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Digital Transformation in Energy Projects Enabling Execution Excellence with a Unified Platform

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Introduction

The energy sector is currently navigating a pivotal transformation. Global electricity demand is set to **double by 2050**, driven by electrification, expanding digital infrastructure, and economic growth—especially in Asia—marking the onset of a new "Age of Electricity" [1],[2]. At the same time, despite a record rise in renewables, the world is still not advancing fast enough to meet the **1.5 °C climate target**, with fossil fuels projected to remain a major part of the energy mix through mid-century [3].

Yet while the energy landscape is shifting fast, the **engineering, procurement, and construction (EPC) sector** remains burdened by persistent inefficiencies [4]. Many projects suffer from fragmented tools, disconnected data workflows, and siloed decision-making, all of which contribute to delays, cost overruns, and rework. One white paper refers to this as the "disconnected ecosystem," where **data collection across multiple platforms is tedious, error-prone, and inefficient** [5]. Similarly, industry commentary highlights that disconnected data leads to lost productivity, missed deadlines, and even litigation risks [6].

This paper argues that **digital unification**—bringing all systems, processes, and teams onto an integrated platform—can be a game-changer for large-scale EPC projects.

We examine a **multi-billion-dollar LNG project** that is currently above **70 % completion**. By integrating more than 15 EPC tools into a unified execution environment, this platform enables real-time data visibility, proactive risk mitigation, and cross-functional collaboration.

The objective of this paper is to evaluate how digital unification improves **delivery predictability**, enhances **operational efficiency**, and drives **sustainability as a built-in outcome**—not a post hoc initiative. We marshal project data, comparative benchmarks, and implementation lessons to demonstrate how execution excellence can become the foundation for cleaner, faster, and more reliable energy infrastructure delivery.

Project Context and Challenges

The case study presented in this paper centres on a **multi-billion-dollar LNG plant expansion**, executed by an **international joint venture (JV) consortium** under a complex governance and contracting structure. The project aims to increase national liquefied natural gas production capacity substantially, contributing to the country's long-term energy security and export growth objectives.

The facility's scope encompasses new process units, utilities, storage, and export infrastructure, along with associated offsites. Engineering, procurement, fabrication, and construction activities are distributed across multiple continents, involving diverse contractors, vendors, and regulatory jurisdictions. The execution environment presents additional challenges: coastal and remote site conditions, intricate logistics for heavy modules, and a high degree of interdependency between engineering deliverables and site readiness.

Pre-Digital Execution Challenges

Before the adoption of a unified digital execution model, the project encountered the typical but serious constraints that affect large-scale EPC undertakings:

- **System fragmentation across EPC phases –** More than 15 distinct engineering, procurement, and construction tools were in use, many operating in isolation. This siloed approach forced manual data transfers, reduced data reliability, and created duplication of effort [7].
- **Workflow misalignment and rework –** Construction packages often advanced without complete engineering information or full material availability, resulting in resequencing, stoppages, and costly rework.
- **Schedule variability –** The effects of external unpredictable events such as but not limited do the COVID, the Russian-Ukraine conflict, transportation threats in middle east/Indian ocean area and in general the world wide instability of the last periods, lead to forecast-actual deviations of several weeks on critical scopes.
- **Sustainability tracking –** Environmental and emissions data were planned to be tracked manually and retrospectively allowing the achievement and in some cases to exceed the initial goals. A further optimisation for carbon and energy reduction during live execution

might have benefitted by a real time integrated sustainability tracking: such methodology and supporting tools were not available during the initial project stages.

Industry Benchmarking

These challenges mirror patterns seen across the global LNG sector. Projects of similar scale, such as **LNG Canada** (Shell, $31 billion, Kitimat) and **Golden Pass LNG** (ExxonMobil/QatarEnergy, $10 billion, Texas), have faced significant delays and cost escalations due to fragmented controls, contracting disputes, and coordination gaps [8],[9]. In both cases, completion slipped well beyond initial schedules despite extensive upfront planning, underscoring the structural nature of these issues.

Need for a Unified Digital Model

For the JV, it became clear that meeting schedule and performance targets would require a **digitally unified execution environment** capable of:

- Integrating data and workflows from all EPC phases into a single, trusted source.
- Providing real-time visibility of progress, constraints, and risks to all stakeholders.
- Reducing execution variability by aligning engineering, procurement, and construction readiness in one platform.

This recognition of the limitations of traditional, fragmented delivery methods set the stage for the implementation of the unified digital platform described in this paper.

Digital Execution Model and Implementation

Platform Architecture

At the core of the project's transformation is PACE OS, Teknobuilt's proprietary unified digital execution platform. Purpose-built for complex EPC environments, PACE OS integrates more than 15 engineering, procurement, and construction systems into a single connected environment, covering 3D modelling, scheduling, procurement, materials management, quality control, and commissioning functions.

The platform's API-driven integration layer connects existing contractor and vendor tools without disrupting their native workflows. All data streams converge into a cloud-based data lake, ensuring a single, authoritative source of project truth. Real-time data pipelines continuously synchronise information across engineering, procurement, and construction disciplines, allowing stakeholders to work from live, verified datasets instead of static or outdated reports.

Data governance is embedded into the platform architecture, with clear ownership, lifecycle management, and access control defined for every data category. Role-based permissions ensure that information is visible only to authorised users, while maintaining transparency across interdependent functions.

This combination of interoperability, high-speed data exchange, and robust governance creates the technical foundation for the platform's operational innovations—most notably the Digital Construction Block™ methodology, which transforms traditional activity-based planning into fully constraint-free execution workflows.

Digital Construction Blocks™ (DCBs)

The Digital Construction Block™ (DCB) methodology is the execution core of PACE OS, replacing thousands of loosely linked activities with intelligent, scope-defined "Blocks" that flow seamlessly from design to delivery.

A Block consolidates all deliverables, resources, and dependencies for a defined scope of work into a single, dynamic execution unit. Each Block is self-contained yet interlinked with others, enabling an assembly-line approach to project delivery — with continuous readiness checks, visibility, and AI-driven optimisation at every stage.

