



Business-friendly Solutions

When Plants Become Products:

Engineering for Assembly at Scale: A New Playbook for Plant Engineering

How DFMA and Digital Twin-led Engineering
are Redefining Capital Project Execution

WHITEPAPER

Executive Summary

The global plant engineering market is entering a major growth phase, driven by three converging investment themes: rapid industrialisation across emerging economies, large-scale data centre build-out, and the resurgence of manufacturing capacity in the Americas. Together, these forces are reshaping the scale, speed, and complexity of capital projects worldwide.

The global plant engineering and services market, currently valued at approximately USD 40- 45 billion, is projected to exceed USD 60 billion by the mid-2030s, supported by sustained capital investment across process and discrete industries.¹ Asia-Pacific remains the largest contributor to new plant engineering demand, led by manufacturing growth, infrastructure development, and supply-chain localisation initiatives.² Within APAC, India and Southeast Asia are seeing accelerated investments across FMCG, Agri-processing, packaging, utilities, and specialty manufacturing, while the Middle East continues to invest heavily in energy, petrochemicals, water, and infrastructure under national diversification programs.^{2 3}

Overlaying this industrial expansion is the rapid rise of data centre construction, now among the fastest-growing segments of plant infrastructure. Hyperscale cloud adoption, AI workloads, and digital services are driving record global investments.⁴ In the United States, data center construction spending has reached historic highs, with double-digit year-on-year growth driven by AI-intensive capacity expansion.⁵

At the same time, reshoring and near-shoring initiatives are accelerating new manufacturing builds across the Americas, particularly in electronics, packaging, chemicals, and advanced manufacturing⁶. Policy incentives, geopolitical considerations, and supply-chain resilience priorities are reinforcing this structural shift.^{5 6} While these trends present a compelling opportunity, they also place unprecedented pressure on engineering organisations to deliver faster, safer, and more predictable outcomes. Traditional, document-centric engineering models struggle under rising complexity, leading to late-stage constructability issues, rework, and cost overruns.⁷

Design for Manufacturing and Assembly (DFMA), long proven in product engineering, is now becoming foundational for capital projects. As plants and data centres increasingly resemble large-scale assemblies of modular systems, DFMA enabled and sustained through a Digital Twin, offers a new execution model. By preserving constructability intelligence from design through commissioning and operations, the Digital Twin led DFMA improves schedule certainty, reduces risk, and enables scalable delivery.^{7 8}

Plant Engineering at Scale: Why Traditional Approaches Are Straining

Plant engineering has always been complex. What has changed is the scale, speed, and concurrency of modern capital programs. Today's projects feature parallel greenfield and brownfield developments, distributed EPC and OEM ecosystems, compressed timelines, and heightened safety, sustainability, and compliance expectations.

In this environment, engineering inefficiencies cascade across procurement, construction, and operations. Fragmented handovers force execution teams to reinterpret design intent, while the absence of a persistent digital plant model amplifies uncertainty rather than containing it.

Core Challenges in Modern Plant Engineering

Across industries and geographies, most plant engineering challenges fall into a small number of interconnected themes.



Fragmented Engineering Information:

Engineering data is created across disciplines, tools, and organisations, often without a unified digital backbone. This results in multiple versions of truth, slow change propagation, and manual coordination. DFMA depends on early system-level visibility, which fragmentation directly undermines. The absence of a digital twin means assembly logic is rarely preserved beyond isolated design reviews.



Late Discovery of Constructability and Assembly Issues:

Many execution failures stem from untested assembly assumptions, such as access constraints, lifting limitations, and sequencing conflicts. Without digital simulation of construction logic, these issues surface on site, where resolution is slow, costly, and disruptive.



Under-utilisation of Modularisation and Prefabrication:

Despite proven benefits, modularisation remains inconsistently realised. Late design freezes, weak interface definitions, and limited digital validation prevent teams from confidently committing to off-site fabrication. Without a digital twin to validate transportability, assembly sequencing, and interface tolerance, projects default to stick-built execution.



Weak Continuity from Engineering to Operations:

Post-commissioning, engineering models often lose relevance. Without a living digital twin, operations rely heavily on experience rather than structured knowledge, limiting maintenance efficiency and future upgrade planning.



