TATA

TCExpression

TATA CONSULTING ENGINEERS

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Engineering Complexity

DELIVERING CERTAINTY

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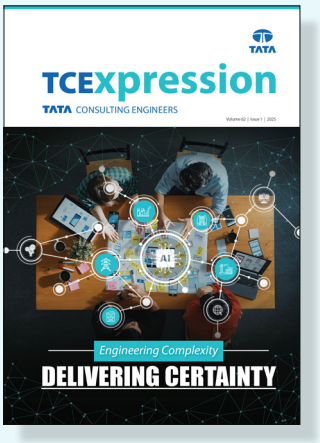


Editor's Note

Dear Readers,

Welcome to the annual edition of TCExpression. This issue is anchored in the theme *Engineering Complexity, Delivering Certainty*, reflecting the realities of today's engineering landscape and the responsibility that comes with it.

As projects grow in scale, ambition and interdependence, complexity has become the norm. Delivering certainty in such an environment demands disciplined engineering, informed decision-making and the intelligent use of digital tools. Across this edition, you will see how digital engineering, AI, circularity and sustainability are being applied to bring clarity, predictability and long-term value to complex challenges.

The stories featured here demonstrate how our teams are navigating technical, regulatory and execution complexity with rigour and foresight. They highlight an approach where innovation is purposeful, sustainability is embedded from the outset and outcomes are delivered with confidence.

My sincere thanks to all our contributors and authors for their thoughtful perspectives. A special note of appreciation to Tejashree Bubane from the Corporate Communications team for designing this annual edition, which brings the theme to life with clarity and intent.

We would be pleased to hear your feedback at marcom@tataconsultingengineers.com.

Happy reading!

Warm regards,
Alpna Singh
Head - Corporate Marketing & Communications

Reflections

Dear Colleagues,

As we step into the New Year, I wish you and your families a very Happy New Year. It is a pleasure to share this year's annual edition of TCExpression, centred on the theme *Engineering Complexity, Delivering Certainty*. This theme reflects the reality of the environment in which we operate today and the responsibility we carry as an engineering and consulting organisation.

Across sectors and geographies, projects are becoming larger, more integrated, and more demanding. Technical challenges now intersect with regulatory expectations, sustainability ambitions, digital maturity, and compressed delivery timelines. In this context, excellence is defined not only by the ability to manage complexity, but also by the discipline to convert it into outcomes that are predictable, reliable, and enduring. Delivering certainty is therefore not an aspiration; it is a capability that must be built deliberately and demonstrated consistently.

Over the past year, Tata Consulting Engineers has continued to strengthen this capability by deepening engineering rigour, advancing digital and data-led decision-making, and embedding sustainability and lifecycle thinking into project planning and execution. The growing use of digital engineering, analytics, and intelligent systems is helping teams make better front-end decisions, manage interfaces more effectively, and reduce risk across the project lifecycle.

This edition brings together perspectives and experiences from across the organisation that show how complexity is being addressed with clarity and purpose. The stories highlight the importance of early decisions, strong cross-disciplinary integration, and a culture that values accountability and collaboration. Together, they reinforce the belief that certainty is achieved not by simplifying challenges, but by understanding them deeply and addressing them with discipline.

As you read through this edition, I encourage you to reflect on how each of us contributes to this shared objective. By staying focused on quality, foresight, and responsible engineering, we can continue to support our clients' ambitions while building resilient assets for the future.

Once again, I wish you a Happy New Year and thank you for your commitment and contributions. May the year ahead bring continued learning, progress, and shared success.

Warm regards,

Amit Sharma
Managing Director & CEO

"Excellence is defined not only by the ability to manage complexity, but also by the discipline to convert it into outcomes that are predictable, reliable, and enduring."

Engineering Complexity, Delivering Certainty: TCE's Way to Achieving Engineering Excellence

Engineering has always progressed alongside society's ambitions. As industries push boundaries in scale, speed, precision and sustainability, engineering complexity has evolved from a technical challenge into a multidimensional responsibility. Delivering certainty in this environment requires more than applying established tools or relying on proven workflows. It demands a deep understanding of contemporary industry needs, the ability to adapt continuously to changing conditions and the discipline to translate complexity into predictable and dependable outcomes.

TCE, an EPCM engineering organisation serving the hydrocarbons & chemicals, power, mining & metallurgy, infrastructure and advanced facilities sectors, treats certainty not as a statement of intent but as a capability demonstrated repeatedly across diverse projects, geographies, regulatory regimes and delivery timelines. This capability is built not only on technology but also on people, processes, and a clear understanding of how industries are transforming in response to the energy transition, digitalisation, sustainability expectations, and global supply chain dynamics.

Modern engineering complexity is inherently multidimensional. Technical complexity arises from integrating multiple disciplines, including process, mechanical, electrical, civil, structural, instrumentation, and automation systems, all of which must function seamlessly as a unified whole. Stakeholder complexity emerges from the diverse and often competing expectations of clients, process licensors, regulators, contractors, suppliers, original equipment manufacturers and local communities.

Regulatory complexity reflects the need to comply with evolving environmental norms, safety standards, and governance frameworks. At the same time, sustainability introduces another critical layer by requiring designs that minimise the carbon footprint, optimise resource efficiency, and enable future adaptability of assets. These dimensions do not exist independently. They interact dynamically throughout the project lifecycle, influencing design choices, execution strategies, risk exposure, and long-term performance. In such an environment, traditional linear approaches to project delivery are no longer adequate.

Certainty can only be achieved through systems-based thinking, early identification of interdependencies, and proactive risk management embedded in engineering and project governance frameworks. Recognising this reality, TCE has adopted an integrated and forward-looking approach to managing complexity. By combining systems engineering principles, digital enablement, structured risk assessment and continuous learning, the organisation navigates complexity with clarity and purpose. This approach allows potential challenges to be anticipated early, informed decisions to be made with confidence, and projects to be delivered consistently and reliably, with trust.

Complexity as a System Reality

While modern engineering complexity is systemic in nature, its points of concentration differ markedly across sectors. Each industry operates within a distinct technical, regulatory, and operational context, shaping where uncertainty is most likely to arise and where engineering discipline is most critical. Understanding these sector-specific manifestations is essential because certainty is rarely lost uniformly across a project. It is compromised at specific interfaces where assumptions break down, interactions intensify, and earlier decisions are tested by reality.

In hydrocarbons and chemicals, complexity is most acute at the intersection of process integration, safety, and environmental performance. Facilities in this sector handle hazardous materials at high pressures and temperatures, leaving little tolerance for deviation. Modern plants are no longer discrete process units supported by auxiliary systems. They are integrated ecosystems in which process design, safety systems, automation, emissions control, and digital monitoring function as a single entity. A modification in one element often propagates across the system, affecting layout, constructability, control philosophy, and operability.

Certainty is particularly vulnerable during late-stage changes, debottlenecking initiatives, or capacity expansions, when established interfaces are disturbed. Engineering discipline in this sector, therefore, depends on rigorous front-end definition, early interface identification, and a conservative approach to late changes that prioritises system stability over short-term gains.

Mining and metallurgy present a fundamentally different pattern of complexity, driven largely by uncertainty that lies beyond engineering control. Geological variability introduces continuous change in ore quality, mineralogy, and recovery behaviour over the life of an asset. Unlike process plants designed around relatively stable feedstock, mining and metallurgical systems must perform reliably across a wide range of operating conditions. This requirement prioritises robustness over optimisation at a single design point. Complexity is further amplified by long asset lives, remote locations, and high dependence on energy and water resources. Environmental and social considerations play a decisive role in project viability, influencing approvals, operating constraints, and community acceptance.