Block Types

1. **Engineering Work Block (EWB)** – Holds all engineering deliverables for a scope, including drawings, 3D models, vendor data, and quantity take-offs.
   Outcome: Engineering is complete, coordinated, and constructible before handover.
2. **Construction Work Block (CWB)** – Captures all construction activities, resources, and constraints tied to the EWB.
   Outcome: Field execution starts without last-minute constraints.
3. **Installation Work Block (IWB)** – Covers installation, inspection, and commissioning.
   Outcome: Smooth turnover to operations with complete as-builts and handover packages.

Execution Logic

The DCB framework follows a defined Path of Construction:

- Plan – Define and package the scope into an EWB.
- Prepare – Align resources, permits, and materials (CWB).
- Execute – Install and commission without constraints (IWB).
- Control – Monitor readiness and progress through the PACE Control Tower.
- Optimise – AI predicts bottlenecks in safety, quality, schedule, and cost before they occur.

Within each Block, discipline-specific work streams — such as Engineering, Materials, Resources, Risk & Safety, and Quality — are progressively completed and verified. Only when all are ready is the Block released for execution.

Benefits

- **Predictability** – Blocks are only released when fully ready.
- **Visibility** – Unified Control Tower view across all scopes.
- **Integration** – Connects engineering, procurement, construction, and commissioning in one flow.

The result is a structured, repeatable execution model that delivers measurable gains — up to 30 % improvement in capex productivity and 18.6 % increase in schedule performance on multi-billion-dollar projects.

Core Functional Modules

The PACE OS platform operationalises the Digital Construction Block™ framework through a suite of specialised, interoperable modules. These modules enable end-to-end visibility, predictive control, and embedded sustainability intelligence across the project lifecycle.

AI/ML-Driven Predictive Analytics

PACE OS applies AI/ML models trained on historical project data to forecast potential schedule delays, manpower bottlenecks, and productivity variances at both block and portfolio levels.

Predictions are embedded in the Control Tower, enabling proactive mitigation before disruptions impact the critical path.

GIS-Powered Progress and Logistics Visualisation

Geo-enabled modules (Geo Plot Manager, Geo Radar) provide spatial mapping of work progress, resource deployment, and material flows. This geospatial context allows for rapid identification of underperforming zones, congestion risks, or logistics delays — critical for large-scale facilities such as LNG plants with multiple active work fronts.

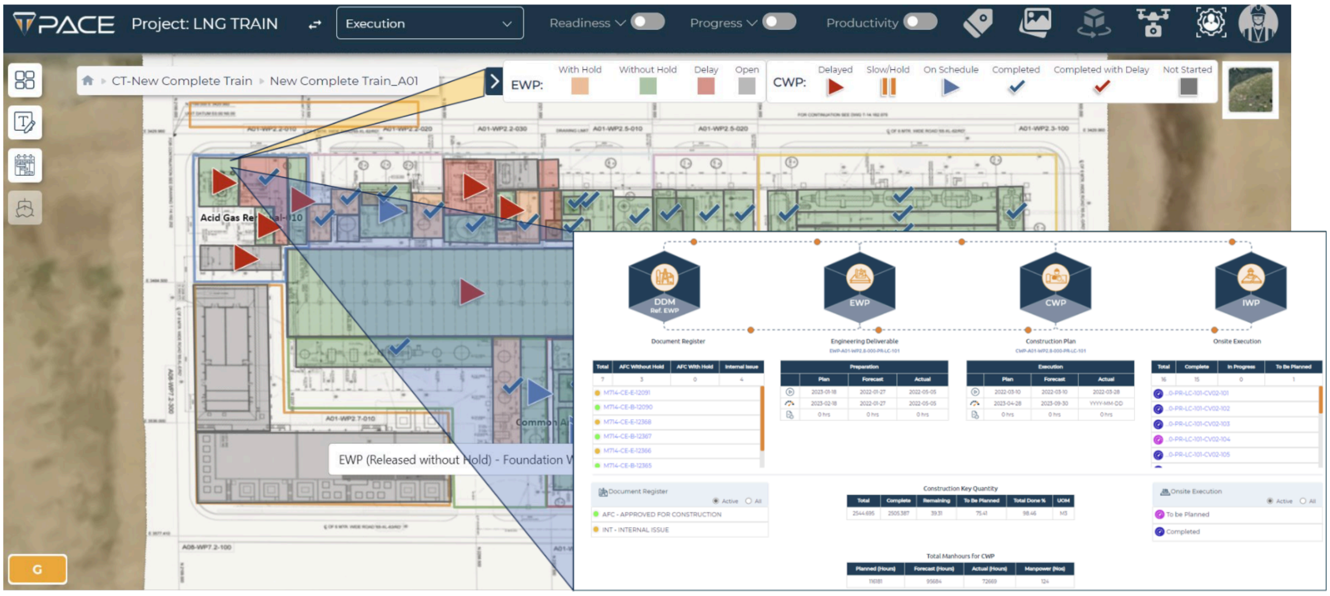


Figure 1 Realtime network intelligence: from design to installation

Integrated Multi-Tier Dashboards

Customisable dashboards consolidate data streams from engineering, procurement, construction, safety, and quality systems into role-specific views. This ensures stakeholders from field supervisors to executive leadership can access real-time, scope-level progress and KPIs without navigating multiple tools.

3D model-based full visibility

The effectiveness of the integration and the perception of the absence of silos working mode can be assessed by the navigation through the 3D model. The navigation shall be facilitated by an intuitive interface that allows the user to move within the model reaching the area of interest. Starting from the Geo Plot view and selecting the discipline of interest, it is possible to easily navigate through the CWAs, reaching the relevant EWB, CWB and IWB. For each IWB it has to be possible to identify the materials that are missing and the Construction stages that are not yet executed allowing to open a constructive exchange with the discipline of interest and driving the completion of that specific CWA. Dedicated tables listing the materials of the CWB and IWB are available in the same page that displays the portion of the 3D model that is being analysed.