Skills and Adoption Gaps:

DFMA and digital engineering demand a shift from discipline-centric outputs to system-centric thinking. Without governance and structured workflows, digital initiatives struggle to scale beyond pilot programs.

Why DFMA Must Be Central - Not Peripheral

Industry studies show that 60- 70% of lifecycle cost and schedule risk is locked during early design, while late-stage rework can add 5- 15% to installed cost.^{9, 10} Hyperscale data centre programs applying DFMA-led modularisation have achieved 20- 40% schedule compression and 30–50% reductions in on-site effort.¹¹ Model-based DFMA workflows also reduce clashes and rework hours by 15- 40%.¹²

However, DFMA delivers sustained value only when embedded within a Digital Twin that preserves assembly logic, sequencing assumptions, and interface definitions across the project lifecycle.

When Plants Become Products: Rethinking Engineering for Assembly

DFMA transformed product engineering by shifting the focus from design feasibility to build reality. Plants and data centres now face similar pressures, only at much higher capital stakes. When supported by a digital twin, DFMA principles scale effectively from products to plants, enabling repeatability, modularisation, and predictable execution across sites and regions.

Dimension	Product DFMA	Plant DFMA
Core Design Intent	Design products for efficient manufacturing, assembly, quality, and serviceability	Design plants for constructability, modular assembly, safe installation, and long-term operability
Unit of Assembly	Parts, sub-assemblies, and finished products	Skids, modules, pipe racks, structural frames, E&I systems, and packaged units
Cost and Risk Lock-In	Majority of cost and quality outcomes fixed during early product design	Majority of project cost, schedule risk, and site rework fixed during early engineering
Role of Digital Models	Digital mock-ups validate assembly logic, tolerances, tooling access, and maintenance	Intelligent 3D models validate fabrication feasibility, logistics, erection sequencing, and access
Standardisation and Reuse	Platform-based designs enable reuse across product variants	Modular designs and templates enable repeatable plant builds across sites and regions
Outcome at Scale	Faster time-to-market, lower unit cost, consistent quality	Predictable schedules, reduced site rework, improved safety, faster commissioning

Outcome: Engineering evolves from document production to execution certainty, designing plants that can be built, commissioned, and operated predictably.

Addressing the Challenges Through a Digital First + DFMA + Digital Twin Strategy

A Digital-First approach is not about adding tools; it is about creating a persistent, intelligent representation of the plant as an assembled system.



Unified Digital Engineering Backbone:

A digital twin anchored in intelligent 3D models establishes a single source of truth across disciplines.

Design changes instantly reveal impacts on fabrication, logistics, and installation, preventing downstream disruption.



Assembly-Centric Validation:

Digital twins allow teams to simulate construction sequencing, lifting paths, access envelopes, and maintenance scenarios early.

Engineers can virtually assemble the plant before physical execution begins, resolving constraints digitally and reducing site-level uncertainty.



Modularisation by Design:

By validating module size, weight, transport routes, and interfaces within the digital twin, modularisation becomes a confident design decision rather than an execution gamble.

This enables parallel fabrication, reduced site congestion, & safer construction—especially critical in data centres and large industrial campuses.



Engineering-to-Operations Continuity:

Sustained value comes from embedding DFMA & digital twin usage into standard processes, design gates, and governance.

When models are trusted as the primary engineering artifact, digital engineering becomes an enabler of predictability rather than overhead.



Governance and Process Integration:

A DFMA-led digital twin persists beyond commissioning, serving as a navigable operational knowledge base.

Operators gain insight into how systems were assembled, how assets can be accessed or replaced, and how future modifications can be executed safely and efficiently.

Conclusion

As capital investments accelerate, traditional engineering models no longer scale with rising complexity.

A Digital-First Plant Engineering strategy, enabled by DFMA and sustained through a Digital Twin, allows organisations to scale infrastructure without scaling risk. Engineering shifts from reactive problem-solving to proactive execution design, enabling faster delivery, reduced rework, and predictable outcomes.

For owners and operators, the key question is no longer who can design fastest, but who can design what can be assembled, commissioned, and operated with certainty in a capital-intensive world.

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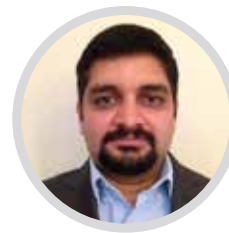
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