The changing nature of engineering complexity

Certainty in this sector is most vulnerable when systems are designed too narrowly or when governance frameworks lack flexibility. Engineering excellence is demonstrated through adaptability, phased development strategies, and monitoring systems that enable informed adjustments over time rather than rigid adherence to initial assumptions. Power projects operate within an ecosystem that is undergoing rapid transition. Traditional power generation was characterised by predictable fuel supply, stable grid behaviour, and long planning horizons. Today's power systems are increasingly diverse and dynamic. Renewable generation introduces intermittency, while storage technologies, flexible thermal assets, and nuclear power must operate in coordination to maintain grid stability. Regulatory frameworks and market mechanisms continue to evolve, often throughout a project lifecycle.

Complexity in this sector is therefore concentrated at the boundary between individual assets and the wider grid. Certainty is most vulnerable when plants are optimised for efficiency without adequate consideration of flexibility and responsiveness. Engineering discipline protects outcomes when grid behaviour, policy trajectories, and multiple operating scenarios are embedded into design decisions from the outset, rather than treated as external variables. Infrastructure projects experience complexity primarily through their interaction with society and the built environment. Technical challenges are often compounded by dense urban contexts, environmental sensitivity, and extensive stakeholder engagement. Transport corridors, water networks, and urban infrastructure must integrate with existing assets while accommodating future growth and climate resilience.

Public scrutiny and regulatory oversight influence design choices, construction methods, and delivery timelines. Certainty is frequently compromised not by engineering failure, but by misalignment between technical solutions and stakeholder expectations. Engineering excellence in infrastructure, therefore, requires early and continuous engagement, transparent governance, and design approaches that balance constructability with long-term maintainability and public value. Phased delivery strategies and modular construction can mitigate disruption, but only when aligned with a clear understanding of social and environmental impact.

TCE leadership values transparency over optimism and preparedness over reaction. When problems are addressed early, options remain available. When they are discovered late, choices become constrained, and certainty erodes. Taken together, these enablers form a critical bridge between engineering capability and delivery assurance.

Advanced facilities such as semiconductor fabrication plants and hyperscale data centres represent the most concentrated expression of contemporary engineering complexity. These assets operate at the limits of precision, reliability, and availability. They demand ultra-clean environments, high-density power systems, advanced cooling architectures, and sophisticated automation, all of which must operate seamlessly from day one. Unlike conventional industrial assets, advanced facilities often require continuous operation with minimal tolerance for commissioning instability. The need for scalability compounds complexity, as capacity is added incrementally while existing operations continue.

Certainty is most vulnerable during integration and expansion, when new systems must interface with live environments. Engineering discipline in this sector is expressed through meticulous interface definition, redundancy planning, digital validation, and disciplined change control that prioritises operational continuity over speed. Across all sectors, a common pattern emerges. Certainty is not undermined by the presence of complexity itself, but by failure to recognise where complexity concentrates and how it behaves in context. Generic solutions applied uniformly across sectors rarely succeed. Engineering excellence requires contextual understanding, informed trade-offs, and alignment between technical ambition and execution reality.

This understanding also reinforces the importance of cross-sector learning. While the sources of complexity differ, the principles of managing it are transferable. Interface discipline, systems thinking, early integration, and robust governance prove effective across industries, even as their application varies. Organisations that operate across multiple sectors are therefore uniquely positioned to recognise patterns, anticipate risks, and adapt proven approaches to new contexts. Understanding how complexity manifests across sectors provides a critical bridge between abstract systems thinking and practical delivery. It reveals where certainty is most vulnerable and where engineering effort must be concentrated.

Certainty as a Strategic Imperative

Certainty is not just a project performance metric. It is a strategic imperative. For clients, certainty means predictable returns on investment, operational reliability and confidence that assets will perform as intended throughout their lifecycle. For TCE, certainty is fundamental to building trust, sustaining long-term client relationships, and creating a durable competitive advantage in an increasingly demanding market. Certainty directly improves cost control by preventing overruns from late changes and rework. It supports schedule adherence by avoiding disruptions from unresolved interfaces and unexpected risks.

	Hydrocarbons and Chemicals	Power	Mining and Metallurgy	Infrastructure	Advanced Facilities
Technical Integration	High	High	High	Moderate	Very High
	Process and safety integration	Generation and grid interaction	Flexible and smelting systems	Multi-utility and urban interfaces	Ultra-precise environmental control
Regulatory Environment and Sustainability Expectations	High	High	High	High	Very High
	Environmental compliance Energy and water intensity	Policy, grid and land regulations	Policy, grid and land regulations	Public, environmental statutory approvals	International standards and certifications
Digital Dependence	Very High	High	High	Moderate	Very High
	Automation and advanced control	Grid management and forecasting	Grid management and forecasting	Smart system and monitoring	Real-time digital control
Stakeholder Complexity	Very High	High	High	High	Very High
	Licensors, regulators, operators	Utilities policymakers	Public agencies and citizen	Public agencies and citizens	Global clients and technology partners

Moderate | High | Very High

Sector-wise Drivers of Engineering Complexity

It reinforces quality assurance by ensuring consistent compliance with codes, standards and specifications. Most importantly, certainty safeguards safety and sustainability, protecting people and the environment while promoting responsible engineering practices. Delivering this level of certainty requires more than technical competence. It demands structured engineering methodologies, integrated execution across disciplines, and a culture of accountability that encourages early risk identification, transparent decision-making, and disciplined follow-through. When these elements come together, complexity becomes manageable, and certainty becomes deliverable with confidence.

Foundations of Certainty

The journey towards certainty in complex engineering projects begins long before construction activities start or procurement decisions are finalised. It starts at the front end of the project, where foundational choices are made that influence every subsequent phase. Concept selection at this stage is one of the most critical determinants of project success.

Decisions taken early have a disproportionate impact on cost, schedule, safety, operability and long-term asset performance. When multiple technology and configuration options are available, the ability to evaluate them holistically becomes essential. Rigorous front-end engineering involves more than technical feasibility. Each option must be assessed through the lenses of constructability, operability, maintainability, sustainability and lifecycle performance. A concept that appears optimal on paper may introduce execution risks if it is challenging to implement under the given site conditions or relies on specialised resources that are scarce.

Aspect	Impact
Cost Control	Prevents overruns and reduces rework
Schedule	Avoids delays caused by unresolved interfaces
Quality	Ensures compliance with codes and standards
Safety	Protects people and the environment
Sustainability	Reinforces responsible engineering practices

Why Certainty Matters

Similarly, an option that minimises initial capital expenditure may increase operational complexity or environmental exposure over time. By systematically evaluating such trade-offs at the outset, engineering organisations reduce the likelihood of downstream surprises and costly course corrections. Strong governance structures play an equally important role in establishing certainty. Complex projects involve numerous stakeholders and intersecting interests, which can easily lead to ambiguity in decision-making. Clear governance frameworks define accountability, decision rights and escalation paths. They ensure that technical authority is respected, risks are addressed at the appropriate level and decisions are taken promptly.

