity, or stability of production flows, nor do they explain the underlying causes of performance deviation, disruption, or waste. As a result, such measures support compliance-oriented control but offer little diagnostic value for understanding why productivity issues arise or how to systematically improve or mitigate them.

Labour productivity, typically expressed as output[2] per hour worked, is widely recognised as a valuable productivity metric, yet its application in practice remains inconsistent and incomplete. On its own, labour productivity does not account for other critical production inputs, such as materials and equipment, particularly in off-site construction. Through our research, we have found that labour productivity is not measured consistently at site level for several reasons:

(i) the perception that increasing levels of off-site or industrialised construction reduce the relevance of labour-based metrics;
(ii) the prevailing view among Tier 1 contractors that responsibility for labour productivity lies primarily with subcontractors, given that Tier 1 contractors' primary focus is on programme and cost control rather than labour productivity; and
(iii) persistent challenges in accessing timely, reliable, and sufficiently granular data.

Collectively, these factors limit the sector's ability to develop a coherent, system-level understanding of productivity and constrain opportunities for proactive productivity improvement (Rathnayake et al., 2024).

[1] A project control method that integrates scope, schedule, and cost to assess project performance and forecast outcomes against a baseline plan

[2] Commonly measured as gross value added (GVA) by economists, though in practice, construction organisations equate project cost and GVA. It is worth noting that using overall project cost as a proxy for output can obscure true productivity: for instance, constructing the same component at a higher material cost does not reflect genuine productive efficiency, i.e., the distinction between installing a tap and a "golden tap."

Lack of project-level productivity databases

Despite widespread recognition of productivity challenges, the construction sector continues to operate with limited access to robust, project-level productivity data and benchmarks. In practice, many estimators still rely on historic time-and-motion studies to determine gang sizes and activity durations, with some datasets tracing back to studies conducted in the 1960s by John Laing Construction Ltd. The continued use of such data raises concerns about its relevance to contemporary construction, given fundamental changes in technologies, construction methods, supply chains, and workforce composition.

While macro-level productivity indicators are available in national economic statistics (e.g., ONS), there is a notable absence of structured, project- and activity-level datasets that enable consistent analysis of productivity across projects. Developing such databases presents several challenges, including defining standardised metrics, capturing consistent and reliable data, ensuring applicability across different construction sectors and sub-sectors, and addressing concerns around confidentiality and commercial sensitivity, which often deter organisations from sharing granular productivity data. As a result, productivity analysis remains fragmented, retrospective, and difficult to benchmark at the level where operational decisions are made.

Addressing these limitations requires a holistic approach to productivity measurement that goes beyond isolated activities or high-level outcomes to capture metrics across the construction process and workflows. An effective productivity framework should:

- Measure labour productivity alongside production rates and costs, incorporating the role of materials and equipment, particularly in off-site construction
- Provide insights into how activities and work packages perform, rather than focusing solely on final project outcomes
- Identify leading indicators to help predict productivity variations and understand their impact on project results
- Leverage data and analytics to improve benchmarking and enhance decision-making in project planning and execution
- Be applicable across different organisations and projects to facilitate the development of industry-wide datasets

In response, this study introduces a **multi-level productivity framework** that examines productivity at three interconnected levels: project, work package, and activity (Murguia et al., 2024). The framework provides a structured approach to data collection and analysis, enabling systematic investigation of productivity variation and facilitating cross-project comparison. By directly addressing the shortcomings of current measurement practices, the framework provides a practical, scalable foundation for improving understanding of productivity and data-driven approaches in construction.

3.2 The productivity framework

The proposed framework provides a structured and scalable approach to measuring productivity across three analytical levels: activity, work package, and project, as illustrated in Figure 2. Productivity measurement is anchored at the activity level, where work is executed and resources are consumed, and is progressively aggregated to the work-package level and, ultimately, to the project level. A key contribution of the framework is the explicit introduction of the work package as an intermediate level of analysis, creating a critical link between activity measurements and project outcomes. This intermediate layer enables a coherent and traceable flow of productivity information across levels, supporting both operational control and strategic decision-making.

1. **Project level**, representing final delivery outputs aligned with defined project objectives and scope
2. **Work package level**, aligned with the work breakdown structure and commercial packages
3. **Activity level**, representing discrete operations where work is executed and resources are directly consumed

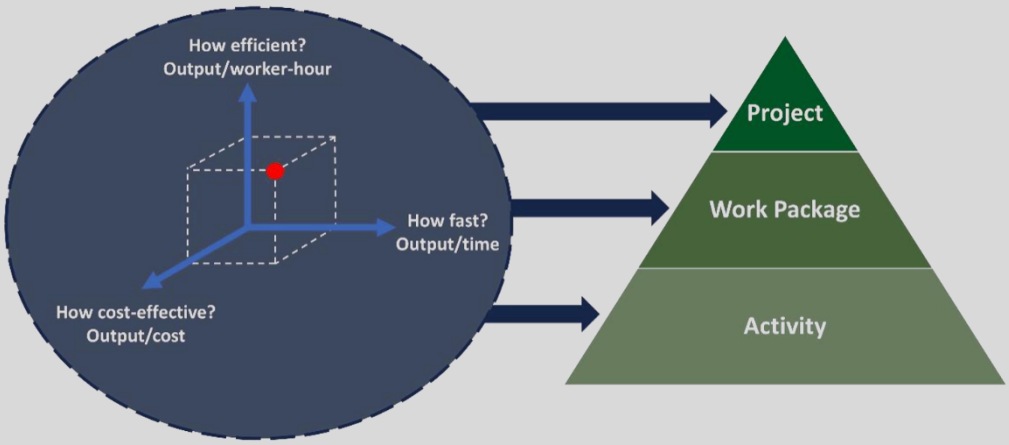


Figure 2: Multi-level three-dimensional productivity framework (Murguia et al., 2024)

Across all three levels, the framework applies a consistent set of productivity metrics, ensuring comparability and alignment of measurement. These metrics are designed to address fundamental productivity dimensions and answer three core questions:

1. **Production rate:** How fast? (Output per unit of time)
2. **Labour productivity:** How efficient? (Output per worker-hour)
3. **Cost-effectiveness:** How cost-effective? (Output per unit of cost)

Together, these metrics provide a balanced, multi-dimensional view of productivity, enabling assessment in terms of progress, efficiency, and cost outcomes across activities, work packages, and projects.

Because all three metrics share a common numerator, measured physical output, they remain directly comparable across activities, work packages, and projects. By using output[3] as the common factor across all three levels, this approach enables direct comparisons. The goal is to achieve faster delivery, with fewer worker-hours, while maximising cost-effectiveness. Implementing this framework across different levels of analysis provides several key advantages, as will be presented throughout this publication:

- Standardised metrics for better comparisons between and within projects
- Greater transparency by revealing productivity variations
- Opportunities for advanced data analysis, such as clustering and big data insights
- More informed decision-making by giving planners and cost estimators deeper insights into productivity trends

By structuring productivity measurement this way, the framework enables clearer understanding at every level, helping project teams make better data-driven decisions.

3.3 From raw data to metrics and insights

Figure 3 illustrates how the multi-level productivity framework structures data collection and transforms raw project data into actionable, data-driven insights. The framework organises information into four complementary data categories: outputs, inputs, descriptors, and variability factors, which are captured consistently across different levels of analysis, from daily activity to work package and project level.

[3] In each case, output refers to the measurable physical quantity of work produced (e.g., m² completed, pieces installed, m³ placed, linear metres completed, etc.)

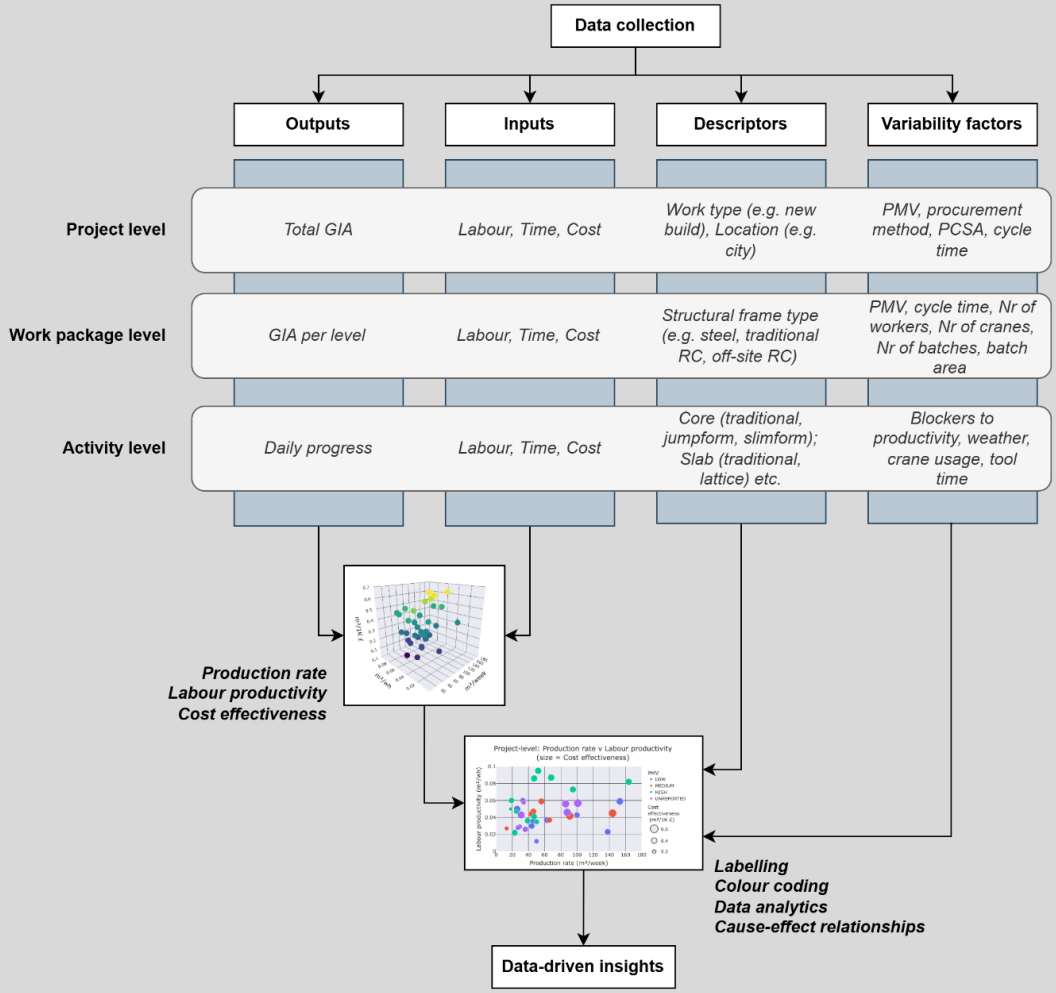


Figure 3: Overview of the process for data integration

Outputs represent the physical production achieved and define what is being delivered. These include measures such as total area (e.g., Gross Internal Area (GIA) for buildings) at the project level, GIA per level or location[4] at the work-package level, and daily progress at the activity level. The appropriate output measure will vary by project type (e.g., for infrastructure projects, relevant units might include lane-

[4] A location is a discrete spatial unit used to plan, sequence, and monitor production, enabling work to be assigned, tracked, and handed over in manageable portions across the work front. For instance, in structural works, floor plates are divided into two or more zones.

kilometres, linear metres of pipeline, or m^2 of bridge deck area). Outputs serve as the numerator for productivity metrics and form the basis for comparing performance over time, locations, and projects.

Inputs capture the resources consumed to generate these outputs, typically including labour, time, and cost. By pairing outputs with inputs, the framework enables the calculation of production rates (output per unit of time), labour productivity (output per worker-hour), and cost-effectiveness (output per unit of cost) consistently across all analytical levels.

Descriptors provide contextual information that characterises the nature of the work but does not directly explain productivity variation. Examples include work type (e.g., new build or refurbishment), structural system (e.g., steel, in-situ concrete, off-site concrete), location, and sector. These variables act as control or grouping variables, allowing results to be normalised, compared, or clustered (e.g., by sector or construction method) and supporting fair benchmarking across projects that differ in type, scale, procurement route, or construction method.

Variability factors capture conditions and operational characteristics that influence productivity and are treated as leading indicators. Unlike simple output-to-input ratios, these factors support the exploration of cause-and-effect relationships and help explain why productivity varies. Examples include:

1. Project level: procurement route and planning methods
2. Work-package level: cycle time, number of workers, batch size, or number of locations
3. Activity level: blockers to productivity, weather conditions, or equipment utilisation

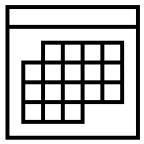
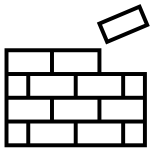
Variability factors can be broadly distinguished by how they are used. Controllable factors (e.g., number of locations, batching strategies, or crew size) are levers that practitioners can actively adjust to improve performance, and their relationships to productivity outcomes can inform planning and operational decisions. Contextual factors (e.g., weather, project complexity) are not directly manageable on a project but provide essential explanatory context, enabling like-for-like comparisons and supporting more meaningful benchmarks across projects.

By integrating these four data categories, the framework enables the analysis of productivity metrics alongside contextual and leading indicators. This structure supports deeper diagnostic analysis, comparison across projects and work packages, and the generation of data-driven insights that go beyond reporting progress to understanding the drivers of productivity variation; not just what productivity was achieved, but why.

3.4 Datasets

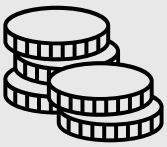
The implementation of the multi-level productivity framework relies on the systematic integration of heterogeneous datasets that capture planned intent, executed work, resource inputs, and contextual conditions. Rather than relying on a single data source, the framework brings together programme, design, progress, labour, cost, and contextual data to enable consistent measurement across activity, work package, and project levels. Table 1 outlines the core datasets required to operationalise the framework, describing their purpose, typical sources, and key considerations for ensuring data consistency, traceability, and analytical reliability.

Table 1. List of example datasets needed to implement the framework

Data	Description
Programme (as planned) 	Programme data typically takes the form of Gantt charts and defines the planned sequence, duration, and logic of construction activities. Where available, both the contract programme and the programme to build[5] should be collected to capture differences between contractual intent and operational planning. Where programmes may exist in multiple revisions, it is important to identify the current revision at each relevant point in time. These datasets provide the baseline against which progress and productivity are assessed.
Digital model (as designed) 	The BIM model is used to extract planned outputs and quantities, such as floor area (m^2) per level, concrete volumes (m^3) per zone or level, and the number of structural or architectural components per zone or level. At the component level, models must use consistent, unique identifiers to enable integration with other datasets, including installation dates, progress records, and cost information.
Progress 	Progress data are captured in a wide range of formats and levels of granularity, reflecting the diversity of data sources used on construction sites. Common sources include digital site apps, planners' spreadsheets, formal progress reports, subcontractors' internal systems, and cloud-based dashboards provided by construction technology (ConTech) companies. Progress can be measured through multiple mechanisms, depending on the trade and system involved. Examples include piece-level installation records for structural steel, cladding, or off-site manufactured components (typically daily); concrete pour records (daily); automated progress reports derived from 360° image capture platforms (weekly); CCTV imagery from tower cranes

[5] Contract programme is a formally issued contractual document as accepted by the employer, whereas the programme to build is the working document used by the site team to plan and execute the works.

	or adjacent buildings (e.g., images every 5–10 minutes); and point-cloud data with embedded progress information (typically weekly). Where applicable, delivery data, such as for precast or cladding components, may be treated as progress data when a “one-touch” handling approach is used, whereby components are lifted directly from delivery vehicles to their final installed location without intermediate storage.
Labour 	The first level of labour data is typically derived from site access control systems (e.g., turnstiles), providing headcount and/or total worker-hours by trade. Careful data cleaning is required to ensure that only operatives and supervisors are included, excluding managers, visitors, trainees, and other roles not directly involved in construction activities that often appear in raw turnstile records. Special attention must be paid in situations where multiple workflows occur simultaneously, such as the parallel construction of two or more buildings or zones, while only a single turnstile is in place at the project entrance. In these cases, turnstile data must be disaggregated to avoid conflating labour inputs across workflows. Workers should be explicitly identified and assigned to the specific workflow, building, zone, or level where they operate, using supplementary data sources as needed. A further complication arises where trade contractors operate concurrently across multiple work packages, as aggregate attendance data will not support direct attribution of labour inputs to individual work packages. In such cases, supervisor-level daily allocation records are a necessary complement, and their collection should be planned as part of the data capture strategy from the outset. More granular labour data can be obtained from digital forms or mobile applications, where supervisors or site engineers record individual workers' daily assignments to specific activities or workflows.
Blockers to productivity 	A structured taxonomy of productivity blockers captures factors that constrain or disrupt production. 33 such blockers are grouped into 10 categories (Appendix A) and serve as inputs to explanatory analysis. Depending on site conditions, these data may be captured directly by supervisors or site engineers using digital forms structured around the taxonomy or derived retrospectively by coding existing site records (e.g., daily reports, site diaries, RFIs), enabling systematic analysis of the causes of productivity variation.
Crane data 	Crane data may include sensor-based information on hook position and movement, visual data identifying lifted objects and lift durations, or records captured via digital applications in which crane drivers log what is being lifted and for which work package or trade. These data provide insight into material flow, utilisation, and constraints at the workface.

Site reports 	Textual data are sourced from planners' reports, dashboards, and contractual or commercial reviews, typically provided as Word or PDF documents. These unstructured data offer qualitative context on productivity, risks, and decision-making, and can be analysed using Large Language Models (LLMs).
Cost 	Cost data includes the total cost paid by the client, captured at the project level and, where available, disaggregated by work package. These data support cost-effectiveness analysis and integration of financial and production metrics.
Weather 	Weather data are sourced from on-site sensors (e.g., crane-mounted anemometers) or from publicly available datasets. Particular attention is given to conditions known to affect productivity and safety, such as wind gusts, rainfall, snow, and extreme temperatures. These data inform causal analysis of productivity variation.

3.5 Varying levels of data requirements and outputs

Construction projects and organisations operate at varying levels of digital maturity. As maturity increases, so does the ability to transform raw data into actionable insights and ultimately into real-time decision support. At a fundamental level, the type, quality, and granularity of available data directly determine the level of analytical output that can be achieved. This progression can be broadly categorised into three maturity tiers:

Bronze - Foundational visibility

At this level, organisations rely on essential, historical, or semi-structured datasets. These datasets enable basic benchmarking and descriptive analytics. Typical outputs include:

- Productivity comparisons (e.g., production rates by number of cranes, batching strategy, or structural frame type)
- Observation of variability within and between projects and establishment of benchmarks

Silver - Diagnostic insight

At the silver level, more structured and connected datasets become available, often combining multiple sources (e.g., cost, labour allocation, equipment usage, and weather data). Here, data begins to support explanation and informed decision-making, rather than just observation. This enables:

- Deeper analysis of productivity variability
- Identification of key productivity drivers and constraints
- More robust benchmarking that accounts for contextual factors
- Early-stage predictive or scenario-based analytics

Gold - Predictive and real-time control

Gold-level maturity is characterised by automated, high-frequency, and integrated data streams, often enabled by sensors, computer vision, and digital platforms. At this stage, data enables continuous feedback loops, allowing teams to move from reactive management to proactive and predictive control. This supports:

- Near real-time monitoring of site activities
- Automated progress tracking and productivity measurement
- Proactive identification of risks and blockers
- Simulation, dynamic planning and optimisation

See Table 2 to see how typical site-level data can be divided into these tiers.