In the figures here below it is reported an example of a CWP visualization with the execution status (Figure 2), the welding status (Figure 3) and the material availability status (Figure 4). The same information are reported at the level of IWP (Figure 5, Figure 6, Figure 7) and in the IWP level view it is included a table with the materials that are still missing.

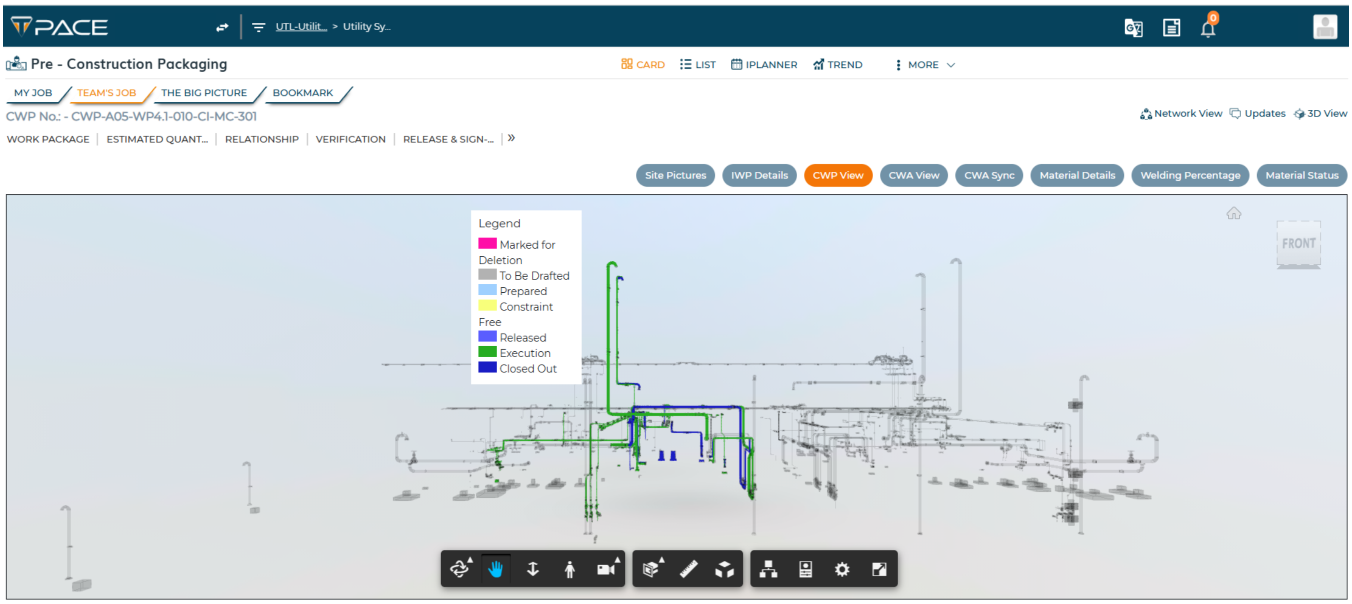


Figure 2 CWP view – aggregate view of the IWPs and their execution status.

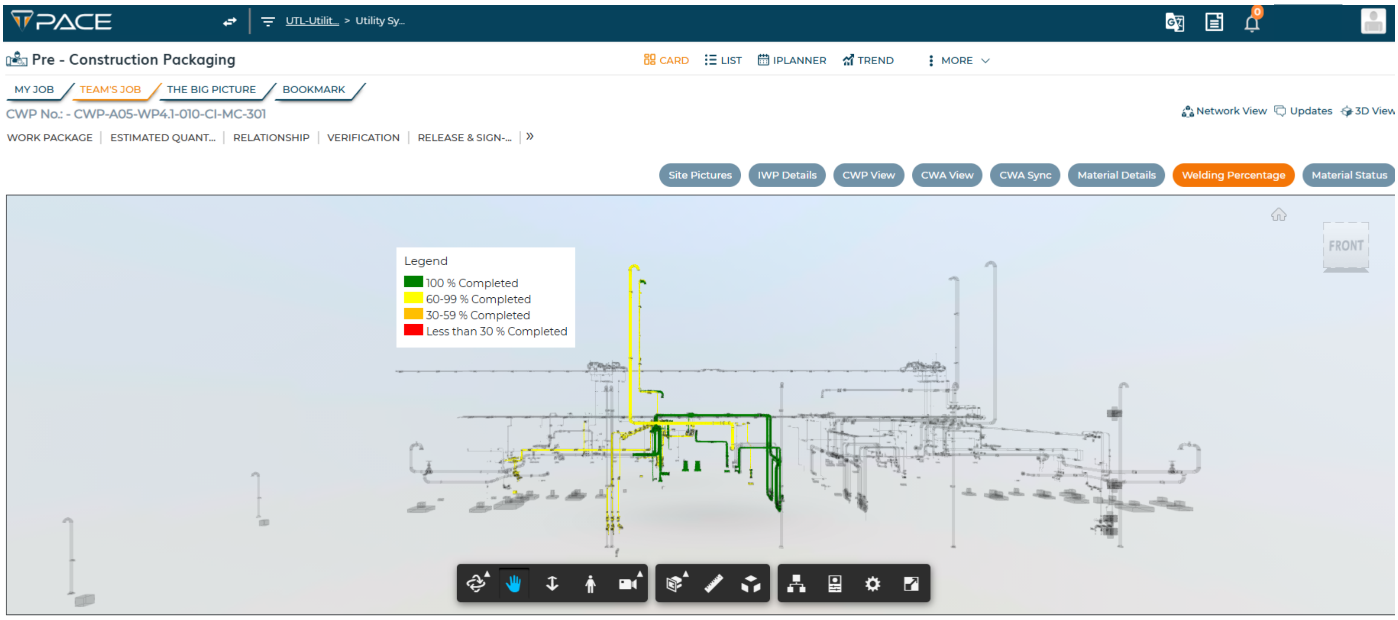


Figure 3 CWP aggregate view with welding status.