When governance is well-structured, uncertainty is contained, and momentum is maintained even in challenging situations. Integrated planning across the project lifecycle further reinforces this foundation. Engineering, procurement, construction and commissioning are often treated as sequential phases, but in complex projects they are deeply interdependent. Integrated planning recognises these interdependencies and aligns activities across disciplines and stages from the outset. This approach prevents the formation of silos, fosters collaboration among teams and ensures that execution realities inform early design decisions. When engineers, project managers, procurement specialists and construction planners work from a shared plan, risks are identified earlier and mitigated more effectively. Value engineering is a central pillar of this integrated approach.

When practised as a continuous discipline rather than a late-stage cost-cutting exercise, value engineering becomes a powerful mechanism for managing complexity. It encourages structured exploration of alternatives that balance performance, cost, schedule, safety and sustainability. Rather than focusing narrowly on reducing capital costs, continuous value engineering evaluates how design choices influence constructability, operational efficiency, and long-term reliability. This process transforms complexity into informed choice, enabling optimisation without compromising quality or intent.

Taken together, robust front-end decision-making, transparent governance, integrated lifecycle planning, and continuous value engineering form the foundations of certainty. They establish a disciplined framework for addressing complexity systematically rather than reactively. When these foundations are strong, projects are better positioned to absorb change, manage risk and deliver predictable outcomes. In an environment where uncertainty is unavoidable, such foundations allow TCE to provide certainty with confidence and consistency.

Foundation	Purpose
Front End Engineering	Evaluates options holistically for cost, safety and lifecycle performance
Governance Frameworks	Defines accountability and decision rights to contain ambiguity
Integrated Planning	Aligns engineering, procurement and construction to prevent silos
Continuous Value Engineering	Optimises design choices for performance, cost and sustainability

Foundations of Certainty

Modularity as a Strategic Response to Complexity

As engineering projects grow in scale and sophistication, modularity has emerged as one of the most effective strategies for managing complexity and delivering certainty. Modularity is not merely a construction technique or a scheduling tool. It is a design and execution philosophy that structures complexity by converting large, intricate systems into manageable, repeatable building blocks.

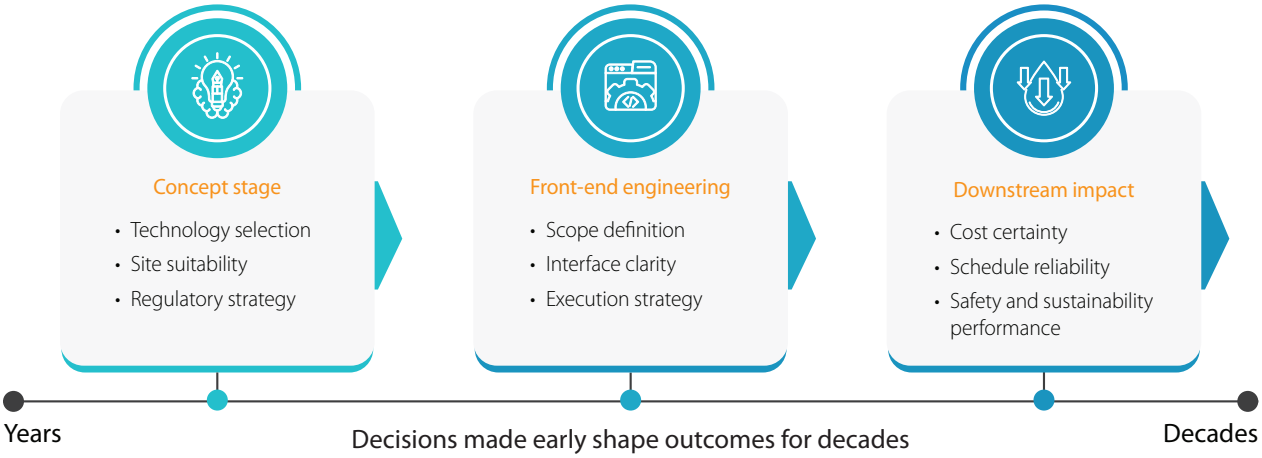
At its core, modularity reduces variability. By breaking large systems into pre-engineered modules, engineering teams can standardise designs, improve quality, and reduce dependence on site-specific conditions.

Fabrication in controlled environments enhances artistry, ensures consistent adherence to specifications and enables rigorous quality assurance processes that are difficult to replicate on site. This shift away from site-intensive construction significantly mitigates risks associated with weather, labour availability, site congestion and safety exposure, all of which are familiar sources of uncertainty in complex projects.

In chemical and hydrocarbon facilities, modularisation enables the replication of proven process units across multiple trains. When similar units are designed once and built many times, learning curves are accelerated, and execution confidence improves. Parallel execution becomes possible, with modules fabricated off-site while civil works and infrastructure development progress simultaneously. This overlap shortens overall project schedules and reduces the risk of cascading delays, thereby enhancing both schedule and cost certainty.

In advanced facilities such as data centres, modularity takes on an additional strategic dimension. Modular power distribution units, cooling systems and IT halls allow capacity to be deployed in phases aligned with business demand. This approach avoids upfront overinvestment while ensuring expansion can occur without disrupting ongoing operations. For clients, this translates into flexibility and resilience, while for engineering teams it provides a structured pathway to manage complexity across successive phases of development.

Modularity also supports sustainability objectives. Controlled fabrication environments reduce material waste and enable more efficient use of resources. Standardised modules are easier to optimise for energy efficiency and can be designed for reuse or relocation where appropriate.



Front-end decisions and their long-term impact

Throughout an asset's lifecycle, modular designs enhance adaptability, allowing systems to evolve without extensive demolition or reconstruction. However, modularity is not inherently simple. Its success depends on disciplined interface management and early integration planning. Each module must align precisely with others in terms of physical connections, process flows, electrical and control interfaces and digital data continuity. Poorly managed interfaces can introduce new risks that undermine the benefits of modularisation. Engineering certainty, therefore, requires that modular strategies be defined early, supported by clear interface definitions and rigorous configuration control.

Advanced modelling and digital engineering play a critical role in enabling this discipline. Three-dimensional models, digital twins, and constructability simulations would allow teams to visualise interfaces, identify clashes, and validate installation sequences before fabrication begins. Digital rehearsals of construction and commissioning activities further reduce uncertainty by exposing potential issues in a virtual environment rather than on-site. When combined with robust change management processes, these tools ensure that modular designs remain coherent and controllable as projects evolve.

Equally important is the alignment of modularisation strategies with procurement and vendor engagement. Early involvement of fabricators and suppliers ensures that module designs are optimised for manufacturing and transport. This alignment reduces late modifications and improves execution predictability. TCE, with its strong vendor evaluation and integration capabilities, is better positioned to realise the full benefits of modularity.

Ultimately, modularity transforms complexity into a structured and repeatable system. It allows TCE to manage scale without losing control, accelerate delivery without compromising quality, and provide clients with confidence that ambitious projects can be executed reliably. When modularity is applied thoughtfully and supported by strong engineering governance, it becomes a powerful enabler of certainty in even the most complex project environments.

Benefit	Explanation
Reduced Variability	Standardised modules improve quality and predictability.
Faster Delivery	Parallel execution shortens schedules.
Sustainability	Controlled fabrication reduces waste and energy use.
Flexibility	Phased deployment aligns with business demand.
Risk Mitigation	Off-site fabrication reduces site-related risks.