Table 2. Different levels of data for different types of outputs

Data Category	Data Type / Description	Typical Source	Bronze (Descriptive)	Silver (Diagnostic)	Gold (Predictive / Real-time)
Outputs	Quantities (e.g., GIA, concrete volume, number of elements)	BIM models	✓	✓	✓
Programme	Planned start/finish dates	Contract programme/ programme to build	✓	✓	✓
Cost	Labour, equipment, and material cost	Commercial systems, cost reports		✓	
Progress Tracking	Actual start/finish dates	Progress reports, installation records	✓	✓	
Progress Tracking (Automated)	Actual start/finish dates and quantities per location	Image data, point clouds and computer vision systems			✓
Labour (Aggregate)	Headcount and total hours by crew	Turnstiles, attendance systems	✓		
Labour (Allocated)	Labour allocation by activity and location	Daily labour allocation forms, supervisor reports		✓	
Labour (Tracked)	Worker-level movement and activity tracking	Bluetooth/RFID/ wearables			✓
Crane (Usage)	Crane bookings and usage logs	Crane management systems		✓	
Crane (Instrumented)	Lift detection, duration, and allocation to trades	Sensors and computer vision systems			✓
Weather	Weather and site conditions	Public datasets, on-site sensors (e.g., cranes)		✓	
Blockers to productivity	Reported blockers (e.g., access, sequencing, delays)	Daily reports, supervisor/planner inputs		✓	
Blockers to productivity (Inferred)	Automatically detected blockers (e.g., delays, coordination issues)	Computer vision systems, audio inputs, and NLP from voice notes			✓

3.6 Step-by-step framework implementation process

While the insights generated by the framework are valuable to a broad range of stakeholders (including clients, senior leadership, and supply chain partners), responsibility for implementing and operationalising the framework on-site sits with project teams. In practice, this means construction leads, project managers, site engineers, and commercial managers working together to embed productivity measurement into routine project delivery. The steps that follow set out how project teams can do this in a structured and scalable way, from initial stakeholder alignment through to live productivity monitoring and benchmarking.

To support the practical adoption of the multi-level productivity framework, this section outlines a structured implementation process for construction organisations and site teams. The process translates the measurement approach into a clear sequence of actions, from establishing stakeholder alignment and defining the scope of work packages and activities, through resourcing, data capture, and template validation, to embedding the framework into routine productivity control and, ultimately, enabling benchmarking and more advanced analytics. Figure 4 summarises these six steps as an end-to-end roadmap to ensure implementation is consistent, scalable, and aligned with site and organisational operations.

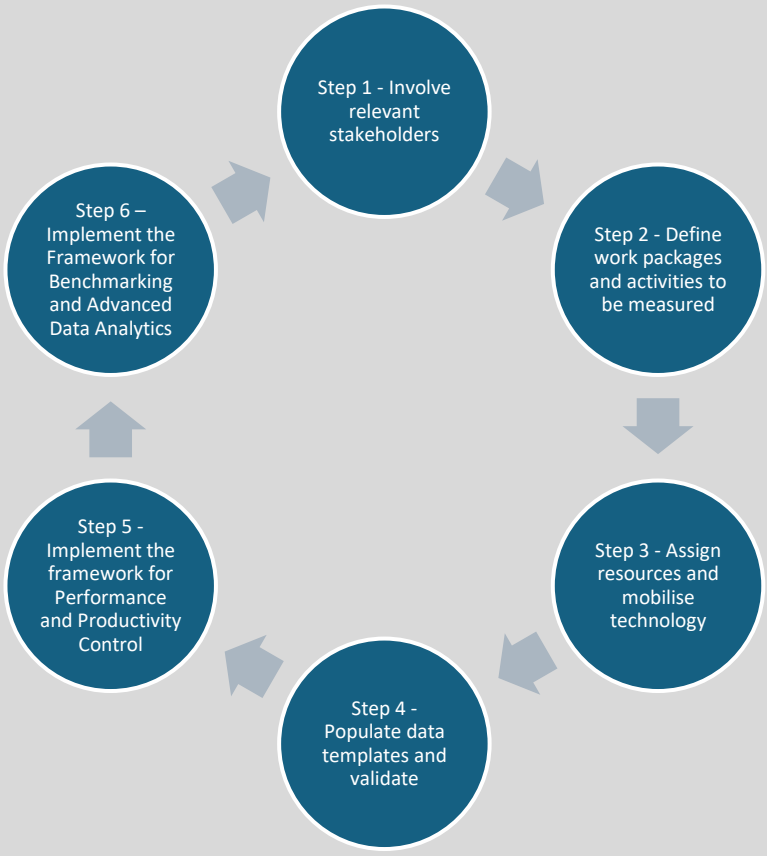


Figure 4: Step-by-step framework implementation process

Step 1 - Involve relevant stakeholders

Implementation begins with early alignment and ownership across key project stakeholders to ensure the framework supports project objectives and can be applied effectively in practice. This step establishes the governance foundations required for data-driven productivity measurement. This step involves:

- **Identify stakeholders:** Engage stakeholders across strategic, commercial, and operational functions, including clients, Tier 1 contractors, key subcontractors, and project-level roles such as project managers, work package managers, quantity surveyors, planners, and site engineers
- **Share the vision:** Communicate the value of the framework using practical examples of visualisation and analytics (as presented in Chapters 4, 5, and 6), demonstrating how comparable and structured data can support better decision-making and benchmarking rather than progress reporting
- **Align objectives:** Use initial workshops to agree on the scope of measurement, identify available data sources, assign responsibilities for data capture and validation, and confirm stakeholder commitment to ongoing participation
- **Establish communication channels:** Define clear communication and data-sharing protocols to facilitate ongoing collaboration and feedback

Step 2 - Define work packages and activities to be measured

Building on stakeholder alignment, the second step focuses on defining the measurement scope by selecting the work packages and activities that will deliver the greatest analytical value. This ensures that data collection and analysis remain targeted, proportionate, and aligned with project priorities. This step involves:

- **Define analytical focus[6]:** Identify the work packages (e.g., substructure, cores, superstructure, cladding, fit-out) and the specific activities within them where productivity insights are most critical, informed by project risk, scale, and repetition
- **Define data granularity:** Determine the level of detail required for analysis at activity and work-package levels, considering both analytical needs and the availability and reliability of data sources as presented in Table 2
- **Define data temporality:** Establish the appropriate time resolution for data capture, with daily installation data typically required and higher-frequency data (e.g., hourly) used where justified by the nature of the work

[6] Defining and prioritising work packages or data granularity shall be based on scale (high-value or resource-intensive), repetition (activities recurring across floors or zones), and risk (packages with high variability or programme pressure)

As a minimum, work-package-level analysis requires programme, actual progress, and labour data disaggregated by location (e.g., floor or zone). Activity-level analysis further requires time- or location-based datasets, such as daily installation records or start and finish dates per activity and location.

Step 3 - Assign resources and mobilise technology

Once the analytical focus is established, the data-gathering approach must be defined. This step involves mobilising the necessary human resources, processes, and technological solutions to ensure consistent, reliable data capture. Key activities include:

- **Assign personnel:** Designate site-based personnel responsible for data collection, validation, and entry to ensure consistency across data sources, and wherever possible, involve trades and supervisors actively in the data capture process to reflect how work is executed on site
- **Leverage technology:** Deploy digital tools appropriate to the nature and scale of the work being measured. Data capture technologies such as CCTV, IoT sensors, point clouds, and 360° imagery are best suited for repetitive or high-frequency activities where continuous monitoring is preferable to manual recording. Active digital platforms (e.g., mobile apps, information systems) are better suited to structured data entry by site personnel. Traditional methods, such as spreadsheets, remain valid when digital infrastructure is limited and are used to capture both structured and unstructured data.
- **Establish processes:** Develop and document standardised procedures for data collection, including protocols for manual entry and automated data capture
- **Define validation and cleaning responsibilities:** Establish clear ownership for data validation and cleaning, including who is responsible for reviewing entries, resolving anomalies, and ensuring data integrity before templates are submitted for analysis. This should be agreed at the outset and reflected in the site team roles.
- **Ensure alignment:** Confirm that selected processes and technologies are consistent with the data granularity and temporality defined in Step 2, ensuring that collected data are relevant and actionable

In addition, targeted training and capacity building should be provided to maximise the effectiveness of data management. This may include training in standardised data collection, data integrity, the interpretation of productivity insights, the effective use of digital tools, and change management to support the adoption of data-driven working practices.



Step 4 - Populate data templates and validate

Once data have been collected, the next step is to populate a standardised template[7] and ensure data quality and consistency. This step is critical to enabling reliable analysis and cross-project comparability. Key activities include:

- **Data entry into templates:** Record collected data using predefined, standardised templates tailored to each analytical level (activity, work package, and project)
- **Automated extraction:** Where feasible, integrate with existing construction information systems, such as planning tools, BIM platforms, or ConTech solutions, via APIs or data exports to automate population of templates and reduce manual effort and errors
- **Validation and quality assurance:** Apply automated validation checks during data entry to verify completeness (no missing required fields), consistency (units, formats, and naming conventions are applied uniformly), and plausibility (values fall within expected ranges for the activity type). Anomalies should be flagged for review rather than automatically corrected to preserve data integrity.

To ensure consistency across projects, all data must be captured using the same standard templates. These templates typically include labour allocation, daily production or piece counts, progress updates, weather conditions, and recorded productivity blockers. Standardisation enables uniform data collection, comparability of productivity metrics across activities and work packages, and efficient automated data processing.

Step 5 - Implement the framework for Productivity monitoring and control (Chapter 4)

Following validation, the collected data are processed by the framework's automated workflows to generate actionable insights at the activity, work-package, and project levels for live construction projects. The framework is a structured method for measuring and managing productivity. The analytical outputs described in this step can be generated using a range of tools, from spreadsheet-based templates through to purpose-built digital platforms, depending on an organisation's technical capability and available infrastructure. At the same time, data collection, integration, and analysis workflows can be automated using digital workflows to reduce manual burden to site teams. This step is where the framework delivers operational value by embedding productivity measurement into routine project control. Key activities include:

- Transform Gantt Charts into flowlines
- Compare plans v actual progress using flowlines
- Compare planned v actual production rates
- Integrate production rates and labour productivity
- Identify blockers to productivity and explain variability

[7] Sample data collection template is provided in Appendix B

Detailed applications of the framework for productivity control are presented in Chapter 4.

Step 6 - Implement the framework for benchmarking (Chapter 5) and data analytics (Chapter 6)

The final step focuses on embedding the framework into an ongoing cycle of benchmarking, learning, and continuous improvement. By systematically aggregating comparable productivity data across projects, organisations can move beyond single-project analyses and develop evidence-based benchmarks to inform future planning and decision-making. Key activities include:

- **Regular data review:** Continuously analyse productivity data to identify trends, underperformance and emerging risks
- **Benchmarking and best-practice identification:** Compare productivity across work packages and projects to identify effective strategies and replicate them in future delivery
- **Targeted improvement actions:** Use recurring patterns of variability and constraint to diagnose bottlenecks and develop focused interventions
- **Feedback into planning:** Provide planners and cost estimaros with historical benchmarks and data-driven insights to improve programme realism, forecasting accuracy, and risk management
- **Advanced data analytics:** Apply advanced analytical techniques to deepen understanding of productivity drivers and update the framework as project contexts, technologies, and organisational needs evolve

Through this structured feedback loop, the framework supports a scalable, data-driven approach to improving productivity and enhancing long-term project performance.

4. Productivity monitoring and control

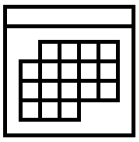
This chapter demonstrates how the framework is applied to a live construction project to measure and manage productivity in near-real time. A case study project illustrates how structured and integrated data enable the consistent calculation of productivity metrics and the application of visualisation techniques that enhance situational awareness, support timely diagnosis of productivity issues, and inform corrective action.

The case study is a high-rise commercial building in London comprising two reinforced concrete cores, columns, and post-tensioned floor slabs. For construction planning and sequencing, each floor slab was divided into two zones of approximately 350 m² each, which served as the basis for defining and measuring construction outputs.

For slab construction, the work package-level analysis focuses on cycle times calculated for each zone and level. Cycle time is defined as the duration between the erection of the first column in a given zone and the completion of the corresponding slab pour. This definition reflects the end-to-end production process for each slab zone and enables consistent comparison across floors.

The results of the work package-level analysis of slab construction are reported in this chapter, presenting productivity metrics calculated for each slab zone and floor level. This illustrates how the framework supports operational control of live projects.

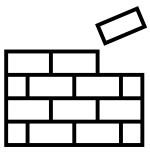
Data Inputs



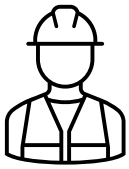
Programme from the Tier 2's programme to build Gantt Charts



Construction output in m^2 of floor area per zone and level, extracted from drawings and BIM models



Superstructure progress was measured by analysing CCTV images and concrete pour records



Labour data collected from labour allocation forms (physical sheets or using an online app)

4.1 Transforming Gantt charts into flowlines

In the UK, construction projects are predominantly planned using Gantt charts, which represent activities on the vertical axis and planned and actual start and finish dates on the horizontal axis. A vertical “drop line” drawn at a given date is often used to indicate variance between planned and actual progress. While effective for reporting activity status, this representation provides limited insight into production flow across locations. An alternative approach we have observed, and advocate for, is to replace activities on the vertical axis with locations, such as floors or zones, while retaining time on the horizontal axis. This seemingly minor adjustment fundamentally changes how programmes are interpreted, shifting the focus from isolated activities to the movement of work through space.

The Gantt chart for the structural frame construction can be transformed into **flowlines**. Flowlines are a visualisation of the construction programme across locations, plotting work sequences against both time and place. In this representation, the vertical axis captures locations across multiple levels, while the horizontal axis represents time. Each segment denotes the start and finish dates (cycle time) for work executed in a specific location. In a single view, the flowline diagram reveals the overall programme logic, intended sequence, and key handover points across the building. Figure 5 provides an example flowline with two hypothetical activities. Figure 6 shows the planned flowlines for a selection of locations for the structural frame of the case study project.

Flowlines make the progression of crews between locations explicit, exposing sequences, overlaps, and interruptions in production. This location-based visualisation establishes a clear baseline of expected flow, enabling practitioners to assess whether work is advancing at the intended rhythm and providing a foundation for systematic production control on projects with repeatable zones or floorplates.

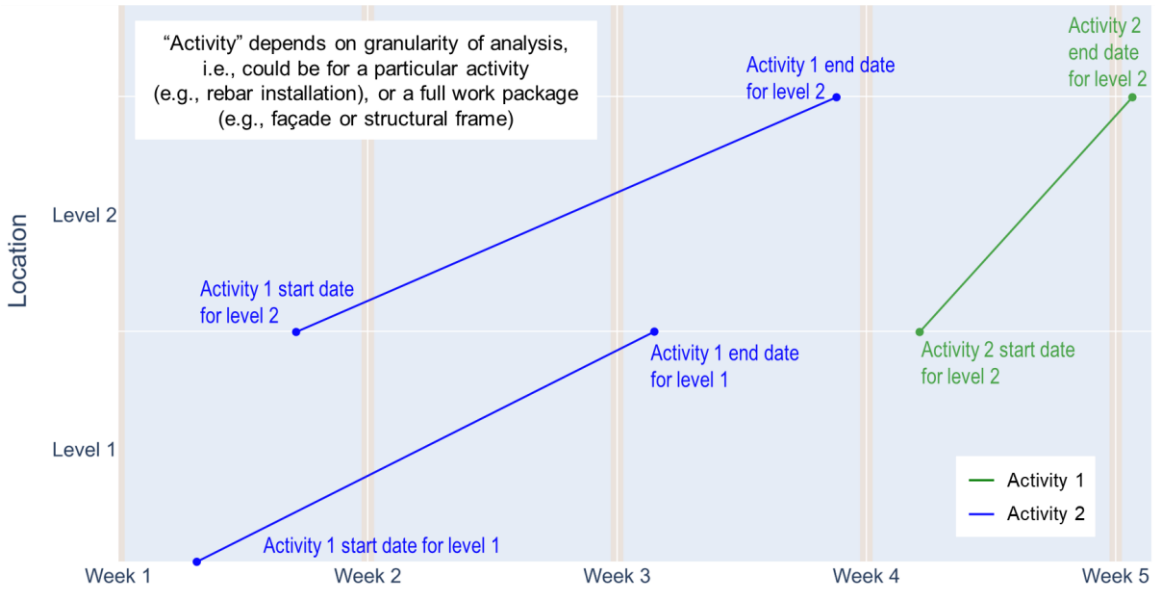


Figure 5: Interpreting flowline diagrams

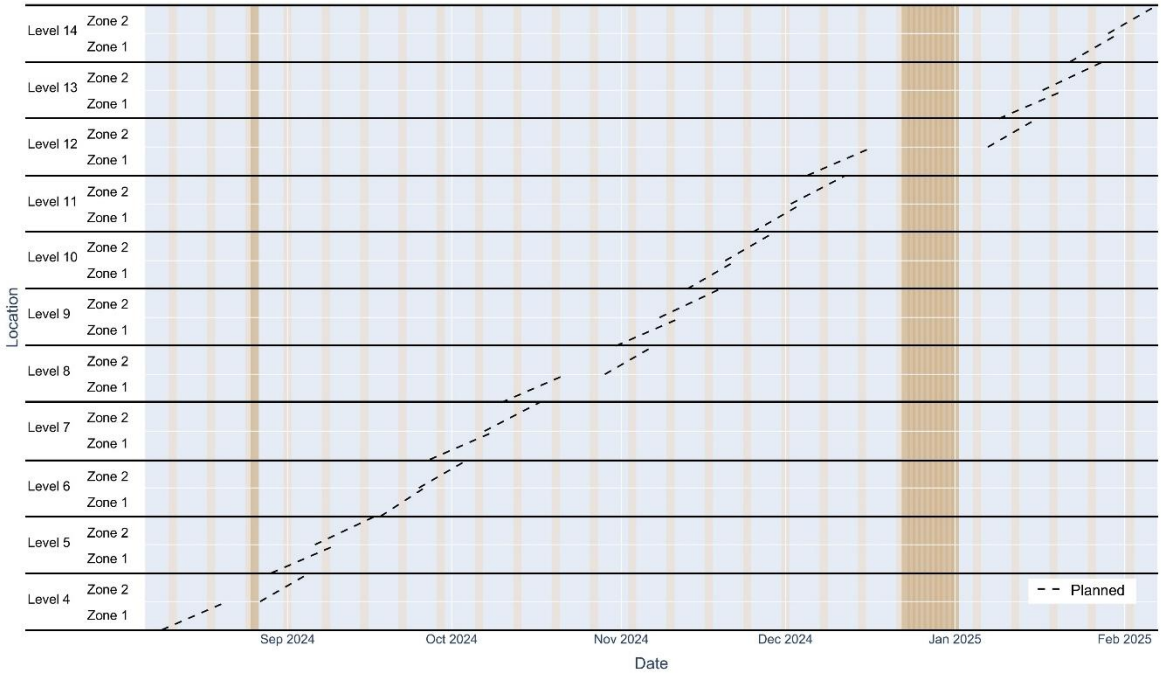


Figure 6: Superstructure flowlines for superstructure construction (planned)

Why flowlines matter for production control

- **Translate plans into locations:** Flowlines convert traditional activity-based programmes into a location-based representation that reflects how work is actually executed on site
- **Make production flow visible:** By explicitly showing the movement of crews through zones and levels over time, flowlines reveal intended sequences, handovers, overlaps, and gaps in production
- **Enable rapid diagnosis:** At a glance, practitioners can assess whether work is progressing at the planned rhythm, identify out-of-sequence working, and detect emerging variability before it escalates into delay or inefficiency

4.3 Comparing planned v actual progress using flowlines

The next step in analysing project performance is to overlay actual progress onto the planned flowline baseline. On the case study project, progress data were derived from two primary sources: CCTV-based observations and concrete pour records. Together, these sources enabled the accurate reconstruction of the superstructure sequence and the extraction of the actual start and finish dates for each location. Computer vision (CV) and Vision Language Models (VLMs) are enabling technologies for automatically extracting timestamps from CCTV images.