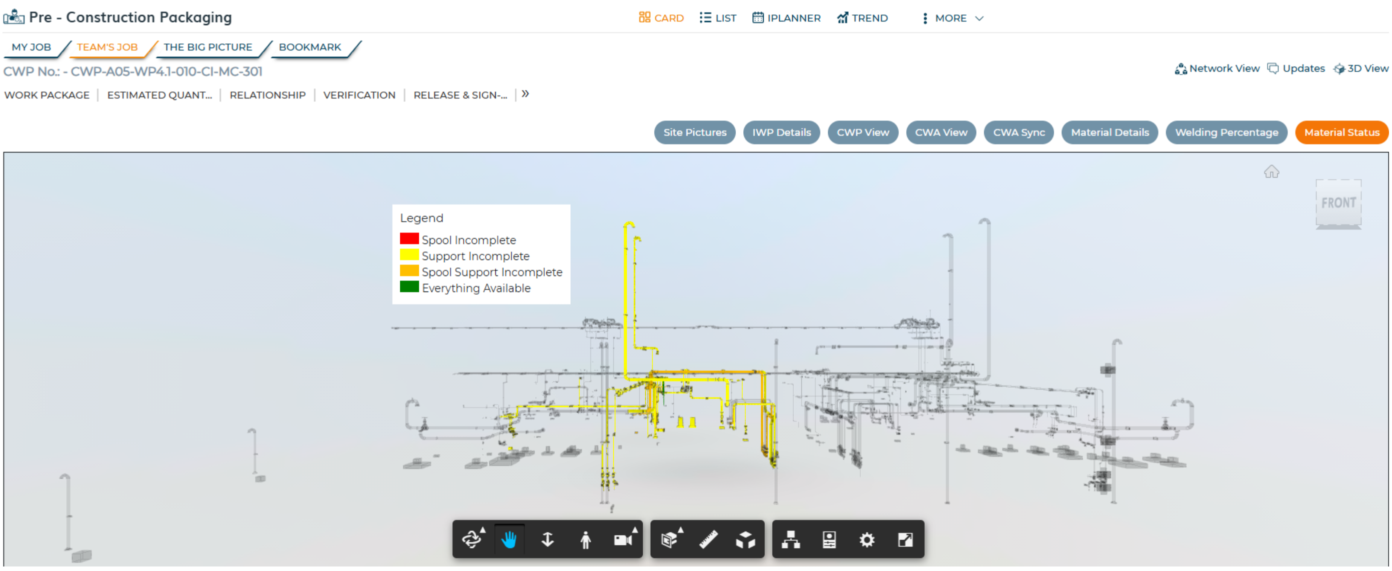


Figure 4 CWP aggregate view with material availability status.

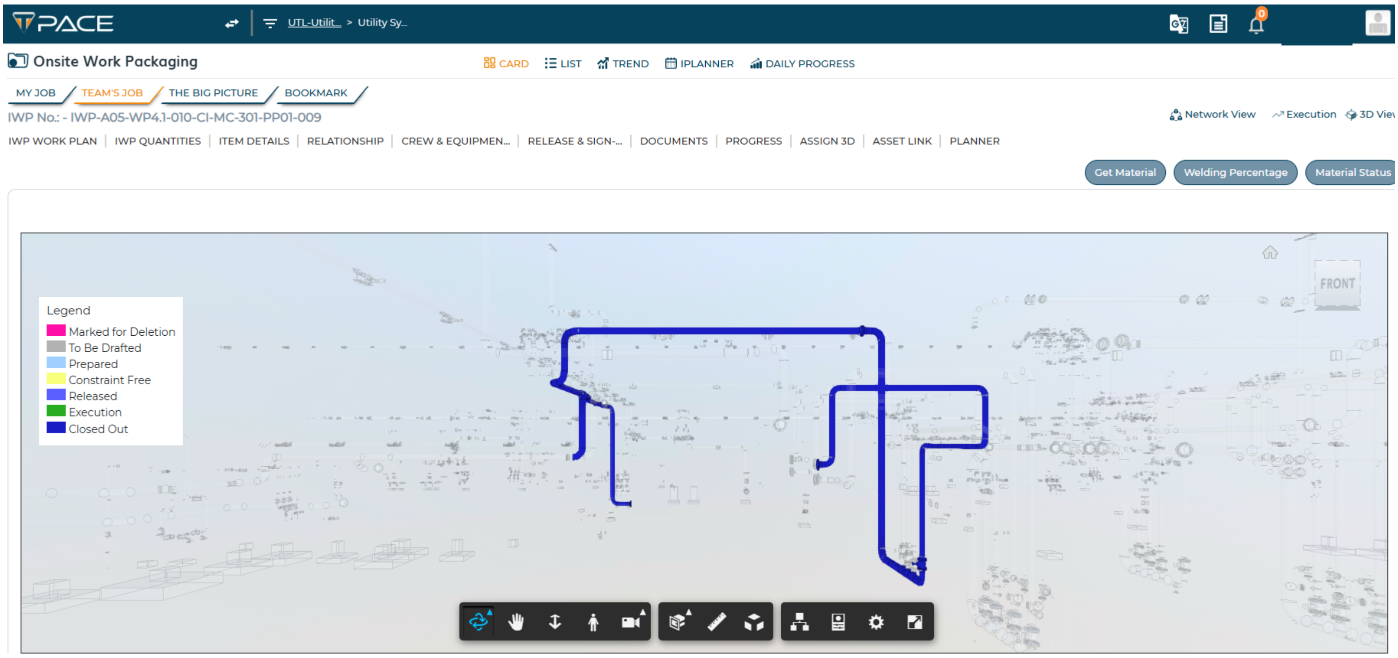


Figure 5 IWP view with status reported as completed.