Benefits of Modularity

Sustainability Embedded in Engineering Decisions

Sustainability is no longer an optional aspiration or a peripheral consideration in project development. It has become a non-negotiable requirement that shapes how assets are conceived, designed, delivered and operated. Clients today expect projects that are environmentally responsible, socially acceptable and resilient to future regulatory and market changes. Engineering organisations are therefore required to embed sustainability at the core of their decision-making rather than treating it as an add-on or a compliance exercise.

Embedding sustainability begins with fundamental design choices. Optimised plant layouts reduce material usage by minimising structural steel, piping runs, cable trays and foundations. Compact and efficient arrangements not only reduce embodied carbon but also improve constructability and operational efficiency. Advanced simulation tools allow engineers to model process performance, energy consumption, thermal behaviour and fluid dynamics with high accuracy. This capability prevents conservative over-specification, which has historically led to excess material use, higher energy demand, and increased capital costs. Right-sized systems represent a convergence of sustainability and engineering certainty.

Material selection is another critical lever. Designs that prioritise durability, corrosion resistance and standardisation reduce replacement frequency and maintenance intensity over the asset lifecycle. Where feasible, engineers increasingly evaluate materials based on recyclability and reuse potential. Designing with disassembly and adaptability in mind enables components and systems to be recovered, upgraded or repurposed in the future. Such foresight protects investments and reduces environmental impact over time.

Sustainability also extends to resource efficiency during construction and operation. Modularisation and off-site fabrication reduce waste generation and improve quality control. Efficient construction sequencing minimises rework and on-site energy consumption. During operation, energy-efficient equipment, heat integration, water management strategies and digital monitoring systems support continuous optimisation. These measures are not only environmentally beneficial but also enhance the reliability and predictability of operating costs.

The relationship between sustainability and certainty is particularly significant. Assets that fail to meet evolving environmental standards face increasing regulatory risk, potential penalties and reputational exposure. In some cases, they risk becoming stranded or obsolete well before their intended lifespan. Engineering certainty, therefore, requires anticipating regulatory trajectories and designing assets that can adapt to stricter norms without extensive retrofits. Early integration of sustainability considerations reduces the likelihood of disruptive and costly modifications later. From a strategic perspective, sustainability aligns engineering outcomes with global decarbonisation goals and broader societal expectations.

Clients increasingly view sustainable assets as a source of long-term value rather than a cost burden. Engineering organisations that understand this shift and translate it into practical design solutions strengthen their role as trusted partners. By embedding sustainability into engineering decisions, they help clients achieve compliance, resilience and competitiveness simultaneously.

Ultimately, sustainability embedded in engineering decisions transforms complexity into opportunity. It enables projects to deliver reliable performance today while remaining viable in an uncertain future. In doing so, sustainability becomes not only a moral or regulatory imperative but a cornerstone of engineering certainty.

Lever	Impact
Optimised Layouts	Reduces material use and embodied carbon
Advanced Simulation	Prevents over-specification and improves efficiency
Material Selection	Enhances durability and recyclability
Modularisation	Reduces waste and improves quality control
Digital Monitoring	Supports continuous optimisation and cost predictability

Sustainability Levers in Engineering

Automation and Digital Intelligence in Engineering Delivery

Automation and digital intelligence are fundamentally reshaping how TCE plans, designs, and executes complex projects. In an environment where speed, accuracy and coordination are critical, digital tools are no longer supportive enhancements. They have become core enablers of certainty. For TCE, managing large, technically demanding projects, the intelligent use of digital technologies directly influences reliability, predictability, and confidence in delivery. Design automation has transformed the early and detailed engineering phases. Repetitive, rule-based tasks that once required significant engineering effort can now be executed rapidly and consistently. Automated design checks, intelligent templates and parameter-driven models reduce human error and ensure uniform application of standards across disciplines and locations. This consistency is critical in large programmes where multiple teams work in parallel. By accelerating routine activities, automation frees engineers to focus on higher-value problem-solving, interface resolution, and optimisation, all of which are essential to managing complexity.

Artificial intelligence extends this capability to knowledge management and decision support. AI-driven knowledge systems provide instant access to decades of organisational experience, including engineering standards, design philosophies, past project data and lessons learned. Instead of relying solely on individual memory or fragmented repositories, project teams can draw on structured institutional knowledge when needed. This capability is particularly valuable in complex projects involving unfamiliar technologies, novel configurations, or challenging site conditions. By embedding experience into digital platforms, TCE reduces variability and strengthens delivery certainty.

Digital intelligence also plays a critical role in procurement and supply chain management. Predictive analytics enable early identification of supply chain risks, such as vendor capacity constraints, delivery uncertainties or quality trends. Performance data can be analysed to optimise vendor selection and strengthen alignment with project objectives. In complex projects with long-lead items and global sourcing, this visibility allows proactive mitigation rather than reactive response, supporting both schedule and cost certainty. Digital twins represent another powerful dimension of digital engineering.

The growing scale, ambition and interconnected nature of modern projects have redefined what it means to deliver engineering excellence. Complexity today is not confined to technology alone. It spans systems integration, sustainability expectations, regulatory frameworks, stakeholder alignment, digital transformation and accelerated delivery timelines.

By creating a virtual representation of the physical asset, digital twins align design intent with operational reality. They allow trained TCE engineers to simulate performance, test operating scenarios and validate control strategies before physical systems are commissioned. This significantly reduces commissioning surprises and accelerates the transition from construction to stable operation. Over the asset lifecycle, digital twins support predictive maintenance by identifying early signs of degradation and enabling timely intervention. This capability enhances reliability and extends asset life, reinforcing long-term certainty for clients. Equally important is the role of digital platforms in enabling collaboration.

Complex projects often involve teams distributed across geographies, time zones and organisations. Real-time data sharing, collaborative design environments and integrated project dashboards ensure that all stakeholders work from a single source of truth. Decisions are made with current information rather than delayed reports, reducing misalignment and rework. In such environments, digital intelligence becomes a unifying force that connects people, processes and technology. It is essential to recognise that these technologies do not replace engineering judgment.

Instead, they amplify it. By providing better information, earlier insights and clearer visibility, digital intelligence enhances the quality of decisions made by engineers and project leaders. In complex projects where minor deviations can have significant consequences, this enhanced decision quality is a decisive advantage.

Enabler	Impact
Design Automation	Speeds up routine tasks and reduces errors
Artificial Intelligence	Provides instant access to organisational knowledge
Predictive Analytics	Identifies supply chain risks early
Digital Twins	Aligns design intent with operational reality and supports predictive maintenance
Collaborative Platforms	Enables real-time data sharing and decision-making

Digital Intelligence Enablers

In the context of modern engineering delivery, automation and digital intelligence are not optional innovations. They are essential capabilities for achieving certainty. As complexity increases and expectations continue to rise, organisations that embed digital intelligence into their engineering and project execution frameworks will be best positioned to deliver predictable outcomes with confidence and consistency.

Talent Development as the Backbone of Engineering Certainty

While technology, tools and processes are powerful enablers, the ultimate determinant of certainty in complex engineering projects remains human capability. Engineering complexity is interpreted, managed and resolved by people. Talent development is therefore not a supporting activity but a foundational pillar in delivering predictable and reliable outcomes.

Modern engineering projects demand far more than narrow technical expertise. Engineers are required to think across disciplines, understand system interactions, anticipate downstream impacts and make decisions under uncertainty. Developing such capability requires a deliberate and sustained investment in people. TCE recognises that formal education provides only the starting point. Continuous learning is essential to keep pace with evolving technologies, regulatory expectations, sustainability requirements and digital transformation.