Using the observed start and end dates per location, an actual flowline was generated and plotted alongside the planned sequence, as shown in Figure 7. This comparison provides a powerful diagnostic view of how the production system performs in practice, highlighting adherence to and deviation from the intended flow.

The flowlines show that, up to Level 7 (shown in green in Figure 7), work progressed out of sequence but remained within the overall programme. From Levels 8 to 11 (in blue), production stabilised, progressing largely in sequence and slightly ahead of plan. A black swan event around the Christmas period disrupted construction at Levels 12 and 13 (in purple). From Level 14 onwards (in red), work again became out of sequence, although the programme was still maintained. The underlying causes of these deviations are discussed in Section 4.5. These patterns are immediately visible through the flowline representation. By distinguishing sequence-related disruptions from productivity-related issues, flowlines enable practitioners to diagnose systemic interruptions more effectively. With minimal inputs (planned programmes, floor area per location, and actual start and finish dates), project teams can rapidly construct planned v actual flowlines to enhance communication, support timely intervention, and identify emerging risks well before they become apparent in traditional programme reporting.

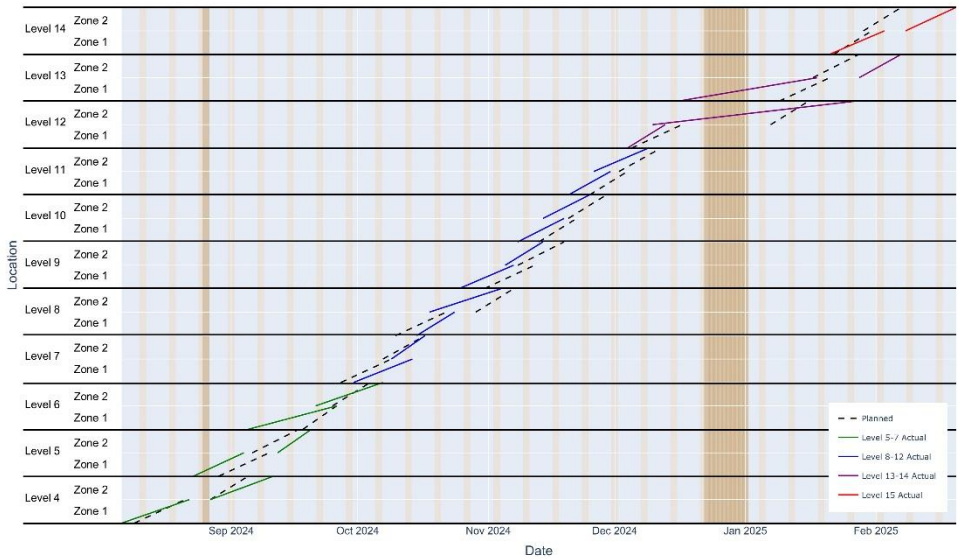


Figure 7: Superstructure flowlines (planned v actual)

4.3 Comparing planned v actual production rates

In flowline representations, the slope of each segment directly reflects the production rate: steeper slopes indicate faster delivery and higher production rates, while flatter slopes indicate longer durations and lower production rates. Using a consistent output definition (m² of floor area per location) and dividing it by the planned or actual cycle time enables the calculation of planned and actual production rates in a comparable and transparent manner.

Figure 8 presents the planned production rates per level, establishing the baseline productivity expectation for the project. The plan itself shows variability. For direct comparison, Figure 9 overlays the corresponding actual production rates. This comparison reveals that while several zones achieved or exceeded the planned rates, others underperformed significantly. Further investigation revealed that these lower rates often align with access constraints, handover delays, or other operational restrictions identified through daily site reporting.

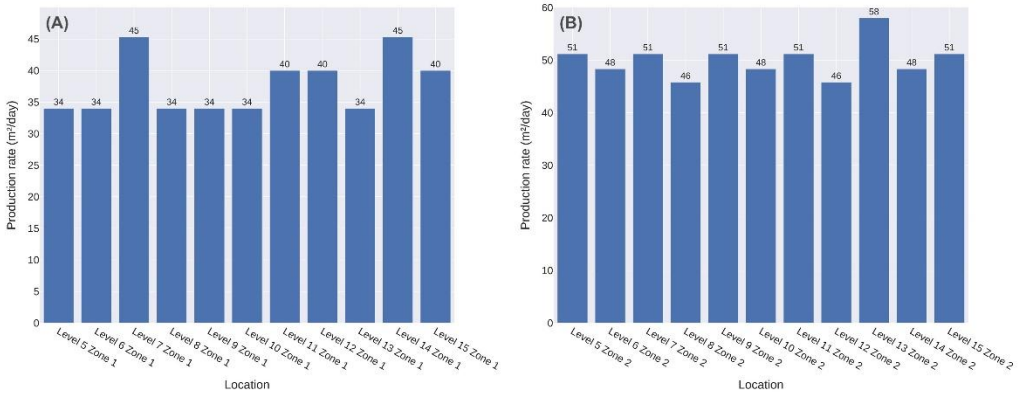


Figure 8: Bar chart for superstructure zone-by-zone planned production rates ((A) Zone 1 (B) Zone 2)

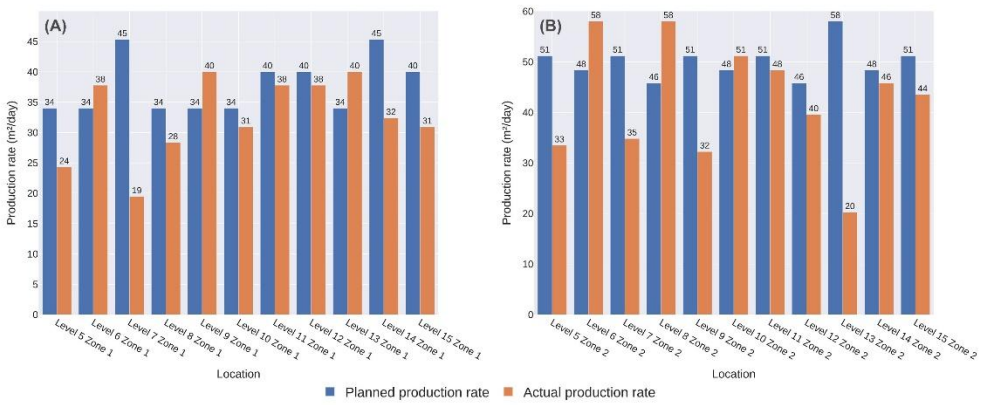


Figure 9: Bar chart for superstructure zone-by-zone planned v actual production rates ((A) Zone 1 (B) Zone 2)

To summarise variability, Figure 10 presents the distribution of production rates using a boxplot. The planned median production rate of 44 m²/day is slightly higher than the actual median of 40 m²/day. For planned production, 50% of observations (between the first and third quartiles) fall within the range of 37-51 m²/day, while the corresponding range for actual production is 32-48 m²/day. A key question that follows is how these observed production rates compare with those achieved on similar projects within the organisation or across the wider commercial building sector in London.

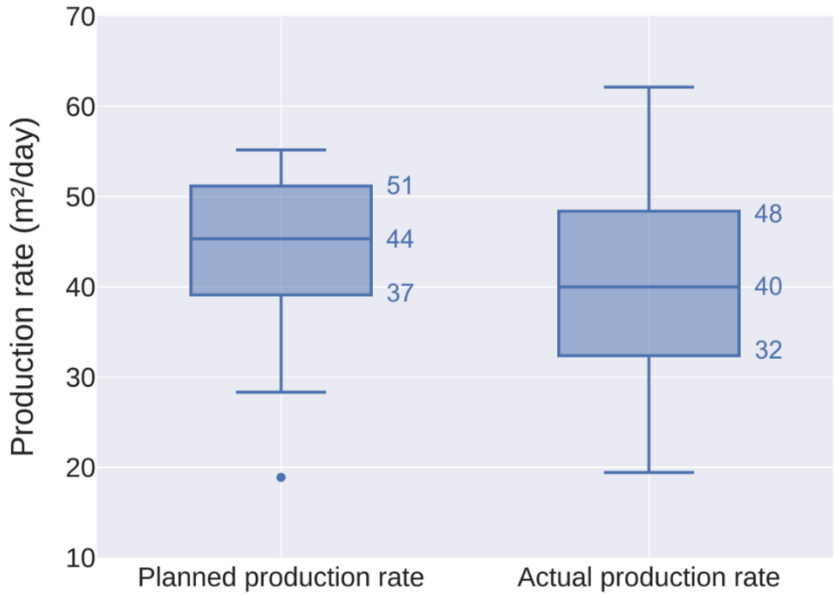


Figure 10: Boxplot showing variability of superstructure planned and actual production rates

For practitioners, the workflow remains deliberately simple: calculate actual cycle times per location, derive production rates, compare actuals against plans, and analyse variability rather than relying solely on averages. This approach supports more reliable planning and the continuous recalibration of cycle-time assumptions and expectations of progress delivery during tender, detailed planning, and execution.

Alternative visualisations to illustrate variability in planned v actual productivity

The four figures below present the same planned v actual comparison through different lenses. They represent the same data interrogated in Figure 9A (Zone 1 only). Each foregrounds a different aspect of productivity: relative achievement, absolute gap, ranked deviation, and the joint distribution of planned and actual rates. Used together, they allow practitioners to move quickly from "how did we perform overall?" to "where were the biggest losses and why does that matter for future planning?" The choice of visualisation should reflect the audience, i.e., percentage performance suits progress reporting; absolute deltas suit operational review; ranked views suit prioritisation; and scatter plots suit benchmarking and tender calibration.

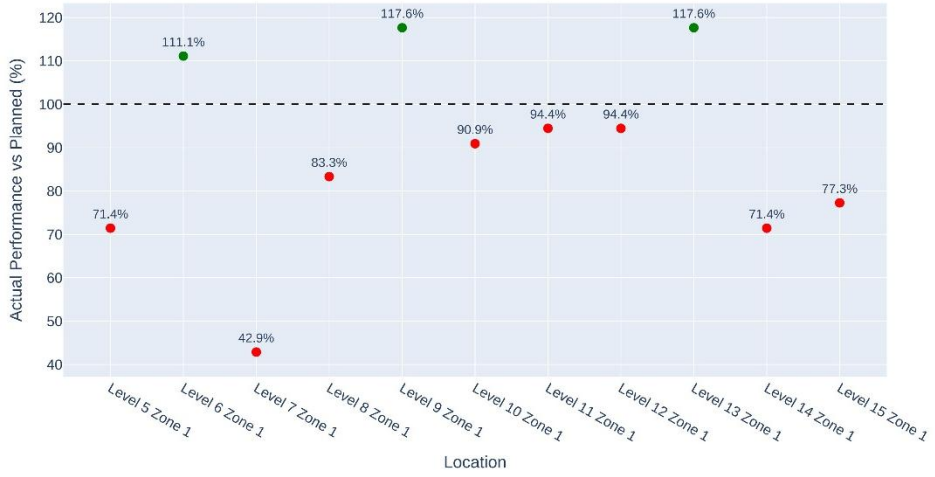


Figure B1: Actual productivity as a percentage of plan by location (Green markers indicate zones at or above plan; red markers indicate underperformance; the dashed line represents 100% plan achievement)

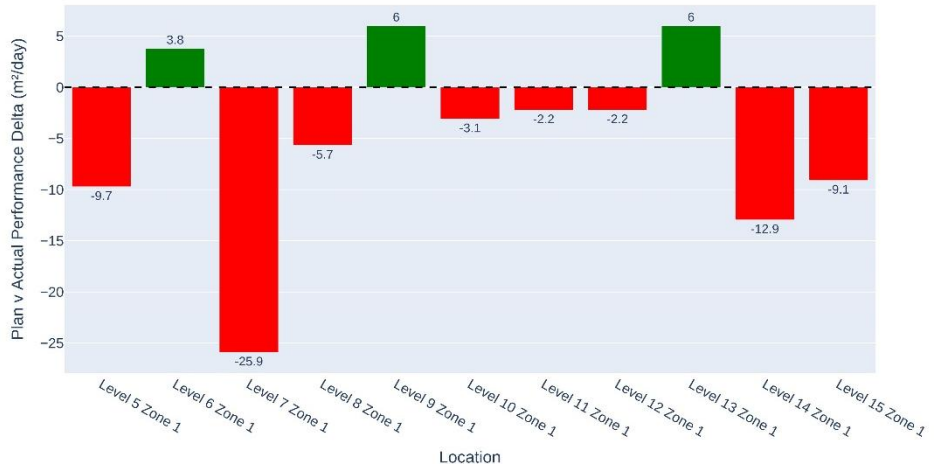


Figure B2: Absolute planned v actual production delta (m²/day) by location in sequence (Positive bars (green) reflect locations that exceeded plan; negative bars (red) reflect shortfalls)

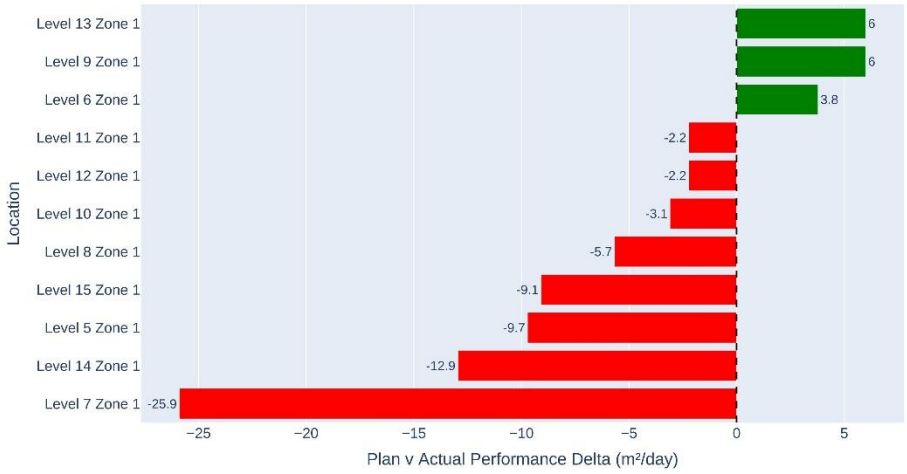


Figure B3: Absolute planned v actual production deltas ranked by magnitude (This view immediately identifies which locations drove the greatest cumulative loss and where recovery effort should be concentrated)

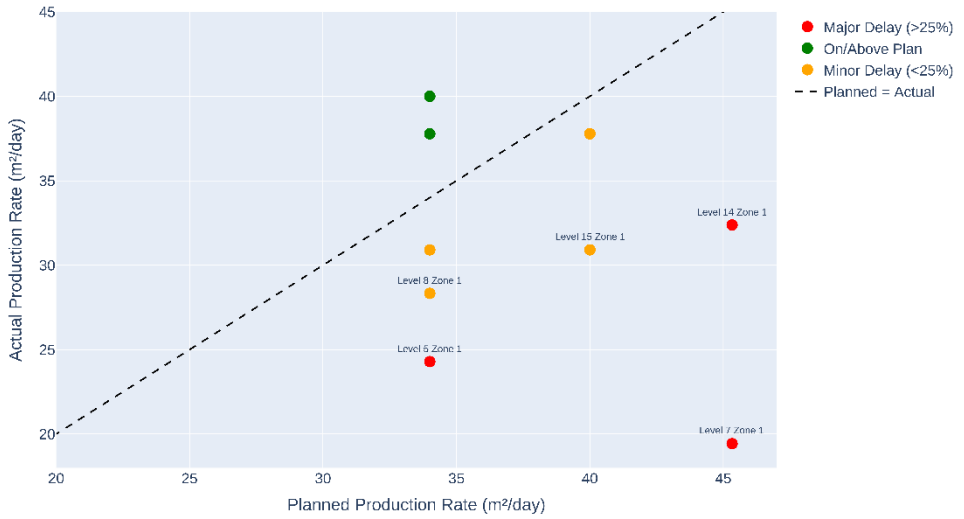


Figure B4: Scatter plot of planned against actual production rates per location (Points below the diagonal underperformed relative to plan, with colour coding distinguishing minor delays (<25%), major delays (>25%), and on-or-above-plan productivity)

4.4 Integrating production rates and labour productivity

The production rates presented in Section 4.3 may be achieved using different labour strategies, including variations in crew size, composition, or sequencing driven by evolving planning decisions. Consequently, integrating labour productivity, measured as output per worker-hour, provides a complementary and necessary perspective on how efficiently work is executed in each location, beyond speed of delivery alone.