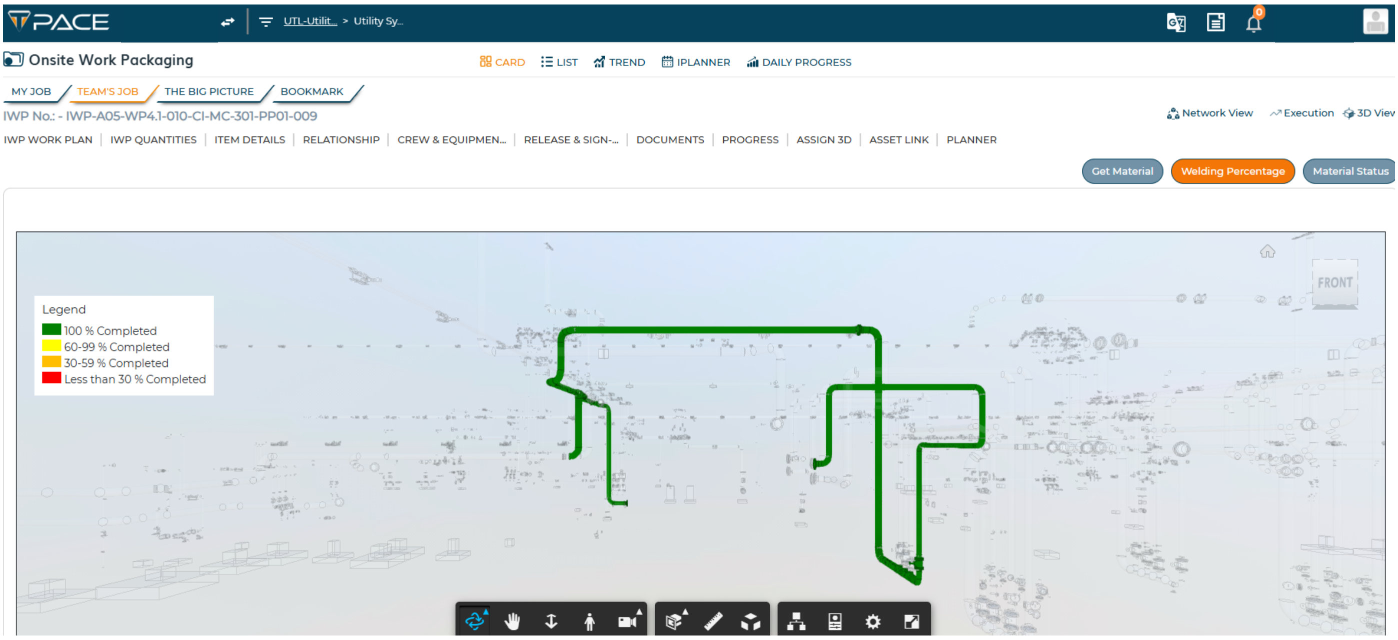
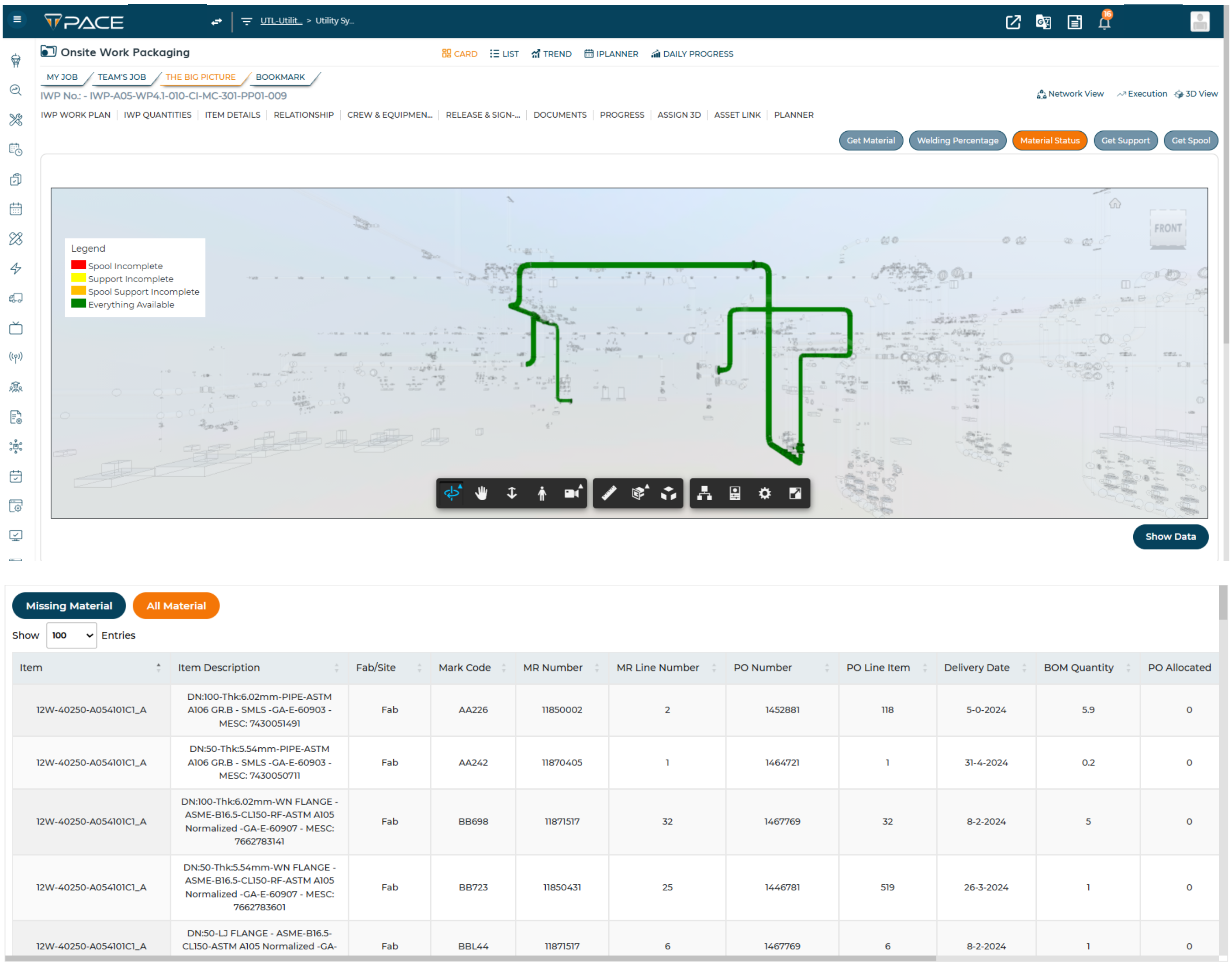


Figure 6 IWP view with welding status reported at 100%.