Structured training programmes play a critical role in building capability within the TCE workforce. Regular upskilling in digital engineering tools, automation platforms, advanced simulation, sustainability principles and emerging technologies ensures that TCE engineers remain effective in a rapidly changing environment. Equally important is training in project management, risk assessment, constructability and stakeholder engagement. Complex projects rarely fail due to isolated technical errors. They falter when technical decisions are disconnected from execution realities. Broad-based capability bridges this gap.

Experiential learning is another essential dimension. Exposure to diverse projects across hydrocarbons, power, metals, infrastructure and advanced facilities builds judgement that cannot be replicated through classroom instruction alone. Engineers who have seen projects evolve from concept through commissioning develop an intuitive understanding of risk, sequencing and integration. Capturing these experiences through structured lessons learned and embedding them into TCE's knowledge management systems ensures that learning becomes institutional rather than individual.

Mentorship and knowledge transfer further strengthen this foundation. Senior engineers at TCE play a vital role in guiding younger professionals, not only in technical matters but also in professional judgement and ethical responsibility. Digital knowledge platforms, enhanced by artificial intelligence, amplify this process by making expertise accessible across teams and geographies. Talent development also supports delivery under challenging schedules. Complex projects often require rapid mobilisation of skilled teams and swift decision-making. TCE, with a deep and well-prepared talent pool, can respond without compromising quality or safety. This agility directly translates into schedule certainty and client confidence. Equally important is cultivating a culture that encourages accountability, curiosity and transparency. TCE engineers feel empowered to raise concerns early, challenge assumptions constructively and propose innovative solutions. A culture that values learning over blame enables proactive problem-solving and continuous improvement.

In complex projects, early identification of issues is far more valuable than late heroics. From a strategic perspective, TCE's talent development aligns engineering capabilities with industry evolution. As clients move toward advanced facilities, digital infrastructure, energy transition projects, and sustainability-driven investments, TCE ensures its people are prepared to deliver in these domains. Continuous training and capability development allow TCE to anticipate client needs rather than react to them. In the context of engineering complexity and delivering certainty, talent development is not an internal initiative. It is a promise to clients.

Pillar	Purpose
Continuous Learning	Keeps pace with evolving technologies and regulations
Structured Training	Builds technical and managerial capability
Experiential Learning	Develops judgement through real-world exposure
Mentorship and Knowledge Transfer	Strengthens professional and ethical decision-making
Cultural Empowerment	Encourages accountability and proactive problem-solving

Talent Development Pillars

It assures them that projects will be delivered by competent, confident, and forward-looking teams who understand not only how to design systems but also how those systems will be built, operated, and sustained. When talent development is treated as a strategic priority, certainty becomes a repeatable outcome rather than a fortunate exception.

Delivering Under Challenging Schedules

Challenging schedules have become a defining feature of modern engineering projects. Market dynamics, regulatory windows, funding constraints and competitive pressures increasingly demand accelerated delivery without compromising safety, quality or performance. In complex projects, schedule certainty is not achieved by compressing activities indiscriminately. It is achieved through intelligent planning, disciplined execution and a deep understanding of how time interacts with design, procurement and construction decisions.

Schedule certainty begins at the earliest stages of the project. Realistic and integrated planning establishes a credible delivery pathway by aligning engineering development, procurement strategy, construction sequencing and commissioning logic. Early identification of critical paths and long-lead items allows mitigation actions to be implemented before constraints materialise. When schedules are built on sound engineering logic rather than optimistic assumptions, they become tools for control rather than sources of pressure. Engineering maturity plays a decisive role in enabling accelerated delivery. A clear scope definition, early interface resolution, and a timely design freeze reduce the risk of downstream rework. Advanced modelling and digital reviews help validate constructability and installation sequences before site execution begins. When engineering decisions are taken with execution in mind, the project gains momentum without sacrificing robustness.

Parallel execution is another key enabler. Modularisation, prefabrication and phased delivery strategies allow multiple activities to progress simultaneously rather than sequentially. While civil works and site preparation proceed, modules can be fabricated in controlled environments, reducing overall duration and exposure to site risks. This approach not only compresses schedules but also improves safety and quality by shifting work away from congested sites. Procurement alignment is equally critical. Challenging schedules demand early engagement with vendors and contractors to confirm manufacturing capacity, delivery timelines and logistics constraints.

Engineering organisations that possess strong vendor evaluation and integration capabilities can align supply chains with project priorities. Proactive expediting, informed by digital tracking and performance data, further reduces uncertainty and supports timely delivery.

Construction planning and management complete the picture. Detailed work packaging, precise access planning and realistic productivity assumptions enable efficient site execution. Digital tools provide real-time visibility into progress, enabling early identification and correction of deviations. When construction feedback is integrated into ongoing engineering and planning activities, the project adapts dynamically rather than reacting late.

Leadership and organisational culture are also essential. Delivering under challenging schedules requires decisive leadership, clear accountability and effective communication. TCE teams are empowered to escalate issues early and collaborate across disciplines. A culture that values preparedness over urgency ensures that speed does not come at the expense of safety or quality.

Ultimately, schedule compression is not about doing more in less time. It is about removing uncertainty from the delivery process. When engineering, procurement and construction are integrated through disciplined planning and digital visibility, challenging schedules become achievable targets rather than sources of risk. In complex projects, TCE's proven track record of delivering under demanding timelines is a powerful demonstration of engineering certainty and execution excellence.

Execution Excellence Enablers: From Capability to Certainty

Delivering certainty in complex engineering projects requires more than conventional tools or established procedures. Digital design platforms, three-dimensional models, and analysis software are now industry standards, but they are no longer differentiators. What truly distinguishes successful delivery is the depth of understanding behind their use and the organisational capability to turn insight into action. With TCE's modern engineering execution philosophy, certainty is achieved not by the presence of tools but by the maturity with which complexity is interpreted, decisions are made, and execution is governed. At the heart of this maturity lies a deep understanding of industry-specific needs and client context.

Enabler	Purpose
Integrated Planning	Aligns engineering, procurement and construction
Engineering Maturity	Reduces rework and accelerates decision-making
Parallel Execution	Enables modularisation and prefabrication
Procurement Alignmen	Secures timely supply chain support
Digital Visibility	Provides real-time progress tracking

Digital Intelligence Enablers

Each sector presents its own operating realities, risk profile and success criteria. A hydrocarbon facility prioritises safety, reliability and regulatory compliance. A power project must align with grid dynamics and policy stability. A metals plant demands process robustness and energy efficiency. Advanced facilities such as semiconductor fabrication plants and data centres require extreme precision, uptime and scalability. Engineering certainty emerges when solutions are not generic but thoughtfully customised to these realities.