In this case study, labour data were captured using two sources: (i) aggregate headcount from turnstile records, and (ii) more granular daily allocations recorded by supervisors using paper-based sheets and a complementary digital application. Turnstile data alone were insufficient, as operatives from the same trade contractor were working simultaneously across three activity workflows (i.e., cores, slabs, and basements), preventing direct attribution of labour inputs to the slab construction. This is a common challenge on projects where trade contractors are deployed across concurrent scopes. As a result, labour allocation, with direct involvement from supervisors, was piloted and successfully implemented through a digital application. Figure 11 introduces a framework for contextualising this performance by plotting labour productivity against production rate and grouping on-site progress observations into four profiles.

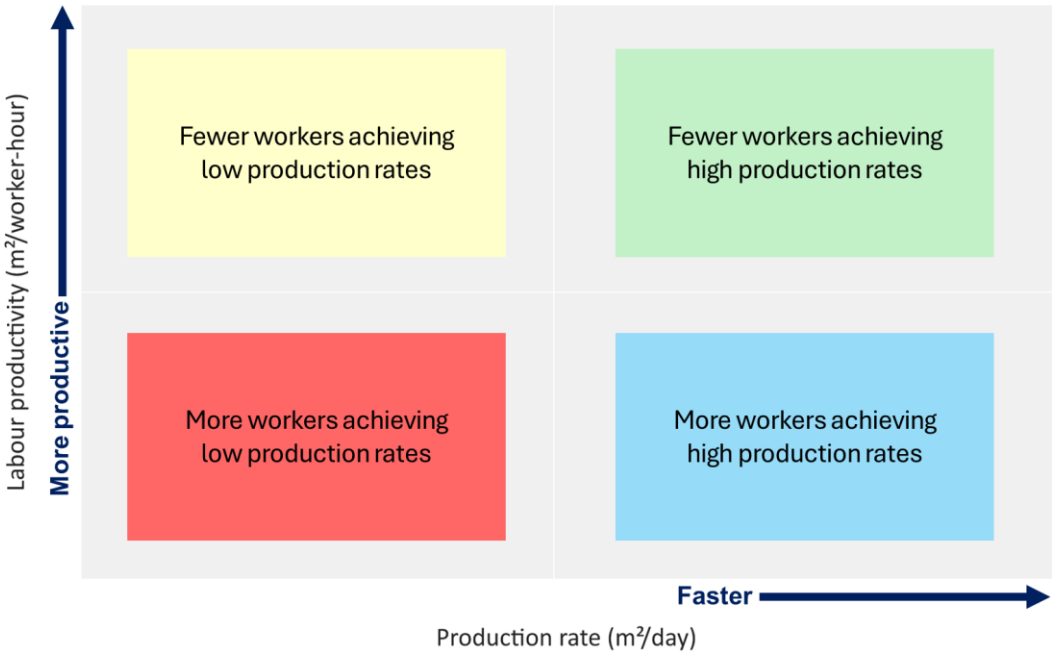


Figure 11: Labour productivity and production rate reveal four faces of workforce efficiency

Figure 12 presents a scatterplot of labour productivity v production rate across all zones up to level 14. Zone 1 (blue) records a median labour productivity of 0.25 m²/worker-hour, while Zone 2 (pink) achieves a notably higher median of 0.36 m²/worker-hour. The overall median production rate of 38 m²/day provides a useful reference point: Zone 2 data points cluster predominantly above this threshold, whereas Zone 1 observations are more evenly distributed on either side. As both zones are broadly comparable in floor area (approximately 350 m² each), the productivity gap is unlikely to reflect differences in task scale or scope. This points instead to other causal factors (e.g., crew composition, sequencing efficiency, localised site conditions or project priorities).

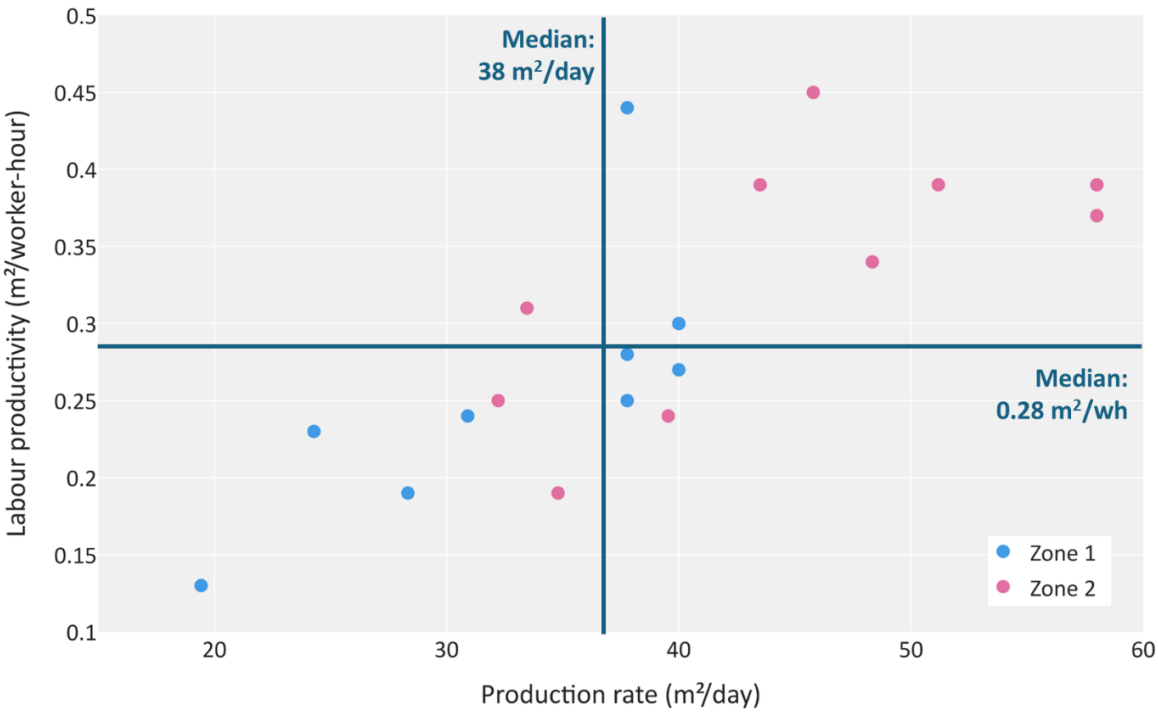


Figure 12: Labour productivity v production rates. Each dot represents a zone (1 or 2) in a high-rise building

Why combining production rates and labour productivity matters

The scatterplot visualisation of production rates and labour productivity by location enables practitioners to:

- **Assess efficiency, not just speed:** Understand whether higher production rates are achieved through efficient labour use or increased resource input
- **Identify exemplar productivity:** Locate high-performing conditions (top-right quadrant of Figures 11 and 12) and investigate the planning, sequencing, and operational enablers that support superior productivity
- **Diagnose underperformance:** Highlight low-performing locations (bottom-left quadrant of Figures 11 and 12) and investigate recurring constraints or blockers to productivity
- **Evaluate variability and benchmarks:** Compare quartile ranges and medians to establish realistic benchmark values for future work within the project or across similar projects (Chapter 5)
- **Build analytical capability:** Archive structured, location-level data to support larger datasets and more advanced productivity analytics and modelling (Chapter 6)

4.5 Identifying blockers to productivity and explaining variability

Analysing blockers to productivity provides a systematic method for capturing and classifying events that disrupt planned production flow. In this framework, all stoppage and delay events are categorised into standard groups, including labour, materials, equipment, planning, logistics, health and safety, design and constructability, weather, and external factors, as defined in Appendix A. These categories can be embedded within digital forms, site diaries, or progress-reporting applications to support consistent data capture.

Figure 13 overlays selected high-impact blocker events directly onto the actual flowline, making visible where and when the intended work sequence was disrupted. In the digital dashboard, these events are presented as contextual hover data linked to specific locations and time periods. Key interruptions on this project included a trade interface clash with the façade works, which forced out-of-sequence execution; a quality issue that required rework; and a black swan event that led to a three-week site shutdown.

Integrating blocker data with flowline deviations is one of the framework's most powerful features. Rather than relying on narrative explanations or retrospective claims analysis, practitioners can visually trace deviations in production flow back to specific, categorised causes. This capability shifts stoppage reporting from a passive, descriptive activity to a proactive control and learning tool, enabling earlier intervention and more informed decision-making.

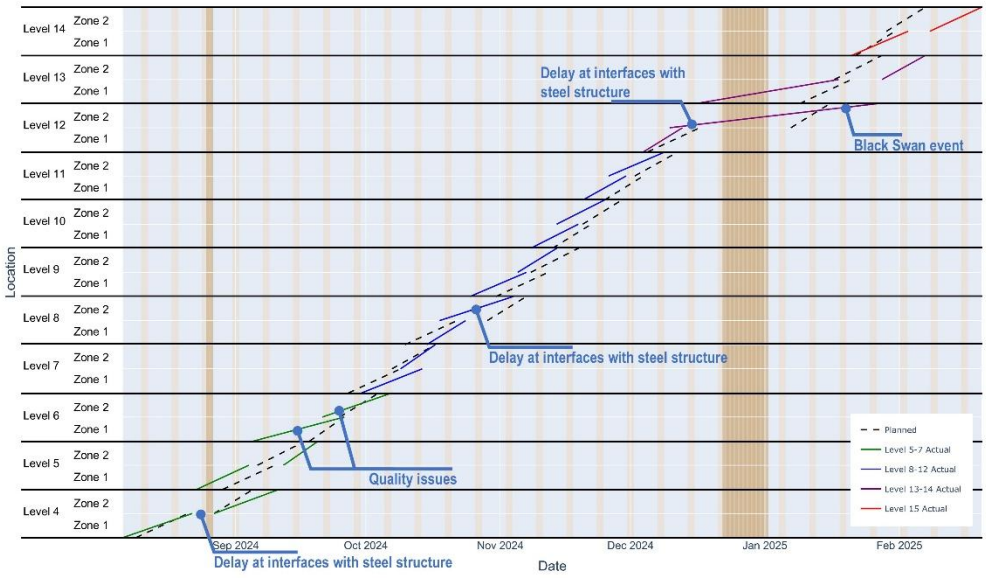


Figure 13: Actual flowline with annotated delay causes

Capturing and Classifying Productivity Blockers in Practice

The following example presents a comprehensive set of productivity blockers recorded for the superstructure work package. The data were captured through digital forms embedded within a common data environment (CDE) and reported daily by site engineers. In total, 47 blocker events were logged and classified according to the taxonomy defined in Appendix A. To maximise analytical and control value, blocker data should be integrated directly into flowline visualisations within digital dashboards, enabling disruptions to be examined in their spatial and temporal context. This integration allows practitioners to link deviations in production flow to specific causes rather than relying on retrospective narrative explanations.

Key implementation challenges remain, particularly maintaining continuity and consistency in reporting when staff rotate, take annual leave, or deprioritise data capture under delivery pressure. Addressing these challenges requires clear leadership, defined accountability, and an organisational learning culture that reinforces the value of systematic blocker reporting as a tool for continuous improvement rather than administrative burden. Reporter bias is also a risk: data collectors may over-attribute delays to external parties while underreporting issues within their own organisation.

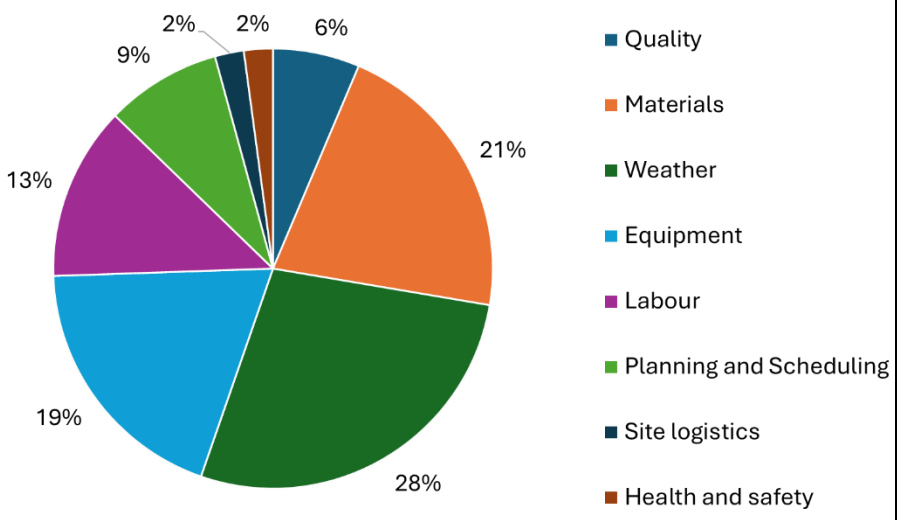


Figure B5: Blockers to productivity for a high-rise building (47 issues found from 512 site records)

Practitioner checklist for productivity monitoring and control

1. **Generate planned v actual flowlines** for each work package and review them in weekly coordination meetings to assess sequencing, handovers, and adherence to planned flow (see Figures 6 and 7)

2. **Monitor production rate distributions** using boxplots and establish control thresholds to trigger focused reviews when productivity falls below the first quartile (Q1) or shows increasing variability (see Figures 8–10)

3. **Analyse labour productivity v production rate scatterplots** to identify exemplar productivity, test whether changes in crew size improve or degrade efficiency, and replicate enabling conditions observed in high-performing locations (see Figures 11 and 12)

4. **Track and prioritise blockers to productivity** by frequency and impact. Overlay blocker data onto flowlines to link disruptions to specific locations and time periods, and review actions during weekly meetings (see Figures 13 and B5)

5. **Integrate flowlines across work packages** at the same locations to visualise the full programme, identifying how major delays in earlier work packages cascade into subsequent packages and assessing the resulting impact on overall project performance (see Figure 13)

This chapter has demonstrated how the framework transforms both planned and actual data into simple, repeatable visual diagnostics that support timely, targeted corrective action. The integration of flowlines, production rates, labour productivity, and blockers to productivity establishes a shared language for planners and site teams, enabling consistent interpretation of productivity across locations.

Used together, these tools enable early detection of deviations, systematic investigation of root causes, and focused interventions to be implemented and evaluated. By closing the feedback loop and measuring whether corrective actions deliver sustained improvement as construction progresses, the framework supports a more stable production flow and continuous performance improvement.

Importantly, data requirements remain modest and largely draw on information already available on most projects, including BIM-derived quantities, basic progress records, and labour headcounts. By structuring these inputs into coherent metrics and visualisations, the framework enables more effective control of variability, improved forecasting, and a stable production system. For practitioners, this translates into stronger project control and a robust foundation for continuous productivity improvement at both project and organisational levels.

5. Benchmarking productivity

The previous chapter demonstrated how structured data and visualisation tools can be used to monitor progress, analyse productivity, and identify the causes of productivity variation on live projects. This chapter builds on that foundation by addressing a complementary and equally important aspect of performance measurement: benchmarking.

Benchmarking productivity involves establishing reference levels of performance against which other projects, work packages, or activities can be evaluated. For example, the productivity of a given project can be assessed relative to the typical or median productivity observed across a set of comparable projects. Such comparisons help determine whether observed productivity is above, consistent with, or below expected levels. A critical requirement for meaningful benchmarking is ensuring that comparisons are made on a like-for-like basis; without appropriate alignment of scope, context, and production characteristics, benchmarking results can be misleading.

In this chapter, benchmarking is applied across multiple levels of analysis: project, work package, and activity. This follows the multi-level productivity framework introduced in Chapter 3. While the framework itself is generic and transferable across construction sectors, this chapter presents practical examples illustrating how benchmarking can be implemented across different projects, work packages, and activities to support evidence-based planning and decision-making.

5.1 Project-level benchmarking

The first application of benchmarking is at the level of the overall project, considering project performance as a whole rather than by individual work packages or activities. To demonstrate how the productivity measurement framework can be used to benchmark performance across multiple projects, a different dataset is introduced here, reflecting the approach taken throughout this chapter of drawing on varied project types and contexts to illustrate the framework's broader applicability.

A dataset of UK school building projects is analysed, as shown in Figure 14. In the figure, the horizontal axis represents production rate, measured as constructed area per week, while the vertical axis represents labour productivity, expressed as constructed area per worker-hour. Cost-effectiveness, defined as constructed area per thousand pounds, is conveyed through the colour gradient of the data points; cost in this instance refers to the total sum paid by the client for the completed project. Each point corresponds to an individual school building project.

Together, these dimensions provide a multi-faceted view of project performance, enabling direct comparison across speed, labour efficiency, and cost efficiency. For this dataset, the overall median benchmark corresponds to a production rate of 50 m^2/week and a labour productivity of 0.045 m^2/worker-hour, providing a reference against which individual projects can be evaluated.

As illustrated in Figure 14, projects that achieve the highest production rates and labour productivity are not necessarily the most cost-effective. Conversely, the most cost-effective projects tend to exhibit moderate production rates and labour productivity. In practice, however, clients and developers do not always prioritise cost-effectiveness alone. In many cases, earlier completion is preferred even if it results in higher direct costs, as extended construction durations can significantly increase exposure to market, financing, and delivery risks. These indirect costs and risk premiums are not captured by the cost-effectiveness metric alone. Consequently, production rate, labour productivity, and cost-effectiveness each offer distinct and complementary insights into project performance and should be considered together when evaluating outcomes.

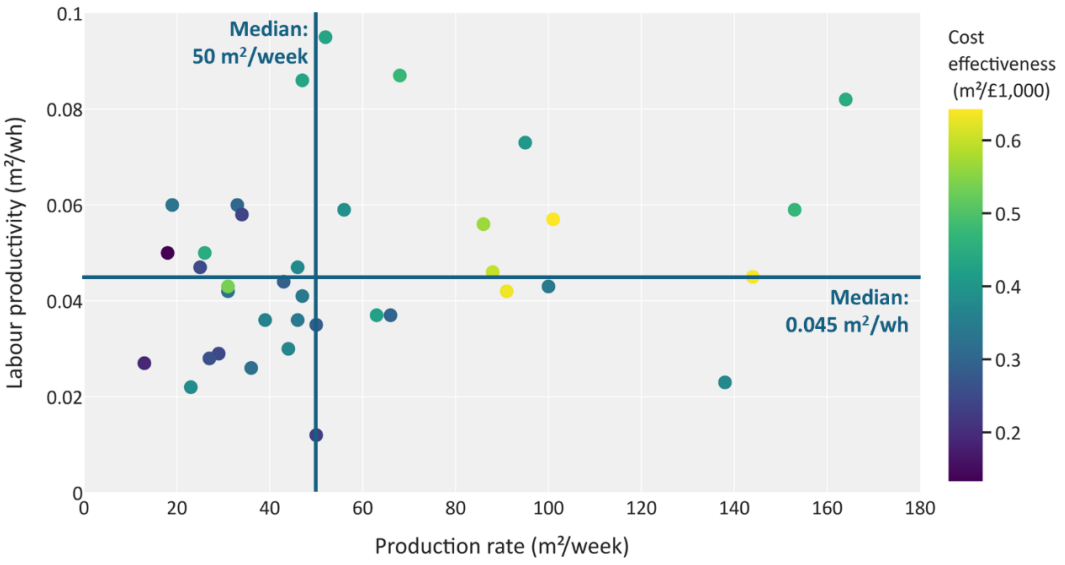
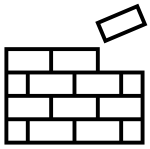


Figure 14: Labour productivity v production rate for school projects (colour bar = cost effectiveness)

Data inputs for project-level benchmarking



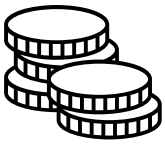
Construction output using gross internal floor area (measured in m^2)



Project duration is measured in weeks from the start on site to practical completion



Labour data was quantified as total worker-hours, including operatives and supervisors and excluding management



Cost was measured as the final price paid by the client

The same metrics can be re-visualised to explore the influence of additional factors on performance. Figure 15 presents a re-representation of Figure 14, incorporating PMV within the colour legend. The figure reveals substantial variability between productivity measures and PMV. Only one high-PMV project achieves both a high production rate and a high labour productivity, while two low-PMV projects attain similar production rates but with lower labour productivity. Three high-PMV projects display high labour productivity (greater than 0.08 m^2/worker-hour), yet their production rates cluster around 50-70 m^2/week. In the upper-right quadrant, four high-PMV projects, one medium-PMV project, and one low-PMV project are observed.