Item	Item Description	Fab/Site	Mark Code	MR Number	MR Line Number	PO Number	PO Line Item	Delivery Date	BOM Quantity	PO Allocated
12W-40250-A054101C1_A	DN:100-Thk:6.02mm-PIPE-ASTM A106 GR.B - SMLS -GA-E-60903 - MESC: 7430051491	Fab	AA226	11850002	2	1452881	118	5-0-2024	5.9	0
12W-40250-A054101C1_A	DN:50-Thk:5.54mm-PIPE-ASTM A106 GR.B - SMLS -GA-E-60903 - MESC: 7430050711	Fab	AA242	11870405	1	1464721	1	31-4-2024	0.2	0
12W-40250-A054101C1_A	DN:100-Thk:6.02mm-WN FLANGE - ASME-B16.5-CL150-RF-ASTM A105 Normalized -GA-E-60907 - MESC: 7662783141	Fab	BB698	11871517	32	1467769	32	8-2-2024	5	0
12W-40250-A054101C1_A	DN:50-Thk:5.54mm-WN FLANGE - ASME-B16.5-CL150-RF-ASTM A105 Normalized -GA-E-60907 - MESC: 7662783601	Fab	BB723	11850431	25	1446781	519	26-3-2024	1	0
12W-40250-A054101C1_A	DN:50-LJ FLANGE - ASME-B16.5-CL150-ASTM A105 Normalized -GA-	Fab	BBL44	11871517	6	1467769	6	8-2-2024	1	0

Figure 7 Material status 3D view with materials report.

Results and Performance Metrics

Forecast vs. Actual Hours by Discipline

A total of **4,358 IWPs** (covering **311 CWPs**) have been analyzed. The evaluation is limited to **Civil (General + Structural), Mechanical, and Piping**, where sufficient data is available to ensure a consistent analysis based on actual achieved progress. Other disciplines (e.g., Electrical – Cable, Instrumentation – Inline) do not yet provide sufficient quantitative data to support a robust retrospective evaluation.

The data overview is given in Table 1 and Figure 8.

Table 1 Manhours recorded by discipline and aggregate

Discipline	**Forecast MH**	**Actual MH**	**Actual/Forecast MH**
Piping	52420	65940	1.25
Civil	78903	78773	0,99
Mechanical	158180	171380	1,08
Aggregate	289503	316093	1,09

Observations

- **Piping** shows significant overruns (**25%**), indicating downstream readiness gaps and constraint mismanagement (see Figure 8).
- **Mechanical** shows a limited variance (**8%**), reflecting both a reduced impact from upstream design activities and the effects of material availability.
- For **Civil**, productivity slightly exceeded expectations by approximately **1%**.
- Overall, the analysis revealed an **inefficiency of 9%**.

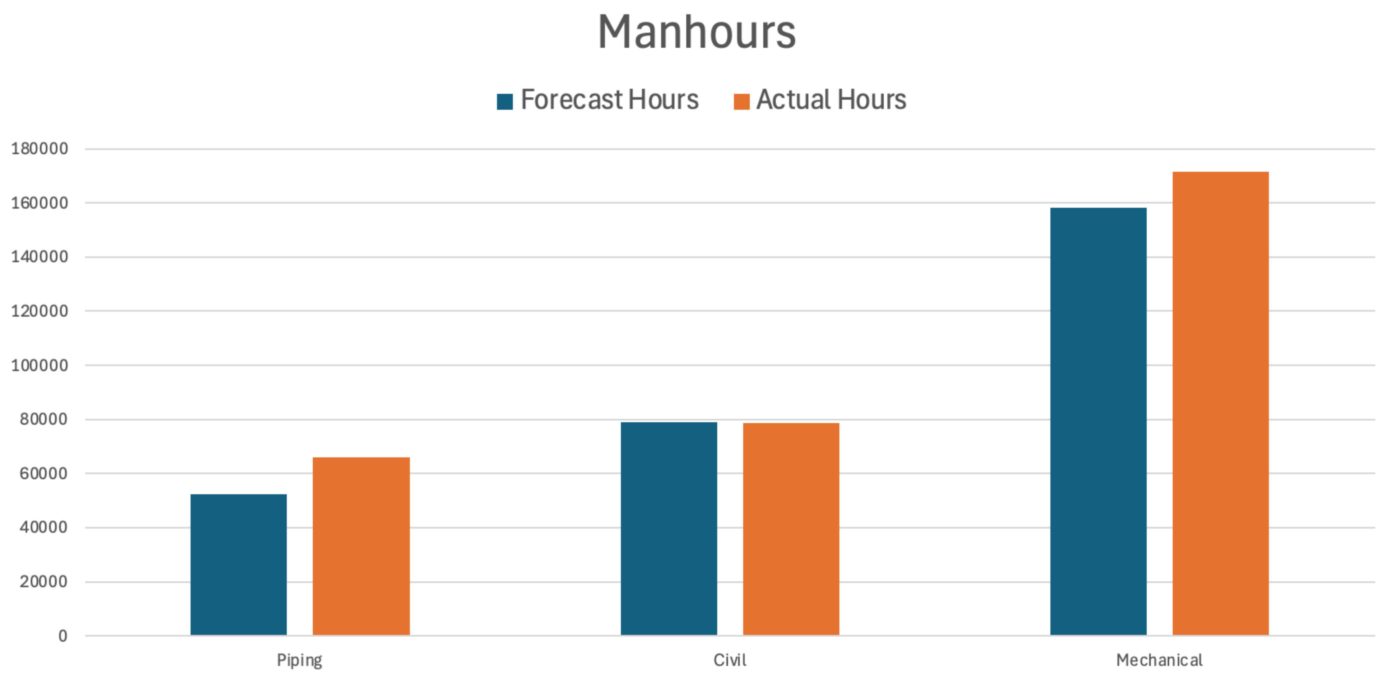


Figure 8 Forecast manhours VS Actual manhours for Piping, Civil and Mechanical

The observed overall inefficiency of 9% provides evidence of the effectiveness of the AWP methodology, particularly when contrasted with the industry benchmark of 40–60% overruns [10].