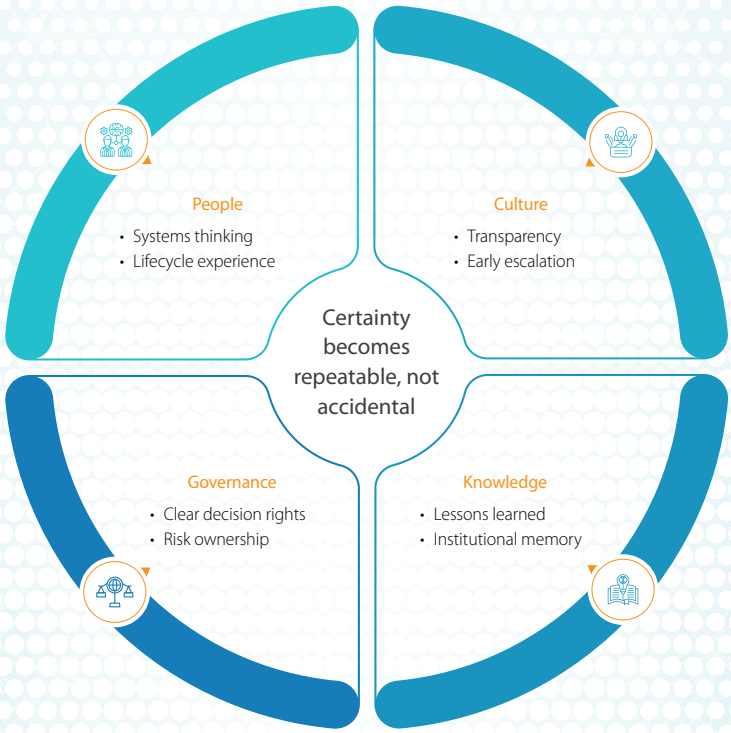
Understanding the client's business objectives, future growth plans, and operating philosophy allows engineering decisions to be aligned with long-term value rather than short-term convenience. This alignment directly influences cost certainty. Optimising costs in complex projects is not about aggressive cost-cutting or selecting the lowest price. It is about making informed trade-offs that balance capital expenditure, lifecycle cost, constructability, schedule resilience, and operational reliability.

TCE delivers certainty by evaluating costs holistically. TCE recognises that apparent savings achieved through design simplification or specification dilution often reappear later as construction delays, performance shortfalls or maintenance burdens. Proper cost optimisation at TCE integrates value engineering, risk assessment and execution strategy to achieve efficiency without compromising intent, quality or safety. Vendor and partner selection is another critical determinant of certainty.

Complex projects rely on extended ecosystems of licensors, equipment suppliers, fabricators, contractors and service providers. The ability to analyse, evaluate and select partners aligned with project objectives is therefore a strategic capability rather than a procurement function. TCE delivers certainty by looking beyond commercial terms to assess technical competence, execution track record, capacity, financial stability and cultural alignment.

Early engagement with key vendors during the engineering phase improves manufacturability, reduces interface risk and enhances schedule predictability. Strong partnerships built on transparency and shared objectives turn external dependencies into sources of strength rather than uncertainty. Execution excellence also depends on proactive troubleshooting and disciplined risk mitigation. In complex projects, issues rarely appear without warning.

They emerge gradually through weak signals such as minor deviations, interface mismatches or early performance indicators. Engineering certainty is reinforced when organisations have the systems, culture and leadership to identify these signals early and act decisively. Structured risk registers, interdisciplinary reviews, and real-time project dashboards provide visibility into emerging risks.



Institutional capability model

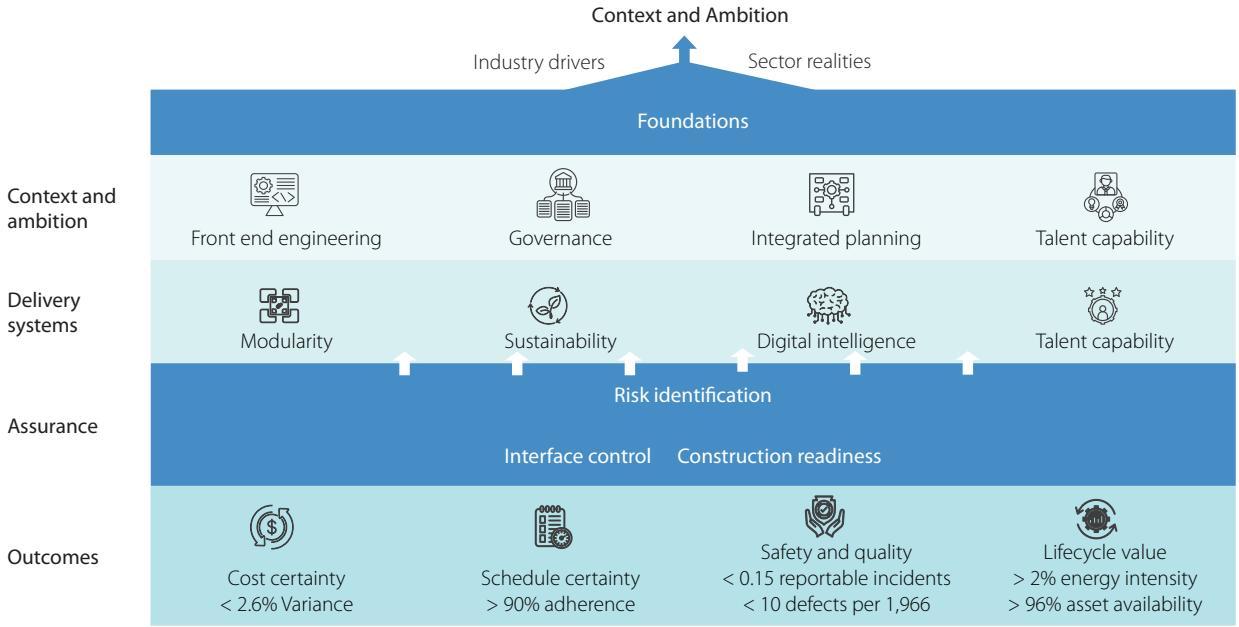
Digital analytics enhances this capability by identifying trends that may not be obvious through traditional reporting. Equally important is the TCE organisational mindset that supports early intervention. TCE engineering teams are encouraged to raise concerns without fear and to challenge assumptions constructively. TCE leadership values transparency over optimism and preparedness over reaction. When problems are addressed early, options remain available. When they are discovered late, choices become constrained, and certainty erodes. Taken together, these enablers form a critical bridge between engineering capability and delivery assurance.

Understanding the industry context, customising solutions, optimising costs intelligently, selecting the right partners, and mitigating risk proactively are not isolated activities. They are interconnected elements of a disciplined execution philosophy. In complex project environments, this philosophy allows engineering organisations to move beyond tool-driven delivery towards outcome-driven certainty.

By embedding these capabilities into their engineering and project management frameworks, organisations such as TCE transform complexity from a source of unpredictability into a structured domain of control. This transformation enables consistent results across sectors, geographies, and project scales. In an era where complexity is inevitable, such execution excellence converts ambition into achievement and confidence into certainty.

Enabler	What It Ensures
Sector and client context understanding	Solutions tailored to real operating needs and long-term value
Holistic cost optimisation	Balanced trade-offs for capital, lifecycle, schedule and reliability
Vendor and partner selection	Reliable supply, better manufacturability and predictable schedules
Proactive risk identification	Early detection of weak signals and timely corrective action
Interdisciplinary governance and reviews	Clear accountability, faster decisions and reduced interface mismatches
Digital dashboards and analytics	Real-time visibility and trend discovery beyond traditional reporting
Early intervention culture	Issues raised without fear, options preserved and certainty protected

Execution Excellence Enablers and Outcomes



Certainty operating model

Concluding Remarks

The growing scale, ambition and interconnected nature of modern projects have redefined what it means to deliver engineering excellence. Complexity today is not confined to technology alone. It spans systems integration, sustainability expectations, regulatory frameworks, stakeholder alignment, digital transformation and accelerated delivery timelines. In this environment, certainty is no longer a passive outcome of good execution. It is a deliberate capability that must be designed, nurtured, and consistently demonstrated.