For the purposes of this investigation, Pre-Manufactured Value (PMV) is defined in a qualitative manner as follows:

- **Low:** steel frame or in situ reinforced concrete with occasional off-site elements
- **Medium:** projects intentionally designed to increase the use of panels or volumetric pods
- **High:** projects where off-site elements comprise a substantial proportion of the building's structure, cladding and services

Note: Rather than expressing PMV as a precise value proportion, this categorical classification was adopted for ease of analysis and visual representation.

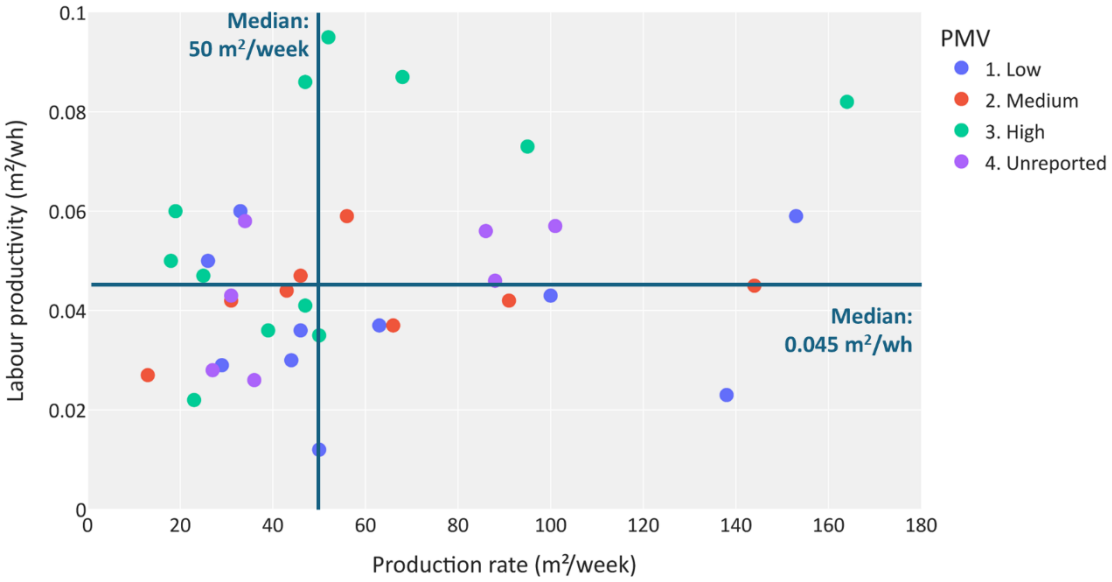


Figure 15: Labour productivity v production rate for school projects (colour = pre-manufactured value)

The relationship between labour productivity and cost efficiency is illustrated in Figure 16. The overall median benchmark for cost efficiency across the dataset is 0.37 m²/£1,000. Projects located in the top-right quadrant, indicating both high production rate and high cost-efficiency, include seven high-PMV projects, four medium-PMV projects, and two low-PMV projects (PMV unreported for three further projects). This distribution suggests that strong cost efficiency can be achieved across a range of project scales, although high-PMV projects appear more frequently among the top performers.

While these results provide useful reference points for project-level benchmarking, they do not explain the substantial variability observed across the dataset. Differences of up to a factor of eight in production rates, four in labour productivity, and six in cost efficiency are evident between the weakest and strongest performers. PMV alone does not account for this spread, and the absence of more detailed contextual data limits further interpretation. This reinforces the need for more granular analysis at work package and activity levels, where the underlying drivers of productivity variation can be systematically identified and benchmarked.

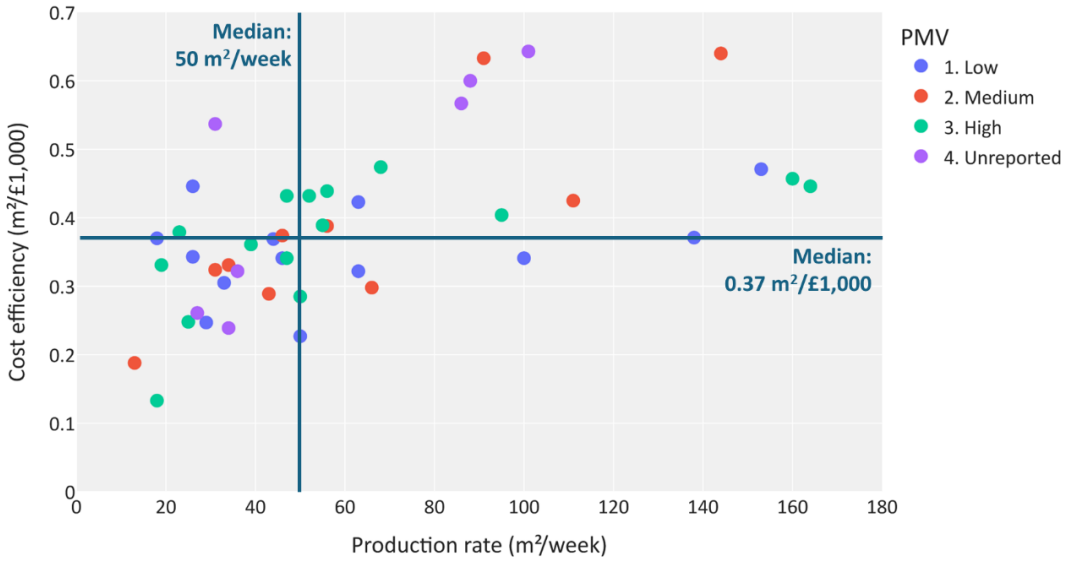


Figure 16: Cost efficiency v production rate for school projects (colour = pre-manufactured value)

Project-level benchmarking

In principle, establishing project-level benchmarks based on final outputs from comparable projects within an organisation should be straightforward. However, our ongoing research indicates that such data are often fragmented, inconsistently captured, and rarely stored in a single, accessible location. As a result, significant effort is typically required to reconcile datasets and standardise metrics before meaningful comparisons can be made.

A simple but revealing test is to ask: *What were the final production rate, labour productivity, and cost-efficiency achieved on your past, comparable 50 projects?* Anecdotal evidence suggests that this remains a difficult question for many organisations to answer with confidence. This gap highlights a persistent disconnect between the data generated during project delivery and the information required for systematic learning, benchmarking, and improved planning in future projects.

5.2 Work package level benchmarking

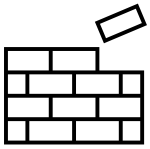
A project comprises multiple work packages, each with distinct outputs, production characteristics, and productivity profiles. The productivity measurement framework can be applied not only at the project level, but also to benchmark productivity across individual work packages such as underground works, structural frames, façades, cladding, and fit-out. This section focuses on benchmarking structural frame productivity across 20 high-rise buildings, as illustrated in Figure 17. For structural frame construction, low PMV corresponds to fully in-situ concrete frames; medium

PMV includes off-site vertical elements (steel or precast concrete) combined with in-situ slabs; and high PMV represents systems with off-site vertical elements and off-site slab components (e.g., lattice or hollow-core slabs).

Data inputs for work package level benchmarking



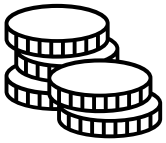
Construction output using gross internal floor area (measured in m^2) obtained from BIM models



Work package duration is measured in days from the start of vertical elements on the ground floor to the end of the last slab on the top floor



Labour data was quantified as total worker-hours, including operatives and supervisors and excluding management



PMV was categorised as low (all in-situ concrete), medium (off-site vertical elements with in-situ slabs) and high (off-site vertical and slabs (e.g., hollow core or planks)

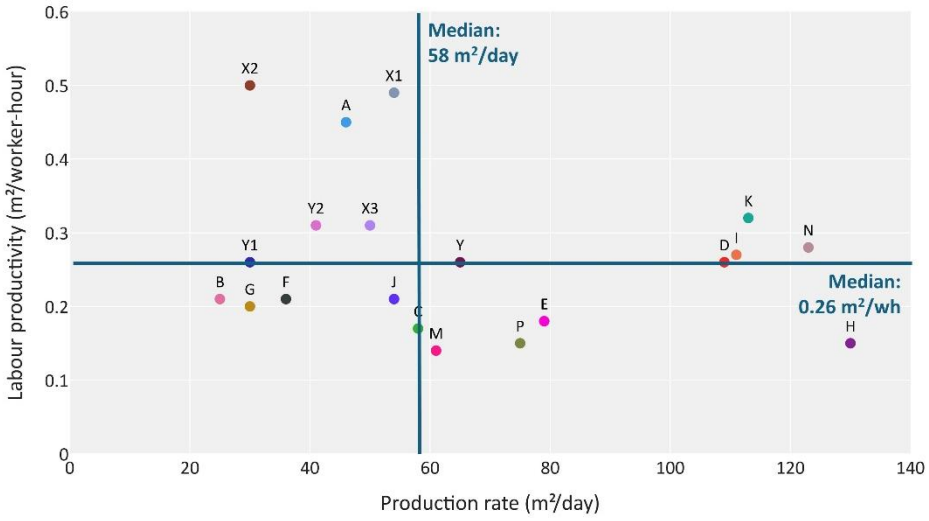


Figure 17: Labour productivity v production rate for the superstructure work package (each dot represents a building)

Figure 17 presents production rate and labour productivity metrics for the structural framework package across various high-rise buildings. The results reveal substantial variability along both dimensions. Across the dataset, the mean production rate is 58

m²/day, and the mean labour productivity is 0.26 m²/worker-hour. However, the fastest-performing building (H) achieves a production rate more than six times higher than that of the slowest building (B). Similarly, the most labour-efficient project (X2) records labour productivity more than four times higher than that of the least efficient projects (M, P, and H). These differences highlight the scale of productivity variation that can exist within a single work package type, between comparable projects.

Figure 18 represents the same dataset with the PMV overlaid. The figure shows that the four projects in the top-right quadrant, characterised by both high production rates and high labour productivity, are all high-PMV projects, giving support to the hypothesis that off-site construction enables faster delivery with improved labour productivity. However, several other high-PMV projects achieve high labour productivity (approaching 0.5 m²/worker-hour) while exhibiting below-median production rates. This suggests that high PMV is necessary but not sufficient for high production rates, and that organisational, planning, or sequencing factors play a determining role in whether the productivity gains enabled by off-site construction are fully realised.

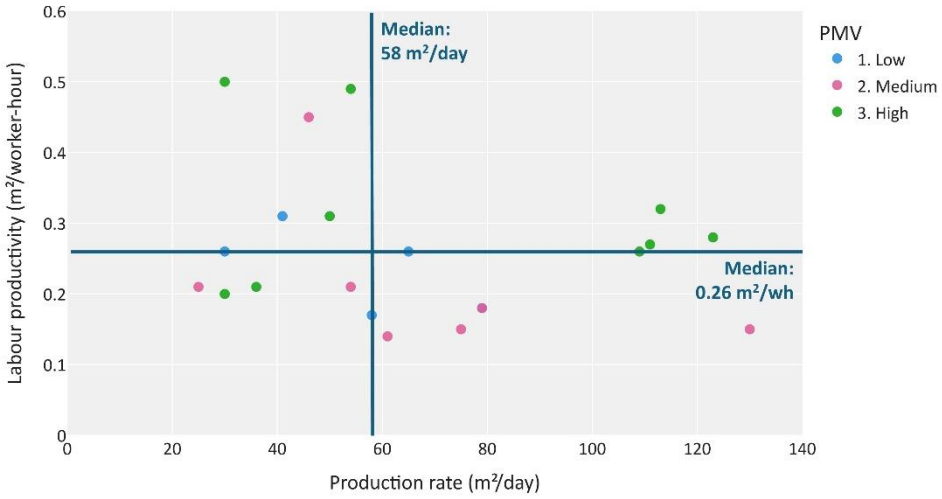


Figure 18: Labour productivity v production rate for the superstructure work package - effect of PMV

In Figures 17 and 18, each data point represents the structural frame as an aggregated whole. In practice, however, each frame is constructed level by level and across multiple locations, often under varying planning strategies, such as different crane allocations, crew sizes, and sequencing approaches. Aggregated work package level metrics, therefore, may mask important within-project variability. To gain a deeper, more actionable understanding of structural frame productivity, more granular analysis at the work package level is required.

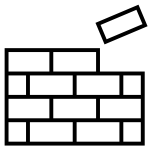
5.3 Location-based work package level benchmarking

This section demonstrates how benchmarking can be extended to a finer level of granularity by analysing productivity by location (i.e., floor-by-floor) within high-rise buildings. The focus is on cycle time at the floor-by-floor scale, defined as the duration from the start of vertical elements to the completion of the slab pour on each floor. This definition captures the combined duration of all activities associated with vertical and horizontal elements, including reinforcement, formwork, and concrete works.

Data inputs for location-based work package level benchmarking



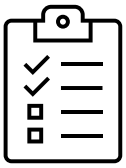
Construction output using gross internal floor area per floor (measured in m^2)



Cycle time is measured in days from the start of vertical elements to the last slab pour on every floor. Data was extracted from concrete pour records and CCTV images



Labour data was quantified as total worker-hours, including operatives and supervisors and excluding management



Descriptors: Structural frame type, number of cranes, number of slabs pours per floor

By measuring productivity across multiple locations over time, it becomes possible to examine how performance evolves within and across projects and identify best- and worst-performing locations. Figure 19 presents this analysis, where each data point corresponds to an individual building level. The dataset comprises 336 levels across 21 buildings (Buildings A–Y2). Overall, substantial variability is observed: production rates vary by a factor of ten or more, while labour productivity varies by a factor of eight or more. The median benchmarks are 54 m^2/day for production rate and 0.26 m^2/worker-hour for labour productivity. Levels in the top-right quadrant include several buildings, notably D, I, K, N, X1, X2, and X3.

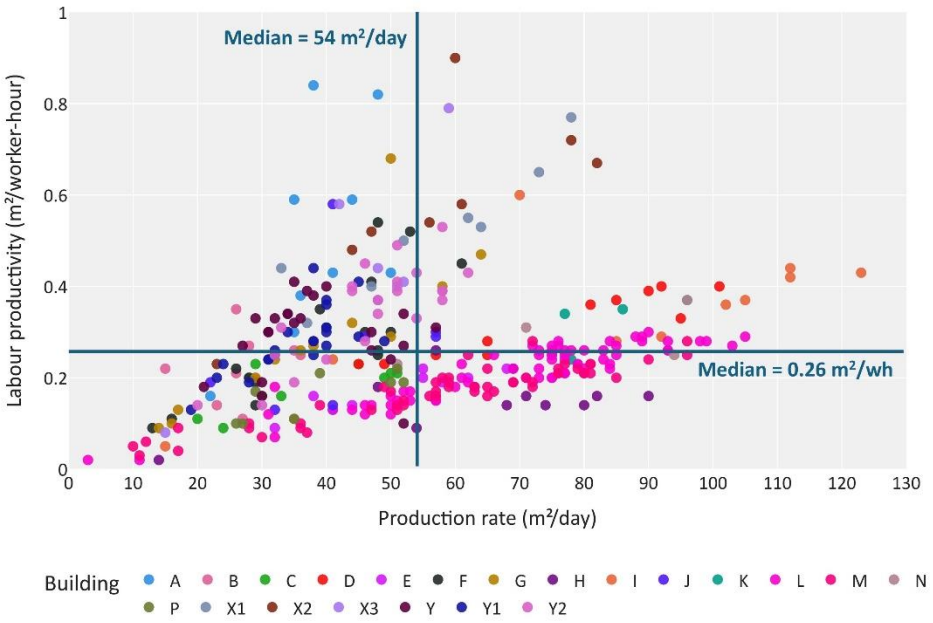


Figure 19: Labour productivity v production rate for the superstructure work package. Each dot represents a single level within a multi-storey building

Figure 20 focuses on these best-performing buildings and highlights that, even within high-performing projects, considerable variability exists between levels. In buildings D, I, K, and N, several levels fall below median production and productivity benchmarks. Similarly, in buildings X1, X2, and X3, some levels perform well below the best observed levels. This within-project variability underscores the limitations of overall work package metrics and the value of location-based benchmarking.

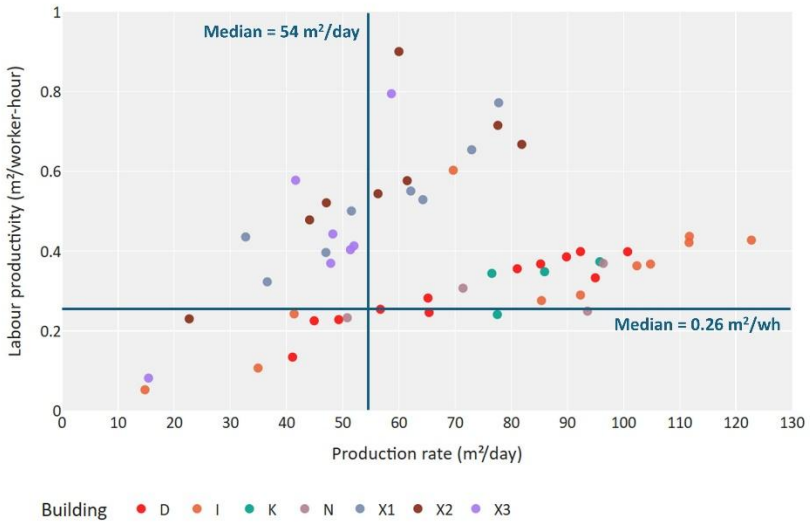


Figure 20. Labour productivity v production rate for the superstructure work package across a subset of the projects. Each dot represents a single level within a multi-storey building.