Disclaimer: The data and results presented are based on the current project progress. Final performance will be reassessed and confirmed upon project completion.

Key Takeaways

- **Opportunities for improved synchronization:** Constraint-driven execution gaps across disciplines led to inflated manhours, highlighting areas where better alignment can further optimize outcomes.
- **Discipline-specific performance patterns:** Variability was observed across disciplines, with Civil exceeding expectations while others (e.g., Piping) showed room for improvement.

- **Validated performance advantage:** With an overall inefficiency of only 9% compared to the industry benchmark of 40–60% overruns, the project demonstrates clear early benefits of applying the AWP methodology and digital execution modeling.

Analysis and Discussion

Discipline-Level Performance Drivers

Civil (Outperformers):

- Benefited from standardized work packages and fewer dependencies.
- Civil works were front-loaded and less impacted by downstream constraints.

Piping (Laggers):

Suffered from fragmented inputs, late vendor deliverables, and high cross-discipline dependencies.

Impact of Digital Construction Blocks™ (DCBs)

- **Shift from Activity-Centric to Block-Centric Planning**: Enabled sequencing and clearance of constraints before workface release.
- **Workface Readiness**: Where DCB adoption was stronger (e.g., Civil), overruns were significantly reduced.
- **Kanban Flow**: Work packaging and "clear-to-execute" logic improved throughput in disciplines with repeatable tasks.

Overruns vs. Industry Baselines

- Project recorded a **9% schedule overrun**, compared to **40–60% overruns** typical in LNG megaprojects.
- Demonstrates that a good digital execution tool, PACE OS, delivers measurable improvement.
- Reinforces prior benchmarking (Golden Pass, LNG Canada) that baseline overruns are systemic across industry.

Change Management and Adoption Curve

- **Cultural Shift**: Teams accustomed to Excel-based planning resisted the DCB approach initially.
- **Training & Champions**: Civil groups had early champions who ensured smoother adoption.
- **Learning Curve Effect**: Initial resistance gave way to adoption once tangible efficiency benefits became visible.
- **Gap**: Specialized disciplines had slower uptake due to less training alignment and fragmented workflows.

Operational Efficiency as a Driver of Sustainability

PACE OS's **digital execution paradigm** reframes sustainability—as not merely a compliance checkbox or a separate initiative—but as an **intrinsic outcome of operational excellence**. By eliminating inefficiencies, the platform simultaneously neutralizes environmental impacts. Here's how:

Reduced Idle Time and Resource Energy Use

Digital Construction Blocks™ (DCBs) with their constraint-aware release mechanism ensure work packages are only released when truly ready. This reduced idle equipment and labor downtime, improving productivity while cutting emissions. Studies show that such workflow readiness models significantly reduce idle resource usage—key for lowering fuel consumption and GHG emissions in EPC environments disconnected.

Minimization of Rework and Material Waste

Rework is not only a cost driver—it's also a hidden environmental burden. Research indicates that **rework can account for up to 5% of construction's total emissions**, driven by poor planning, design changes, and inadequate coordination [11]. By enabling earlier defect detection and quality intervention at IWB/CWB levels, PACE OS substantially reduces rework—and therefore material waste—contributing directly to project-level emission reduction.

Efficiency Metrics as Carbon Proxies

The project's **overall performance efficiency of 1.8** indicates reduced resource performance relative to forecast—yet, compared to typical industry overruns of 40–60%, this execution variance (~9%) reflects a meaningful eco-efficiency gain. When viewed through the lens of carbon intensity per unit of work delivered, that improved predictability and reduced waste equate to a tangible reduction in lifecycle carbon footprint.

Embedding Sustainability as an Outcome

Rather than constructing a separate sustainability "bolt-on," PACE OS enables **built-in environmental accountability**. Carbon budgets linked to each Block allow teams to optimize decisions (e.g., sequencing, logistics, rework interventions) in real time, aligning delivery performance with carbon-conscious execution. This shifts the narrative: sustainability becomes a byproduct—rather than a side goal—of operational efficiency

Innovation and Strategic Value

Non-Invasive Integration

One of the most common barriers to digital transformation in capital projects is the **cost and disruption of replacing legacy systems**. Traditional rollouts often require complete IT overhauls, which trigger resistance from project teams and delay adoption.

PACE OS addresses this challenge by taking a **non-invasive integration approach**:

- It connects with **15+ industry-standard and proprietary tools** through **open APIs and real-time data pipelines**.
- Data is unified but yet distributed into **cloud data buckets (the DCBs)**, where it becomes actionable without altering the underlying system architecture.

- The model allows EPC contractors and owners to **preserve existing IT investments** while gaining unified visibility across the project lifecycle.

This approach ensures a **"plug-in, not rip-and-replace"** transformation, making adoption faster and less disruptive.

Data Democratization

Megaprojects typically suffer from **data silos** — engineering owns one dataset, procurement another, and construction yet another. This creates mismatches, duplication, and disputes.

PACE OS enables **data democratization** by ensuring that validated project data is accessible to **all stakeholders** through **tiered dashboards**:

- **Owners and Regulators** → Portfolio-wide progress, safety, and carbon metrics.
- **EPC Contractors** → Integrated engineering-procurement-construction dashboards with bottleneck alerts.
- **Subcontractors & Field Supervisors** → Workface readiness, manpower allocation, and daily activity tracking.