As this article has explored, engineering certainty at TCE is built on strong foundations established at the front end through rigorous concept selection, integrated lifecycle planning, transparent governance and continuous value engineering. It is reinforced by strategic responses to complexity, such as modularisation, which bring structure, repeatability, and predictability to large-scale projects. Sustainability embedded in engineering decisions ensures that assets remain viable, compliant, and resilient throughout their whole lifecycle, aligning project outcomes with global decarbonisation and resource-efficiency goals.

Automation and digital intelligence have emerged as indispensable enablers of certainty. Design automation, AI-driven knowledge systems, predictive analytics and digital twins enhance decision quality, reduce variability and provide real-time visibility across geographically distributed teams. These technologies amplify engineering judgment and enable proactive risk management that would otherwise remain hidden until it is too late. Equally critical is the role of people. Talent development, continuous training and structured knowledge transfer ensure that engineering organisations retain the capability to interpret complexity and respond effectively.

Skilled teams, supported by strong leadership and a culture of accountability, can deliver on challenging schedules without compromising safety or quality. Integrated project management, digital dashboards and transparent stakeholder engagement further strengthen trust and alignment throughout the delivery ecosystem. Taken together, these elements form a coherent and repeatable approach to managing complexity and delivering certainty. They reflect an understanding that certainty is not achieved by avoiding risk, but by anticipating it, structuring it and responding with discipline and insight. For clients, this translates into predictable returns, reliable operations and confidence that investments will perform as intended.

For TCE, it reinforces long-term partnerships, strengthens competitive advantage and affirms its role as a trusted engineering partner in an increasingly demanding world. As industries continue to evolve and projects grow more complex, the ability to deliver certainty will define engineering leadership. By combining deep technical expertise, systems thinking, digital intelligence and a strong people-centric culture, engineering complexity can be transformed from a source of uncertainty into a foundation for confidence. In doing so, TCE fulfils its enduring purpose of enabling progress and ***engineering a better tomorrow with responsibility, reliability and trust.***

Author

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Managing Complexity through Coordination and Collaboration – IIT Hyderabad Campus Development

In the modern construction industry, the role of a Project Management Consultant is central to the success of large and complex projects. The PMC acts as the client's representative and is responsible for the entire project lifecycle. This responsibility covers all stages from the early inception and conceptualisation of the project to its design, execution, completion, and final handover. The PMC ensures that the project is delivered according to the agreed scope, within the planned time and budget, and meets the specified quality standards. It must also fulfill all functional and technical expectations as outlined in the contract.

Beyond managing time, cost, and quality, the PMC's true strength lies in its ability to coordinate and collaborate with multiple stakeholders. The success of any project depends on how effectively the PMC creates a shared vision, aligns objectives, and builds collaboration between the many participants involved in design, engineering, construction, finance, and operations. A study conducted by the Project Management Institute (PMI) shows that projects which focus on stakeholder collaboration and communication are far more likely to achieve their intended outcomes within the expected timeframe and cost limits.

This case study illustrates how Tata Consulting Engineers Limited (TCE), acting as the Project Management Consultant for the Phase II Campus Development Project of the Indian Institute of Technology Hyderabad (IIT Hyderabad), applied structured principles of coordination, communication, and stakeholder management to deliver a complex project that faced major challenges including scope variations, academic changes, and the COVID-19 pandemic.

Understanding the Stakeholders

TCE began by identifying all stakeholders and classifying them based on their roles, responsibilities, and influence over the project. The team understood that every stakeholder, whether internal or external, had unique expectations, concerns, and contributions.

Internal stakeholders included the project management team, design engineers, architects, contractors, subcontractors, and site management staff. These were the groups directly involved in day-to-day execution. External stakeholders consisted of the client, funding and regulatory bodies, academic end users, design consultants, suppliers, and the local community.

To develop an effective strategy for coordination, TCE carried out a detailed analysis of stakeholder interests and their influence on project decisions. This analysis helped the team design specific engagement plans suited to each group. It also allowed the team to determine how communication should be managed to ensure clarity, transparency, and efficiency.

Communication was organised into three broad categories. The first was informing, which dealt with sharing updates, reports, and schedules within the internal team. The second was consulting, which focused on two-way communication with decision-makers, authorities, and regulatory agencies to seek clarifications, directions, or approvals.

The third was collaborating, which brought together internal and external stakeholders to jointly finalise the project scope, design, and execution strategies. This structured communication ensured that all stakeholders remained aligned and engaged throughout the project.

Principles of Coordination and Collaboration

The foundation of TCE's stakeholder management approach rested on transparency, open communication, and mutual trust. The project team made it a priority to share accurate and timely information, hold regular meetings, and resolve issues before they could escalate. By encouraging collaboration at all levels, the PMC helped ensure that each stakeholder understood the project's objectives, limitations, and opportunities.

Early engagement of key decision-makers and end users helped prevent design conflicts and reduced the chances of changes during execution. The team also created mechanisms for continuous feedback, which allowed all participants to voice their concerns and contribute to the decision-making process.

Technology played a vital role in improving coordination. Digital tools such as Building Information Modelling (BIM) and project management software allowed for detailed planning, visualisation, and progress monitoring. Data was shared in real time, enabling quick decisions and accountability. Regular updates, review meetings, and digital reports created a rhythm of communication that kept the entire project moving in harmony.

Project Overview

IIT Hyderabad is a leading academic institution developed on a 576-acre campus. The Phase II development began in March 2019 and was financed partly through a loan from the Japan International Cooperation Agency (JICA). The project aimed to create a self-contained, modern educational environment combining academic, residential, and social spaces.

The development included guest houses, sports facilities such as a swimming pool and indoor sports complex, eight departmental buildings with laboratories and classrooms, hostels, an administration building, lecture halls, a student commons area, a school, hospital, library, research and technology parks, convention centres, and complete utility infrastructure including electrical substations, chiller plants, water distribution, drainage, and fire protection systems. The total built-up area of the project was approximately 3,11,000 square metres.

TCE's Role as Project Management Consultant

TCE was entrusted with the complete management of the project. This included pre-construction planning, contract administration, variation and change management, time management, construction supervision, EHS compliance, quality assurance, and post-construction responsibilities during the defect liability period.

The project was divided into two major construction packages. One was executed by Larsen and Toubro Limited and the other by Shapoorji Pallonji and Company Private Limited. The University of Tokyo served as the concept designer for selected buildings, and four design consultants were engaged for specific components. TCE classified stakeholders into three main categories for clarity. The approvers and influencers included the funding agencies, client management, administrative heads, and regulatory authorities who had the power to make critical decisions. The executors and performers consisted of architects, consultants, contractors, vendors, and suppliers responsible for delivering the work. The observers and controllers were represented by the PMC teams responsible for ensuring that project goals, quality standards, and timelines were met.

Stakeholder Relationship Management

TCE's stakeholder relationship model was built on early engagement, inclusiveness, and responsiveness. The team worked to establish trust from the beginning of the project by communicating with openness and consistency. Decision-makers were encouraged to participate actively in discussions to resolve bottlenecks and claims.