Further insight is gained by classifying floor-by-floor metrics according to structural frame typology. This classification refines the three PMV categories defined earlier by subdividing the high PMV group to distinguish among different off-site slab systems. Figure 21 presents the same dataset grouped by four frame types: (1) fully in-situ vertical elements and slabs; (2) off-site vertical elements with in-situ slabs; (3) off-site vertical elements with partially off-site slabs (e.g., lattice or hollow-core systems); and (4) off-site vertical elements with off-site slabs (e.g., cross-laminated timber). The figure shows that most data points in the top-right quadrant correspond to Types 3 and 4, indicating that higher levels of off-site construction are associated with superior production rates and labour productivity. A small number of Type 1 levels also appear in this region, achieving strong production rates but with labour productivity closer to the dataset mean.

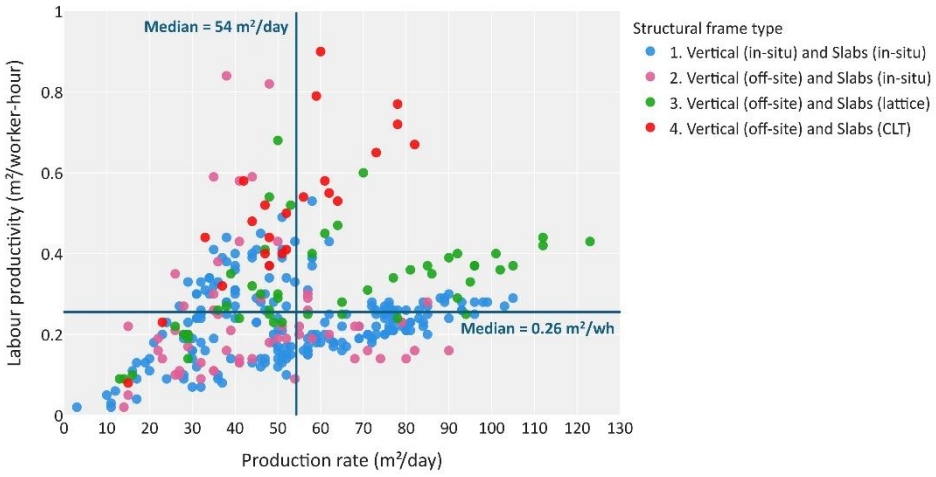


Figure 21: Labour productivity v production rate for the superstructure work package – slab construction. Colours represent the structural frame type

While location-based work package benchmarking aggregates all activities within the package, it does not explain how specific handovers, crew sizes, or activity-level disruptions drive observed variability. To address this, the next section applies the framework at the activity level, enabling a more detailed examination of the mechanisms influencing productivity.

5.4 Activity-level benchmarking for in-situ construction

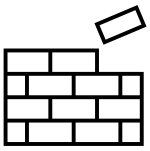
A work package or workflow combines multiple activities performed by different crews. Assessing productivity at the aggregated level of the work-package can conceal variation within individual tasks. For example, low productivity in a work package may be driven by a single underperforming activity, even if others are efficient. Benchmarking at the activity level helps uncover these differences, revealing which tasks set the productivity standard, drive the critical path, and require intervention. While analysing every activity may be impractical, focusing on the most critical ones provides valuable benchmarks and guides targeted improvements across similar workflows.

This section illustrates activity-level benchmarking for superstructure construction, focusing on four key activities: columns, slab formwork (decking), slab rebar installation, and slab concrete pouring. Figure 22 presents the activity flowlines between Levels 5 and 12, for the project analysed in Chapter 4, with each level having two construction zones (Zone 1 and Zone 2).

Data Inputs



Quantity of each activity per location. For instance, m^2 of column/slab formwork per zone/level



Activity duration is measured in days from start to finish for each activity at each location. Data was extracted from CCTV images



Labour data, including operatives and supervisors. Granular data is required through supervisor input through mobile apps or allocation sheets



Blockers to productivity to identify the constraints to continuous flow. Data captured through mobile apps or site reports



Crane data to identify usage by trade, lift times, and downtimes



Weather data to check if downtimes corresponded with wind gusts



Figure 22: Superstructure activity flowlines for levels 5 to 12 in a commercial tower building

Figure 22 demonstrates how activity-level flowlines provide direct insight into the mechanisms that shape overall work package productivity. Several locations exhibit exemplar productivity (e.g., Level 6 Zone 2, Level 8 Zone 2, and Level 10 Zone 2), where activities progress smoothly, overlapping activities where possible, handovers are timely, and crews maintain consistent cycle times across zones. In contrast, a few other locations, such as Level 5 Zone 1, Level 7 Zone 1, and Level 8 Zone 1, show longer cycle times with delays concentrated in specific activities, such as extended slab formwork ('decking'), which subsequently disrupts downstream activities. Instances of out-of-sequence work are also evident, where delayed completion in one zone forces resequencing in the other (see changes in sequencing from level 6 to 7). These deviations propagate through subsequent activities and trades, degrading the continuity of flow. Such patterns are not readily identifiable from aggregated work package metrics alone but become explicit when activities are visualised through flowlines and benchmarked individually.

To further illustrate this point, Figure 23 isolates a single activity, slab formwork, and plots labour productivity against production rate for each zone across all levels. Each point represents the productivity of slab formwork in a specific zone and level. The medians of both metrics are overlaid to provide a reference benchmark (97 m^2/day and 0.62 m^2/worker-hour). The spread of points highlights substantial variability in both production rate and labour productivity, despite the activity being repetitive and undertaken by the same trade. Data points in the upper-right region of the plot represent exemplar slab formwork productivity achieved under favourable sequencing, access, and handover conditions. Conversely, points below the medians indicate days where productivity was constrained, often corresponding to disruptions observed in the activity flowlines.

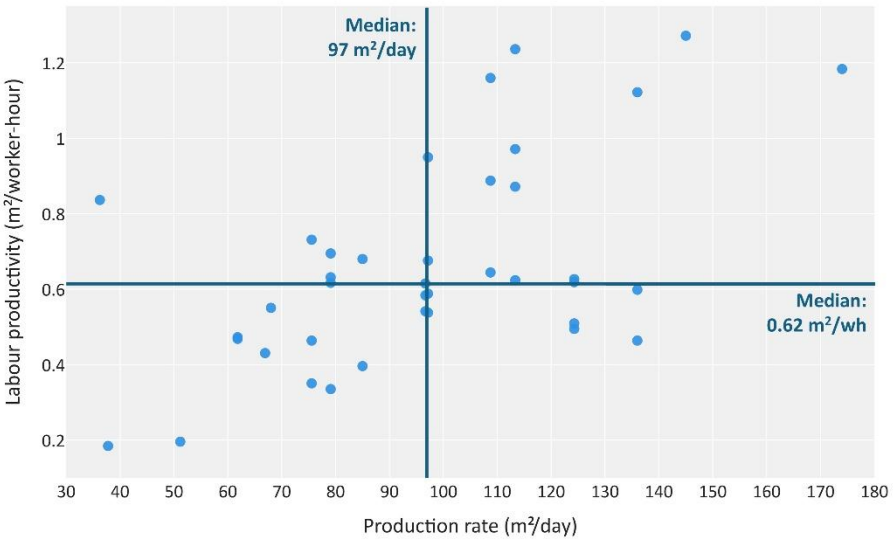


Figure 23: Labour productivity v production rate for the slab formwork activity per zone

From a planning perspective, activity-level benchmarking provides a practical way to validate planning assumptions against actual site productivity. By benchmarking individual activities, planners can identify which tasks reliably achieve expected production rates and which consistently constrain delivery. This evidence supports more realistic cycle times, improved sequencing, and better-informed lookahead and phase planning. Over time, these benchmarks strengthen the feedback loop between planning and execution, improving the reliability of future programmes and estimates.

From a site management perspective, activity-level benchmarking aligns directly with day-to-day control decisions. Site teams intervene at the activity level by adjusting crews, managing handovers, and resolving constraints. Clear benchmarks help distinguish normal variation from underperformance, providing early warning when productivity deviates from expectations. Just as importantly, benchmarking makes exemplar productivity visible, allowing enabling conditions to be identified and replicated, shifting productivity management from reactive response to proactive control.

5.5 Activity level benchmarking for off-site unitised panels

As off-site construction becomes increasingly prevalent, activity-level productivity data provide a direct means of evidencing its potential benefits, including faster delivery and improved labour efficiency. To illustrate this application, the framework is applied to the installation of off-site cladding panels.

Figure 24 presents daily installation rates for a cladding package delivered between August 2024 and April 2025. Each data point represents the number of panels installed per day. The results reveal substantial day-to-day variability, as illustrated by the accompanying boxplot. The median installation rate is 13 panels/day, with first- and third-quartile values of 9 and 20 panels/day, respectively.

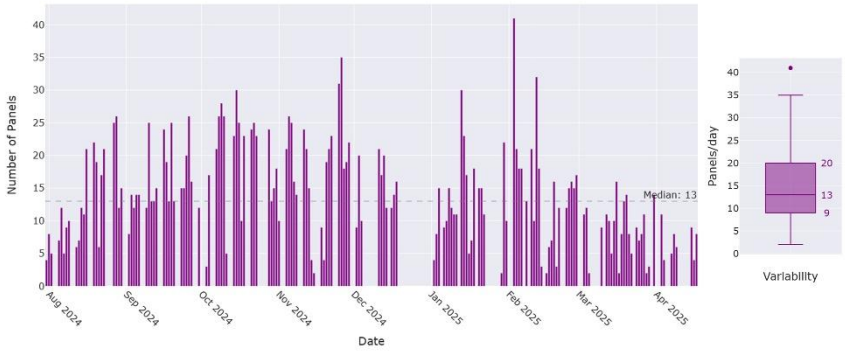


Figure 24: Piece count of unitised panel installation throughout a project. The median is 13 panels/day, and the Q3 productivity is 20 panels/day. Data extracted from subcontractor records.

Variation in daily installation rates can be partially attributed to changes in crew size over the construction period. Figure 25 presents the daily headcount of cladding operatives and supervisors on site. The median site presence is 34 operatives/day.

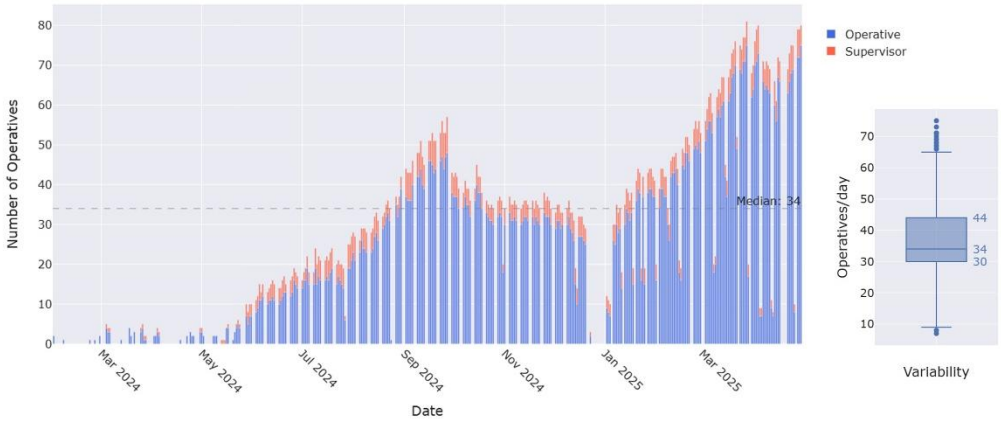


Figure 25: Crew size for unitised panel installation throughout a project. The median is 34 workers/day, and the Q3 is 44 panels/day. Data extracted from turnstile records.

Using the daily output and the labour size, Figure 26 presents the scatterplot of labour productivity v production rate. In this analysis, the output has been expressed in m^2/day (m^2 of façade covered by the installed panels) rather than pieces/day. The corresponding benchmark values are 89 m^2/day and 0.16 m^2/worker-hour. When wind data is overlaid on this plot, only a handful of days with low production rates are explained by strong wind gusts (e.g., >40 mph). Instead, factors such as panel availability, preparation of work areas, installation strategy, and workflow coordination appear to be key enablers of high productivity. Subcontractor interviews confirmed that productivity was maximised when panels were staged on time and working areas were fully prepared.

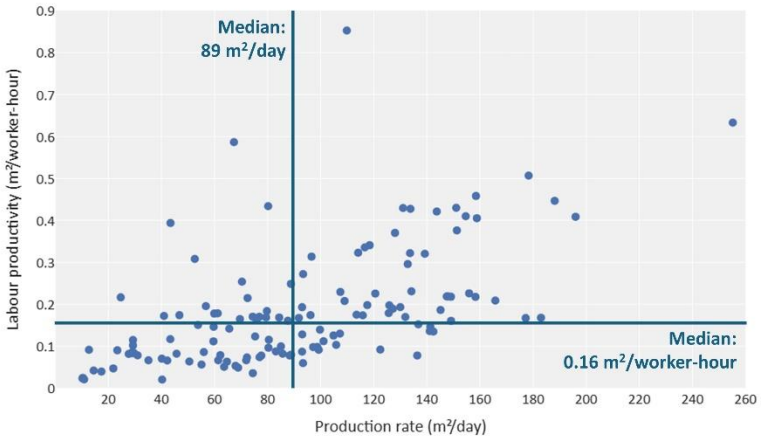
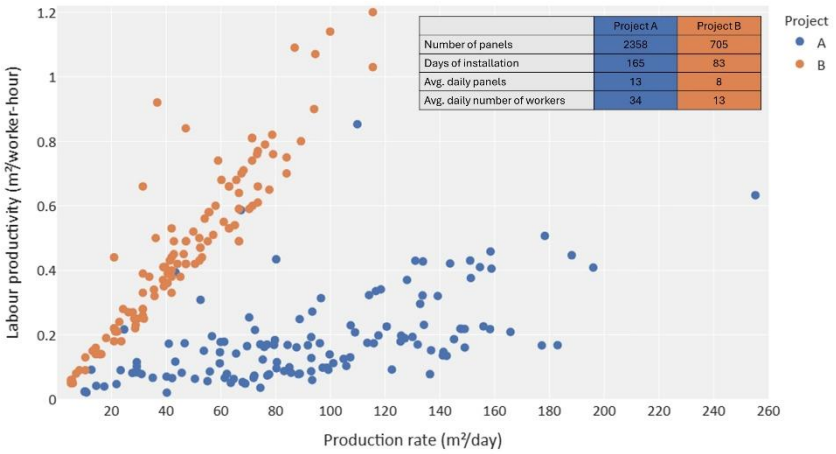


Figure 26: Labour productivity v production rate for unitised panel installation. Each dot represents a day. The median production rate is 89 m²/day (equivalent of 13 panels/day), and the median labour productivity is 0.16 m²/worker-hour

When applied consistently, the framework enables multiple projects to be measured and benchmarked on a like-for-like basis. As organisations accumulate larger datasets, planners and cost estimators can use these benchmarks to improve programme forecasts, test resourcing strategies, and reduce delivery and cost risk.

An example of inter-project comparison is illustrated in Figure 27, which compares cladding installation datasets from the above Project B and a new Project A. The comparison shows that Project B achieved faster overall delivery than Project A, while Project A exhibited higher labour productivity. Project B installed nearly three times as many panels as Project A but completed installation in only twice the duration, indicating a higher production rate. However, this faster delivery was achieved through substantially higher labour input, resulting in lower labour productivity. On average, Project B deployed 34 workers/day, compared with 13 on Project A.

These results demonstrate how benchmarking can inform planning decisions by linking expected outputs to viable crew sizes. Rather than relying solely on planned quantities, planners can use empirical benchmarks to balance delivery speed, labour efficiency, and resourcing strategies to achieve realistic, controllable site outcomes.



	Project A	Project B
Number of panels	2358	705
Days of installation	165	83
Avg. daily panels	13	8
Avg. daily number of workers	34	13

Figure 27: Labour productivity v production rate for unitised panel installation. Comparison of two projects

Benchmarking provides an essential first level of insight by allowing current productivity to be positioned relative to a pooled dataset, for example, identifying whether outcomes fall below the median or exceed the upper quartile (Q3). However, benchmarking alone does not explain why productivity differs. Productivity is shaped by multiple interacting factors, including crew size, construction method (on-site v off-site), crane allocation, and planning and sequencing decisions. As a result, observed variability often reflects differences in managerial choices and production strategies rather than inherent project capability. Under these conditions, simple averages can be misleading and are insufficient as a basis for comparison or decision-making.

To address this limitation, the next chapter moves beyond descriptive benchmarking and applies data analytics techniques to cluster and interrogate the data, isolating the factors that most strongly influence productivity. As construction projects become increasingly data-rich, the ability to benchmark dynamically across activities, work packages, and projects, and to understand the drivers behind observed outcomes, will be central to achieving continuous productivity improvement and advancing evidence-based construction engineering.

6. Productivity data analytics

Pooled productivity datasets enable deeper analytical insights that extend beyond monitoring and benchmarking, providing valuable evidence to support planning, estimating, and programme decision-making. Unlocking this value represents a significant opportunity for construction organisations, as such insights are rarely realised despite the availability of large volumes of project data.

By aggregating datasets across projects, work packages, and activities, the framework creates the foundation for advanced data analytics and the application of machine learning techniques. These methods can be used to explore relationships between productivity outcomes and key project parameters, and to support predictive analysis of alternative planning scenarios. Some parameters are fixed or largely predetermined, such as floor area, building typology, or on-site v off-site construction, while others are actively designed and controlled by project teams, including crew size, slab pours per floor, and crane allocation. Systematic iteration of these variables enables decision-makers to assess trade-offs, reduce programme risk, and adopt a more data-driven approach to construction engineering. This chapter also examines emerging patterns in the benefits of off-site construction and the conditions under which these benefits are realised.

6.1 Benefits of off-site construction

Figure 28 presents an alternative view of the work package dataset for structural frames introduced in Section 5.3, where each data point represents the production rate and labour productivity achieved on a single floor of a multi-storey building. In Figure 28, data points are clustered by the average number of workers deployed per floor. The clusters range from 5–10 workers in Cluster 1 to more than 50 workers in Cluster 9. Lower workforce levels are typically associated with construction methods that reduce on-site labour demand, such as off-site construction, while larger crews are more characteristic of fully in-situ construction.

A key observation from Figure 28 is the cross-cluster pattern, i.e., increasing crew size generally raises production rates but reduces labour productivity, reflecting the trade-off between throughput and labour efficiency[8]. Together, these clusters define a productivity frontier for the dataset, representing the highest achievable productivity for a given crew size. Clustering, therefore, enables the identification of exemplar productivity within each workforce category, providing realistic, context-specific targets rather than relying on global averages.

[8] This is expected as the total number of hours to calculate labour productivity is a function of the number of days used to calculate the production rate, the number of workers, and the daily shift.