This **"single source of truth"** reduces errors, accelerates approvals, and minimizes claims. More importantly, it fosters **trust across stakeholders**, a key success factor in megaproject delivery.

Digital Construction Blocks (DCBs) as Scalable Units

The **DCB framework** is one of the most strategic innovations of PACE OS. Instead of executing projects as **millions of isolated activities**, DCBs consolidate work into **repeatable, intelligent units** that align with the logical Path of Construction.

- **Engineering Work Blocks (EWB):** Validate design completeness and constructability.
- **Construction Work Blocks (CWB):** Align manpower, equipment, and safety prerequisites before field release.
- **Installation Work Blocks (IWB):** Manage installation, inspection, and turnover seamlessly.

The **scalability** of DCBs is critical:

- Large projects (e.g., LNG plants) can consist of **thousands of blocks**, each optimized through AI-driven readiness checks.

- Smaller projects (renewables, infrastructure) may use hundreds of blocks but still benefit from the same **standardized methodology**.
- As blocks are reusable, PACE OS creates a **knowledge library of "execution templates"** that can be applied across different projects, industries, and geographies.

This transforms EPC delivery from an **ad-hoc, activity-based process** into an **industrialized, repeatable assembly-line model**.

Blueprint for Industry Transformation

The cumulative innovation of PACE OS positions it as more than a platform — it is a **blueprint for next-generation EPC delivery**:

- **Standardization:** DCBs provide a unified execution logic applicable across industries.
- **Transparency:** Dashboards eliminate disputes by aligning all stakeholders on a common dataset.
- **Sustainability:** By embedding carbon and efficiency tracking, operational gains directly support net-zero targets.
- **Scalability:** Non-invasive integration ensures both greenfield projects and brownfield upgrades benefit without IT overhaul.

In this sense, PACE OS aligns with global trends in **industrialized construction and sustainability-driven project delivery**, making it a **strategic enabler** for the energy transition.

Lessons Learned & Adoption Challenges

Technical Integration vs. Behavioural Change

One of the clearest lessons is that **technology alone is not enough**. While PACE OS demonstrated seamless integration with existing EPC tools, the **bigger hurdle was behavioural**:

- Field teams accustomed to Excel or manual reporting were reluctant to transition into structured DCB workflows.
- Managers required assurance that dashboards reflected reality and not just "another reporting layer."

- Overcoming this required **hands-on training, role-specific dashboards, and change champions** within each discipline.

Adoption Curve Across Disciplines

Adoption was not uniform:

- **Civil** was quickest to adopt DCB workflows, seeing immediate benefits in sequencing and progress visibility.
- **Mechanical** took longer, as they often work on multi-layered systems with overlapping dependencies.

Balancing Standardization with Flexibility

Performance thrives on standardization — yet projects often require tailored execution approaches. PACE OS strikes a strong balance between the two: the platform is highly configurable, while the Digital Construction Block (DCB) framework drives standardization by design.

- Some contractors sought to customize dashboards or work-block definitions beyond standard templates.
- Over-customization risked undermining the **repeatability** of DCBs.

The key takeaway is that **flexibility must be bounded**: standardized logic should hold, but configurable views and filters keep stakeholders engaged.

Change Management & Leadership Commitment

Perhaps the most critical lesson was the role of **leadership commitment**:

- Where team leaders actively sponsored PACE OS adoption, uptake was rapid and measurable.
- In contrast, teams without strong sponsor backing saw pockets of resistance, with digital tools relegated to "side systems."

Cultural Shift Towards Data-Driven Decisions

Introducing AI/ML forecasts, readiness checks, and efficiency ratios challenged long-standing **intuition-driven decision-making** in EPC projects.

- While some managers welcomed predictive insights, others were skeptical until proven against actuals.
- Over time, **trust built through accuracy** of forecasts and visible efficiency gains turned scepticism into advocacy.

Future Adoption Considerations

Looking ahead, the key adoption challenges to anticipate include:

- **Regulatory Alignment:** Ensuring digital progress and sustainability metrics align with emerging compliance frameworks.
- **Cross-Enterprise Scaling:** Shifting from single-project implementations to enterprise-wide adoption will significantly enhance performance, as the new approach gains broader acceptance and stronger integration across the organization.
- **Talent Development:** Building a digital-savvy workforce that can manage DCBs, AI forecasts, and carbon-linked KPIs.

Conclusion

Recap of Achievements

The deployment of PACE OS with the Digital Construction Block (DCB) framework has shown that digital unification can transform EPC delivery from fragmented, reactive execution into **predictable, efficient, and sustainable operations**.

- **Predictability:** AI/ML forecasting reduced deviations, with measurable efficiency gains across disciplines.

- **Reduced Deviation:** Performance efficiency reached 1.09, outperforming industry norms where overruns of 40–60% are common.
- **Embedded Sustainability:** Operational efficiency directly translated into lower idle time, reduced rework, and lower transport emissions — proving that sustainability is a **natural outcome of execution excellence**.

This marks a shift from digital pilots to tangible, field-proven results.

The Future Standard for EPC

The broader implication of this work is clear: **digital unification is no longer optional**. Fragmented tools and siloed reporting cannot meet the pace of the energy transition, infrastructure growth, and ESG imperatives.

- DCBs provide the blueprint for execution at scale.
- PACE OS is positioned as the digital operating system for EPC projects, bringing together engineering, procurement, construction, operations, and sustainability into one unified workflow.
- This creates a model not just for individual projects, but for the future of capital project delivery worldwide.

The path forward is about **institutionalizing these gains** — embedding digital execution as the standard, not the exception. With proven results, expanding capabilities, and alignment to regulatory and sustainability frameworks, PACE OS and DCBs stand as a **new execution paradigm**.

Predictability achieved. Efficiency unlocked. Sustainability embedded.
The roadmap ahead is to scale this success — turning digital unification into the global standard for EPC delivery.

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