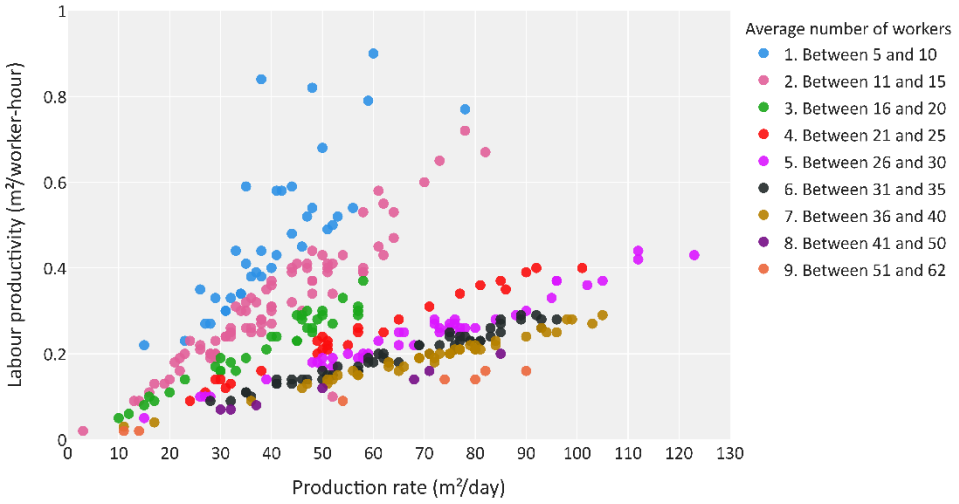


Figure 28: Superstructure productivity. Each dot represents a level within a multi-storey building. Colours represent the average number of workers

Despite these trends, substantial variability exists within each cluster. To explore the underlying drivers, two workforce ranges are examined in detail: (1) 21–25 workers and (2) 26–30 workers. Figures 29a–29d disaggregate these clusters by level of off-site construction. Figures 29a and 29b show that the highest productivity for these crew sizes is achieved on projects with high levels of off-site construction, where both vertical elements and slabs (i.e., lattice) are manufactured off-site.

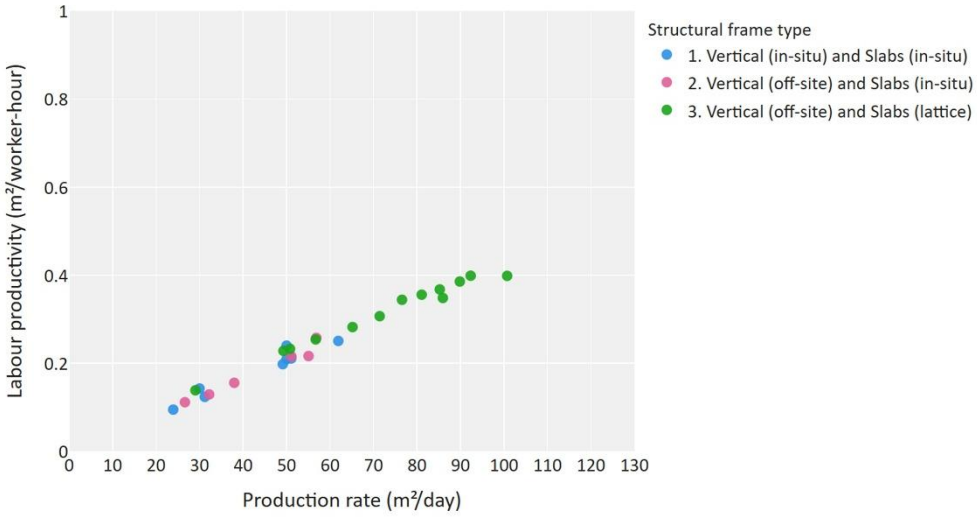


Figure 29a: Superstructure Productivity for an average of 21–25 workers (In colour = Structural frame Type)

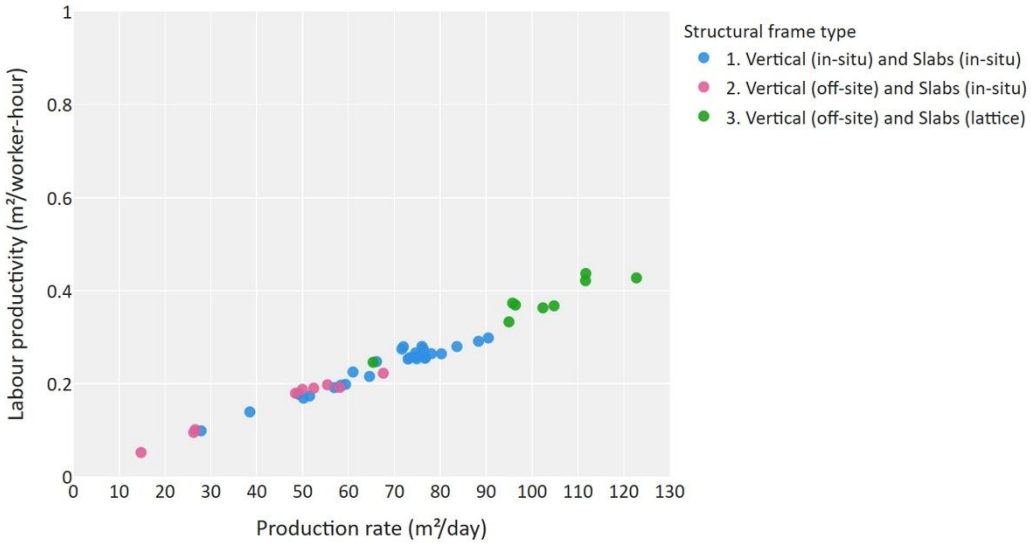


Figure 29b: Superstructure Productivity for an average of 26–30 workers (In colour = Structural frame Type)

6.2 Batching strategy

For in-situ concrete slabs, batching, defined as dividing the construction of a single floor into multiple locations for slab pours, is a widely used strategy to maintain crew continuity and stabilise production flow (Murguia et al., 2023). Despite its prevalence, there is limited empirical evidence on how to optimise batching strategies for different floor sizes and crew configurations. This section addresses that gap by analysing how the floor area, number of pours per floor, and average batch area interact with workforce deployment and productivity outcomes.

Figures 30a and 30b show that for an average crew of 21-25 workers, the best-performing observations consistently fall within a batch size range of 400–600 m², whereas smaller and larger batches have lower production rates. These results demonstrate how the batching strategy directly influences production continuity, flow stability, and overall productivity, offering clear, evidence-based insights for planners and site teams.

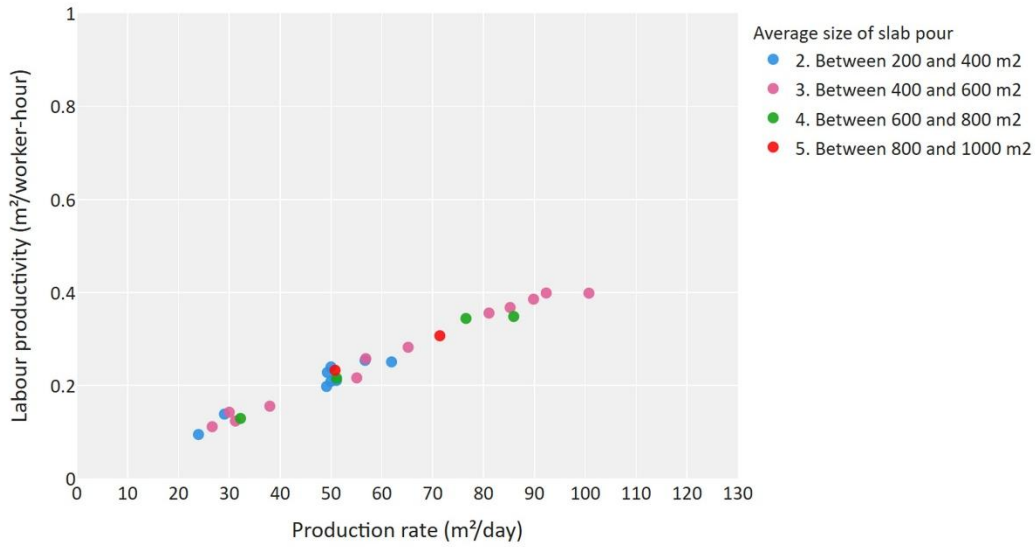


Figure 30a: Superstructure Productivity for an average of 21–25 workers (In colour = Average size of slab pours)

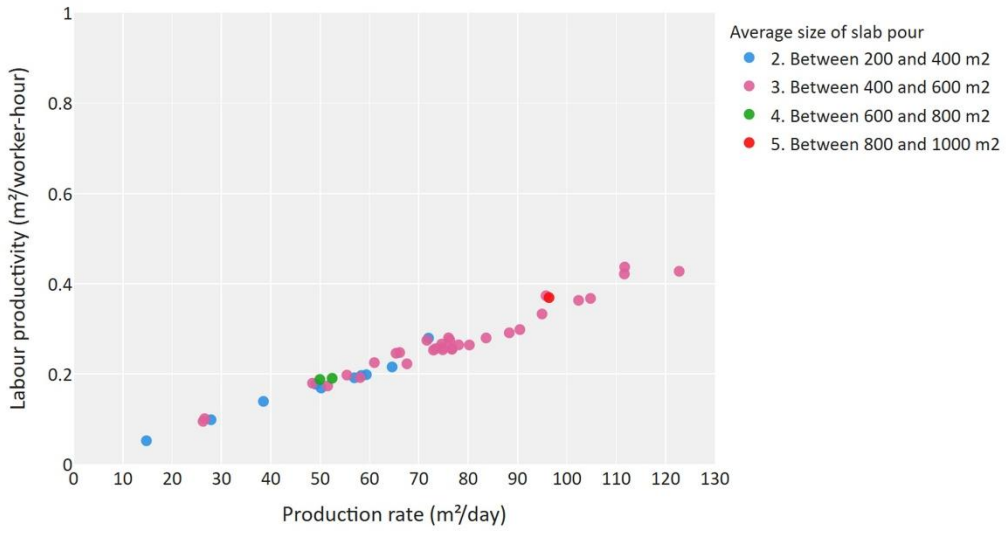


Figure 30b: Superstructure Productivity for an average of 26–30 workers (In colour = Average size of slab pours)

6.3 Cycle time

Cycle time is defined here as the duration required to complete the first batch on a given floor, enabling construction of the subsequent level to commence. For small floor plates (typically 500 m² or less) delivered using a single-batch strategy, the cycle time corresponds to the full floor construction duration. Cycle time is a critical productivity variable in high-rise or linear construction, as it governs handover between floors and directly affects the master programme's critical path.

Figure 31a presents a scatterplot of production rates coloured by achieved cycle time, ranging from 5-10 days to more than 40 days. As observed in earlier analyses, productivity varies widely across the dataset. Figure 31b focuses on floors with cycle times between 11 and 15 days, which are generally associated with higher production rates (often exceeding 80 m²/day), although some observations fall below 50 m²/day. This dispersion suggests that cycle time alone does not fully explain productivity and that factors such as crew size and batching strategy, examined in Sections 6.1 and 6.2, also play a significant role.

To better understand this relationship, Figure 31c presents boxplots of production rate by cycle-time category. These distributions show that the highest production rates are consistently achieved with shorter cycle times, and that outputs exceeding 90 m²/day are observed only when cycle times are between 5 and 15 days. Figures 31d and 31e further reinforce this finding by disaggregating cycle times by crew size. For both the 21-25 and 26-30 worker groups, top productivity is achieved exclusively within the 5-15 day cycle time range.

Overall, the results indicate that shorter cycle times are essential for both compressing programme duration and achieving high production rates. While shorter cycles alone do not guarantee success, the data show that the best-performing floors are consistently associated with cycle times of 5-15 days, highlighting this range as a critical target for planning and control.

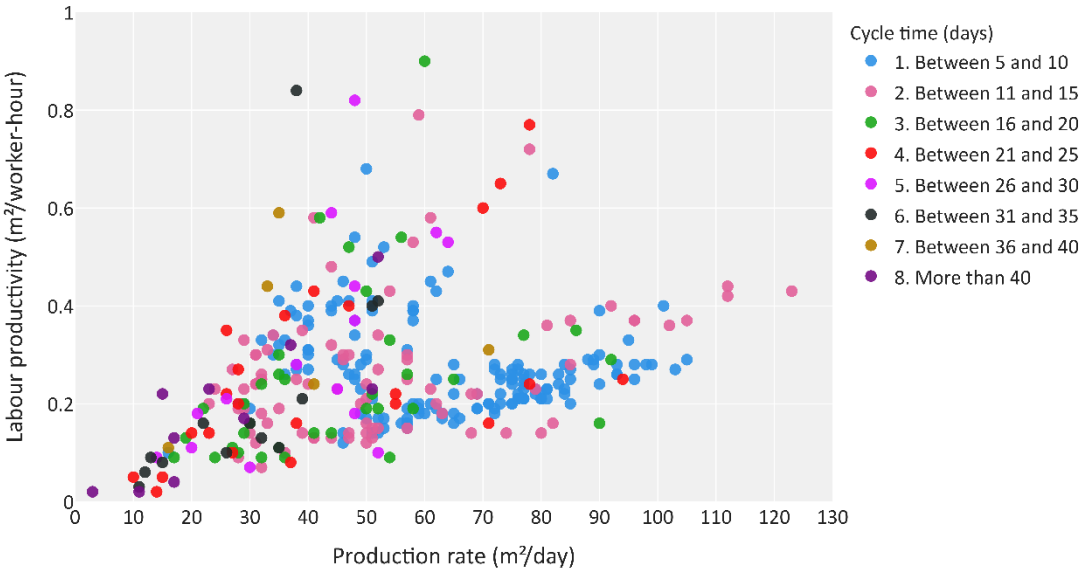


Figure 31a: Superstructure productivity. Each dot represents a level within a multi-storey building. (In colour = Cycle time)

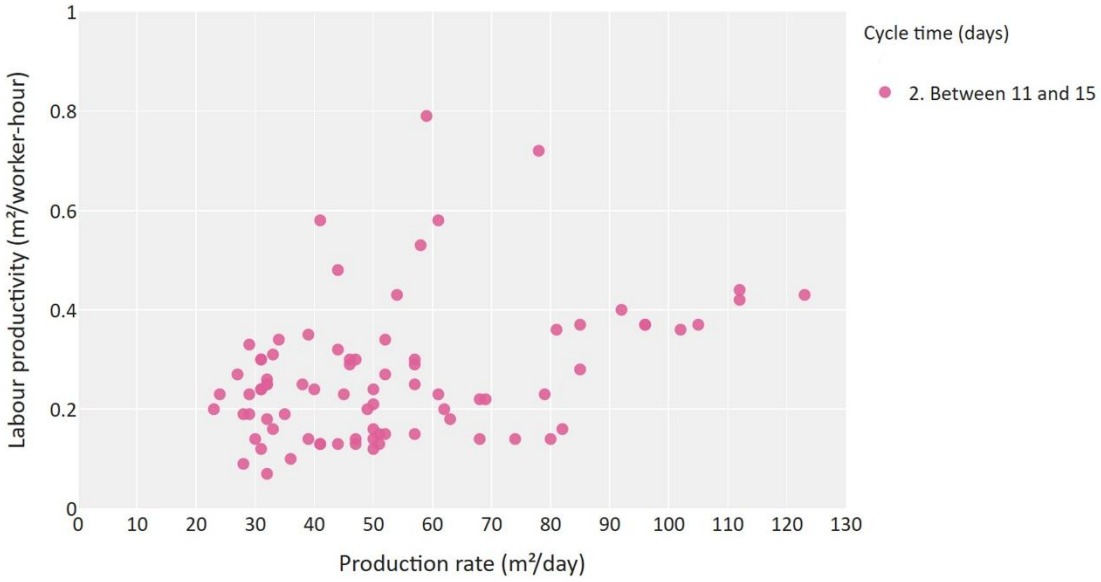


Figure 31b: Production rate variability per cycle time

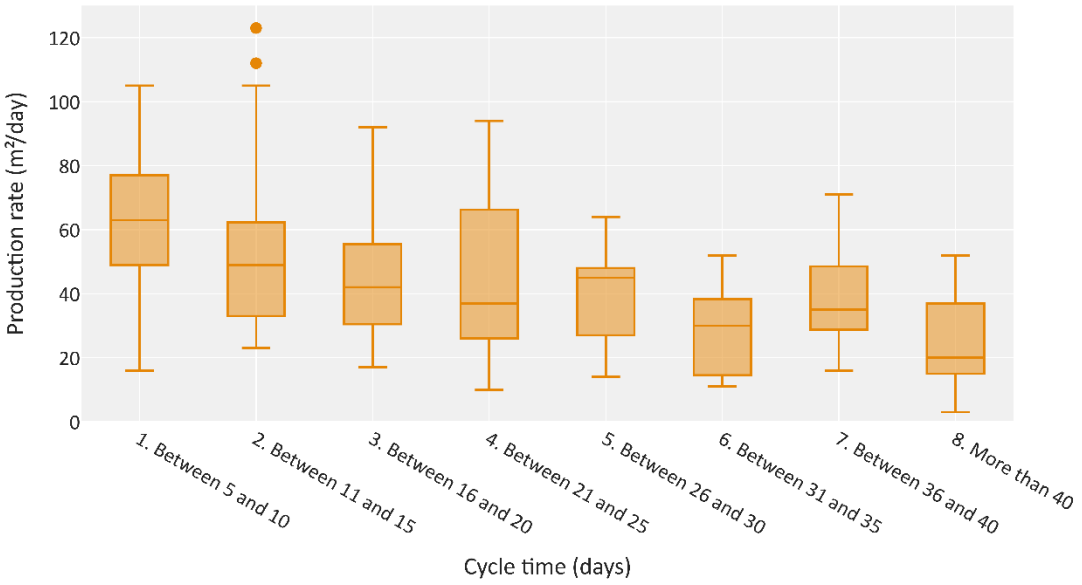


Figure 31c: Production rate variability per cycle time

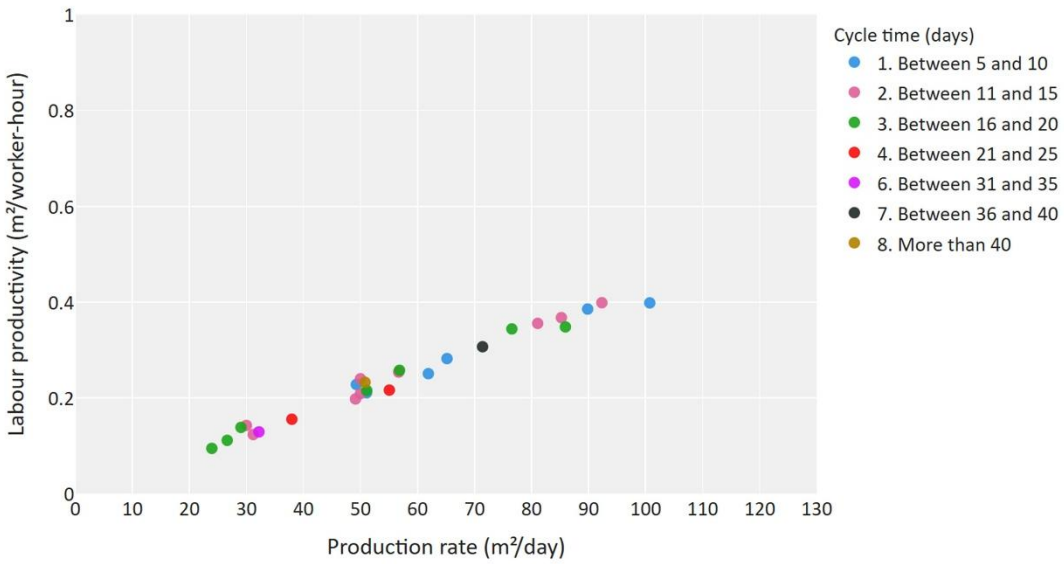


Figure 31d: Superstructure Productivity for an average of 21–25 workers (In colour = Cycle time)

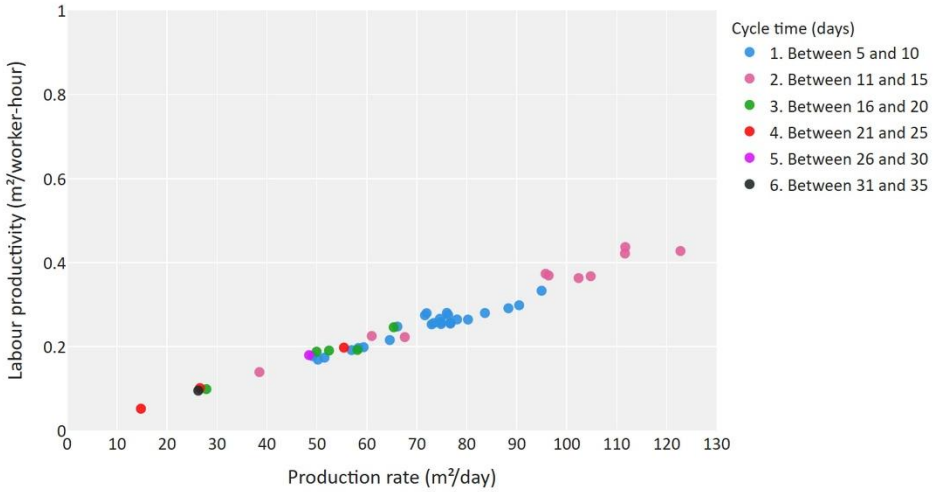


Figure 31e: Superstructure Productivity for an average of 21–25 workers (In colour = Cycle time)

6.4 Number of cranes

Crane allocation is a strategic management decision influenced by multiple factors, including floor plate size, level of off-site construction, supply chain logistics, access constraints, and site configuration. A commonly cited planning assumption across industry partners is that a single hook can serve approximately 500 m² of construction area per week, with programme durations often derived from this rule of thumb. This section examines whether such assumptions are supported by observed productivity data.

Figure 32a groups the work package dataset by crane allocation, distinguishing between projects using one crane and those using two. As expected, performance distributions overlap, indicating that crane number alone does not determine productivity. However, Figure 32b shows that, on average, projects with two cranes achieve higher production rates than those with a single crane. The upper-quartile (Q3) production rate for single-crane projects is approximately 60 m²/day, compared with around 80 m²/day for two-crane projects. These figures correspond to roughly 300 m²/week and 500 m²/week, respectively, and suggest that the commonly assumed 500 m²/week capacity is achieved by two cranes.

Figures 32c and 32d further disaggregate productivity by crew size. For both the 21-25 and 26-30 worker groups, exemplar productivity is observed exclusively on projects using two cranes. Consistent with findings from earlier sections, these high-performing cases are also associated with off-site construction methods and larger floor plates, often up to 2,500 m². Together, these results indicate that crane allocation must be considered alongside workforce configuration, construction method, and batching strategy, rather than as an isolated planning parameter.

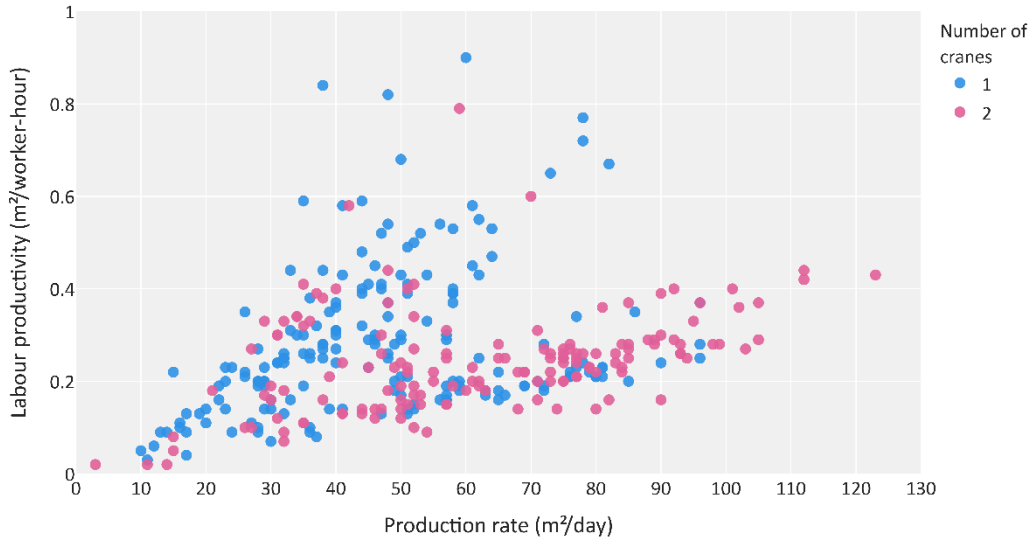


Figure 32a: Superstructure productivity. Each dot represents a level within a multi-storey building (In colour = Number of cranes)

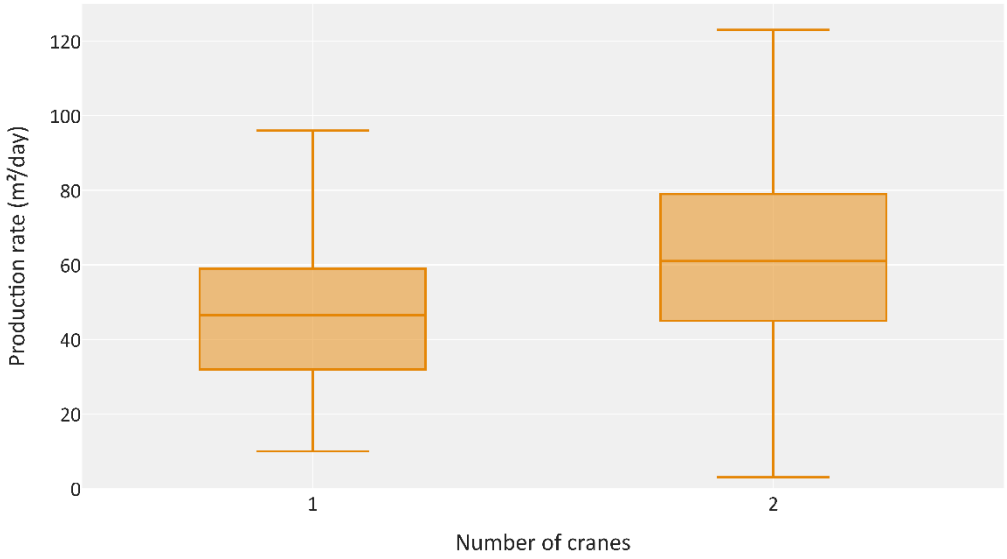


Figure 32b: Production rate variability per number of cranes

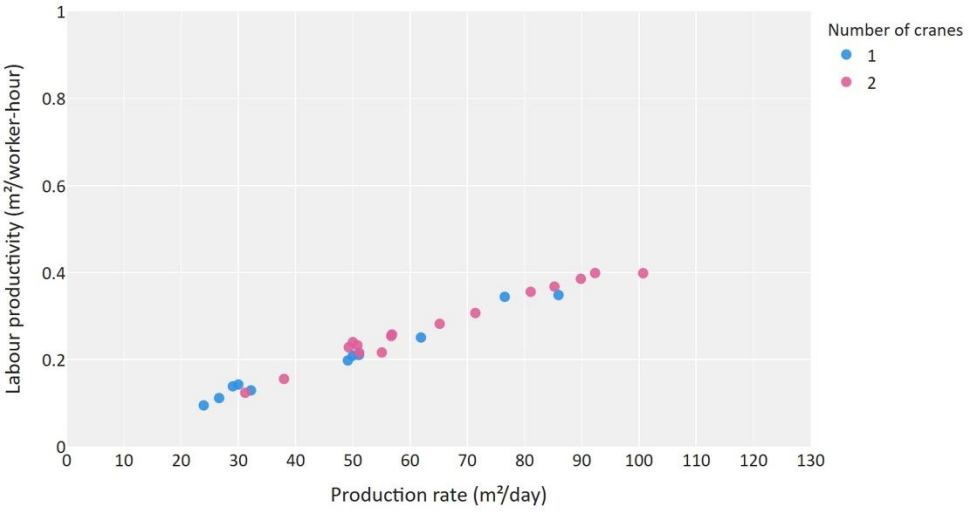


Figure 32c: Superstructure Productivity for an average of 21–25 workers (In colour = Number of cranes)

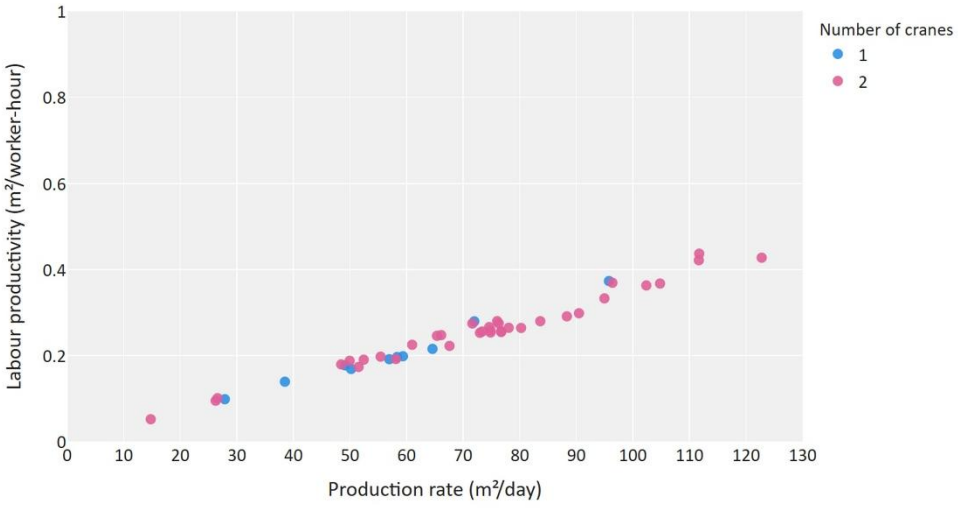


Figure 32d: Superstructure Productivity for an average of 26–30 workers (In colour = Number of cranes)

This chapter has demonstrated how additional insights can be extracted by moving beyond simple benchmarking of median and upper-quartile (Q3) productivity. By systematically scrutinising pooled datasets, the analysis highlights how multiple interacting variables shape productivity outcomes. The breadth and structure of the data presented create the conditions for applying machine learning techniques to predict floor durations, cycle times, and overall programme performance by combining factors under the direct control of decision-makers. This capability enables the development of more realistic programmes, improved risk assessment, and tangible evidence that data-centric approaches to construction engineering are both feasible and valuable.

While the examples in this chapter focus on structural frame construction, the framework and analytical methods are transferable to other work packages, such as cladding and fit-out, and to a wide range of project types, such as hospitals, schools, data centres, prisons, and linear infrastructure.

7. Conclusion

This publication has presented a practical, data-centric approach to measuring, benchmarking, and analysing productivity in construction. It has addressed a long-standing gap between the abundance of data generated on projects and organisations' limited ability to translate it into actionable insights. By introducing the "Cambridge Framework for Construction Productivity", spanning activity, work package, and project levels, this publication demonstrates how construction productivity can be measured consistently, diagnosed rigorously, and used to enhance decision-making.

At the core of the framework is a deliberate shift away from progress-only reporting towards a production-oriented view of construction. Flowlines, location-based metrics, standardised productivity indicators and blockers to productivity provide a common language that reflects how work is actually delivered on site. The case studies in Chapter 4 illustrate how this approach supports live project control, allowing teams to detect deviations early, understand their causes, and evaluate whether corrective actions deliver sustained improvement.

Benchmarking, explored in Chapter 5, extends this capability beyond individual projects. By pooling data across projects, work packages, and activities, organisations can establish empirical reference points for production rates, labour productivity, and cost efficiency. Crucially, the publication shows that meaningful benchmarking requires like-for-like comparisons and sufficient granularity to avoid misleading averages. Project-level benchmarks provide strategic context, but work package and activity-level benchmarks reveal the true drivers of productivity variation and expose opportunities for learning that are invisible in aggregated reporting.

Chapter 6 demonstrates how these pooled datasets unlock further value through advanced data analytics. By clustering data according to decision variables, such as crew size, batching strategy, cycle time, and crane allocation, the analysis moves beyond describing what happened to explaining productivity variability by the system design. The findings provide clear, evidence-based guidance on how management decisions influence productivity outcomes and on the trade-offs between speed, efficiency, and resource intensity. Importantly, the chapter shows that high productivity is rarely the result of a single factor; rather, it emerges from coherent combinations of construction methods, planning strategies, and resource configurations.

Across all chapters, a consistent message emerges. Productivity improvement in construction is not primarily a technological challenge, but an organisational and methodological one. The data required to implement the framework already exists on most projects, although low granularity and gaps persist. What has been missing is a structured way to organise that data, link them across levels, and use them to support decision-making. By standardising metrics, visualisations, and analytical workflows, the framework lowers the barrier to adoption and enables scalable learning across projects and organisations. The message is simple: ***"Leverage the data you already have and make it work for you."***

While many examples in this publication focus on high-rise structural frames, the principles and methods are deliberately generic. They are applicable to the building and infrastructure sectors and to a wide range of building types, including healthcare, education, prisons, data centres, and linear infrastructure. As construction projects become increasingly data-rich, the ability to consistently measure productivity, dynamically benchmark, and analyse drivers of productivity will be central to improving reliability, reducing risk, and advancing evidence-based construction engineering.

Ultimately, this publication argues that productivity improvement are achievable when data are treated not as a reporting by-product, but as a strategic asset. By embedding measurement into everyday project controls and linking it to learning and decision-making, construction organisations can move from reactive management to proactive, informed, and continuously improving delivery.

Acknowledgements

The authors would like to thank all the organisations and individuals who have engaged with this research over the past five years. Their willingness to share real project data, pilot the “Cambridge Framework” on live projects, and contribute openly to knowledge exchange has been fundamental to the development and validation of this work. This level of open data sharing, transparency, trust, and collaboration between industry and academia is rare and represents a significant contribution to advancing research on construction productivity. We are grateful to the Construction Productivity Taskforce for its support and engagement throughout the programme. We would also like to thank Dr Brian Sheil and Tercia Jansen van Vuuren for their thoughtful feedback on earlier drafts of this publication.

This work was completed by researchers at the University of Cambridge Laing O’Rourke Centre for Construction Engineering and Technology.

The Laing O’Rourke Centre for Construction Engineering and Technology was launched in 2010 with industry partner Laing O’Rourke to fulfil a shared vision of transforming the construction industry through innovation, education and technology.

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Appendix A: List of blockers to productivity

Categories	ID	Sub-categories
Labour	1	Labour shortage/workers not attending site
	2	Labour lose time due to unplanned meetings/coordination
	3	Labour work slow due to health and safety caution
	4	Labour productivity is less than planned/expected
Materials	5	Material not available on site
	6	Material delivery issues (late delivery, out of sequence etc.)
Equipment	7	Equipment/crane/hoist being used by other trade
	8	Equipment/crane/hoist breakdown
	9	Equipment/crane/hoist in maintenance
Planning	10	Poor sequencing of activities
	11	Late handover from previous trade
	12	Other trades in the work area/work area not available
Logistics	13	Insufficient crane availability/crane being used by other trades
	14	Loading bay areas/storage area are unavailable
	15	Trades moving materials/tools/equipment to the work area
	16	Material not available in the work area
	17	Trades walk long distances to the welfare area
Health & safety	18	Labour being trained/inducted
	19	Safety non-compliance
	20	Safety incident/accident/near miss interrupting workflow
	21	Safety stand-down due to health and safety
Design and constructability	22	Design information not available
	23	Design issues (incorrect drawings/information, etc.)
	24	Design changes/change orders/scope change
	25	Constructability issues (clashes, poor interfaces, etc.)
Quality	26	Quality issue (material, equipment, final deliverable, etc.)
	27	Re-work
	28	In-progress trade snagging/correcting
Weather	29	Strong winds
	30	Heavy rain
	31	Temperature
	32	Heavy snow
External	33	Interruptions (natural disasters, black swan events, etc.)

Appendix B: Data template for superstructure productivity monitoring

Level	Area	Planned start	Planned finish	Actual start	Actual finish
0	691	24/05/2023	06/07/2023	28/05/2023	13/08/2023
1	691	27/06/2023	13/07/2023	20/08/2023	04/10/2023
2	691	11/07/2023	27/07/2023	01/10/2023	09/11/2023
3	691	25/07/2023	10/08/2023	02/11/2023	10/12/2023
4	691	08/08/2023	24/08/2023	30/11/2023	28/12/2023
5	691	22/08/2023	07/09/2023	11/01/2024	04/02/2024
6	691	05/09/2023	26/09/2023	05/02/2024	25/02/2024
7	691	20/09/2023	10/10/2023	26/02/2024	11/03/2024
8	691	08/10/2023	24/10/2023	12/03/2024	26/03/2024
9	691	22/10/2023	07/11/2023	27/03/2024	14/04/2024
10	691	05/11/2023	21/11/2023	14/04/2024	30/04/2024
11	691	19/11/2023	05/12/2023	01/05/2024	17/05/2024
12	691	03/12/2023	19/12/2023	19/05/2024	13/06/2024
13	691	17/12/2023	02/01/2024	16/06/2024	01/07/2024
14	691	31/12/2023	16/01/2024	02/07/2024	21/07/2024
15	691	14/01/2024	30/01/2024	22/07/2024	06/08/2024



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