The team placed strong emphasis on proactive communication, providing clear and timely updates to all stakeholders. Every stakeholder knew the project's progress, challenges, and expectations. TCE's teams remained accessible to all parties and maintained a professional and balanced approach to conflict resolution. By actively listening and showing empathy, they created an environment of mutual respect and cooperation.

The PMC also established structured processes to ensure accountability. A detailed project charter was signed at the start, outlining the vision, scope, and key deliverables. Within the first month, TCE facilitated the preparation and approval of a comprehensive Master Project Schedule. The schedule was developed using a combination of the Critical Path Method, the Last Planner System, resource-oriented planning, and the Line of Balance method. Software such as Microsoft Project and Primavera were used for scheduling and tracking.

Design deliverables were coordinated through CAD, and layout issues were addressed using BIM and Revit models. Digital processing systems were introduced for drawing reviews, approvals, and document tracking, which reduced delays and ensured transparency. A digital document control system ensured that all teams worked with the latest approved information.

Regular Reviews and Governance

To maintain strong governance, TCE conducted weekly and monthly review meetings with all stakeholders. These meetings were held both on site and online using MS Teams. Every interaction was documented and circulated in the form of minutes of meetings, ensuring that decisions were recorded and actions were traceable.

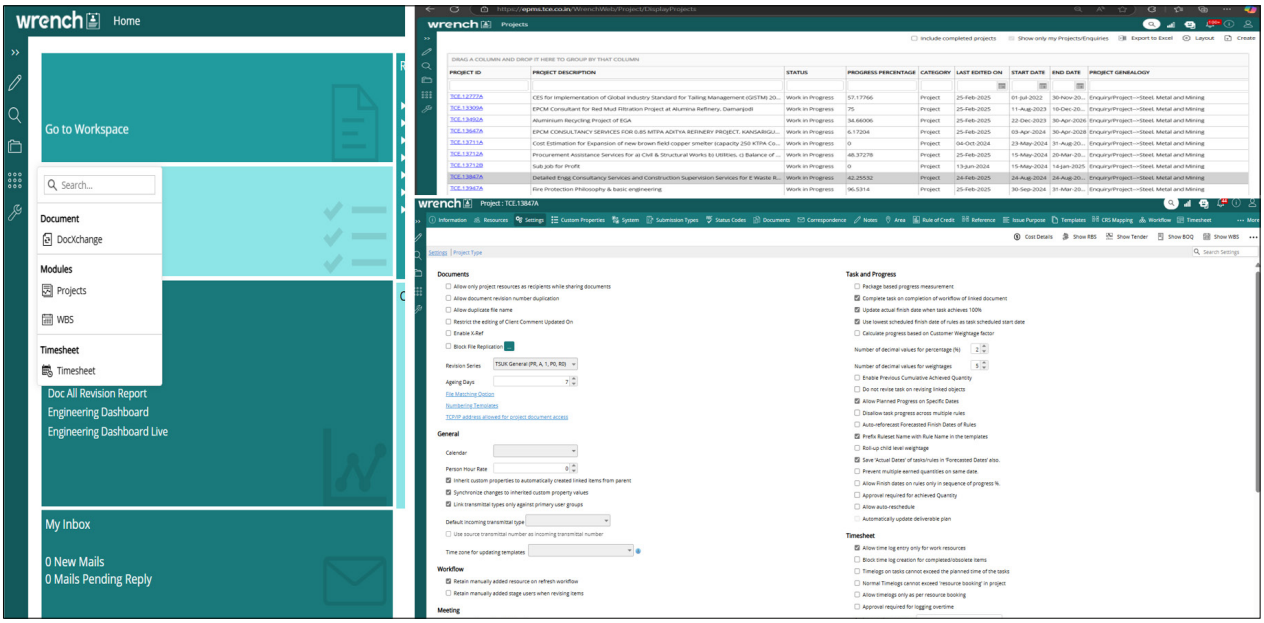
Progress was continuously tracked against the project goals, and early warnings were issued for any potential delays. Delay analysis, recovery plans, and risk mitigation strategies were shared proactively with the concerned authorities.

Disputes were resolved before they could affect progress. A systematic procedure was also followed for administrative and financial approvals for variations and additional work items. TCE maintained strong control over schedule management, process governance, and reporting through well-defined dashboards and performance metrics.

Change orders were managed according to FIDIC contract provisions and approved by the Project Advisory Committee and the Director of the institute whenever required. Extension of time approvals were processed periodically, supported by detailed justifications and analysis, and communicated formally to all stakeholders.

EDMS

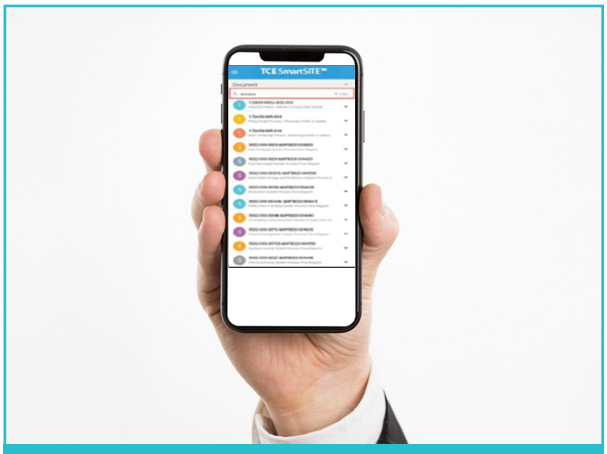
- Review of drawings
- Communication and collaboration
- Uploading of documents



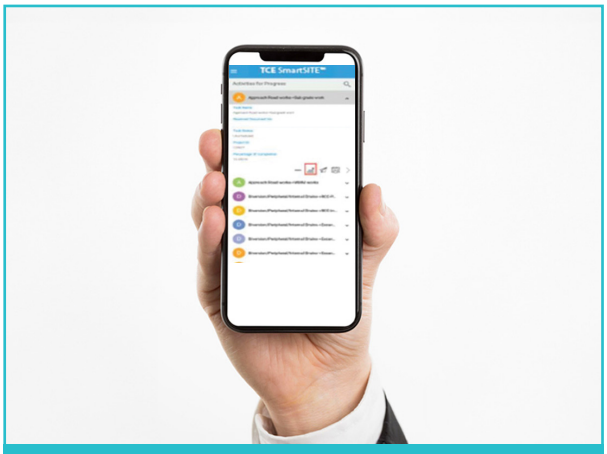
Digital Transformation through Wrench SmartSite

The COVID-19 pandemic brought unforeseen challenges to the construction industry. During this period, TCE accelerated digital transformation by implementing its proprietary platform, Wrench SmartSite. This platform digitised design approvals, document submissions, and reporting processes, significantly reducing dependency on physical paperwork. Initially, the team faced challenges in defining weightage matrices for different buildings, updating schedules, and coordinating data among site teams.

With training and adaptation, these hurdles were overcome. The system provided an integrated dashboard for all stakeholders to view real-time progress, track updates, and identify bottlenecks. Wrench SmartSite proved to be a powerful tool in maintaining continuity during the lockdown. It allowed the team to manage workflows remotely and sustain momentum in the project even when physical access to the site was restricted. It also improved accuracy in reporting, reduced duplication, and created an audit trail for every activity.



Checklist & Pour card



Raise Snag, Safety NC, Quality NC and issues

Tata Consulting Engineers demonstrated how a well-structured governance model, supported by clear communication and digital technology, can overcome disruptions and deliver sustained results.

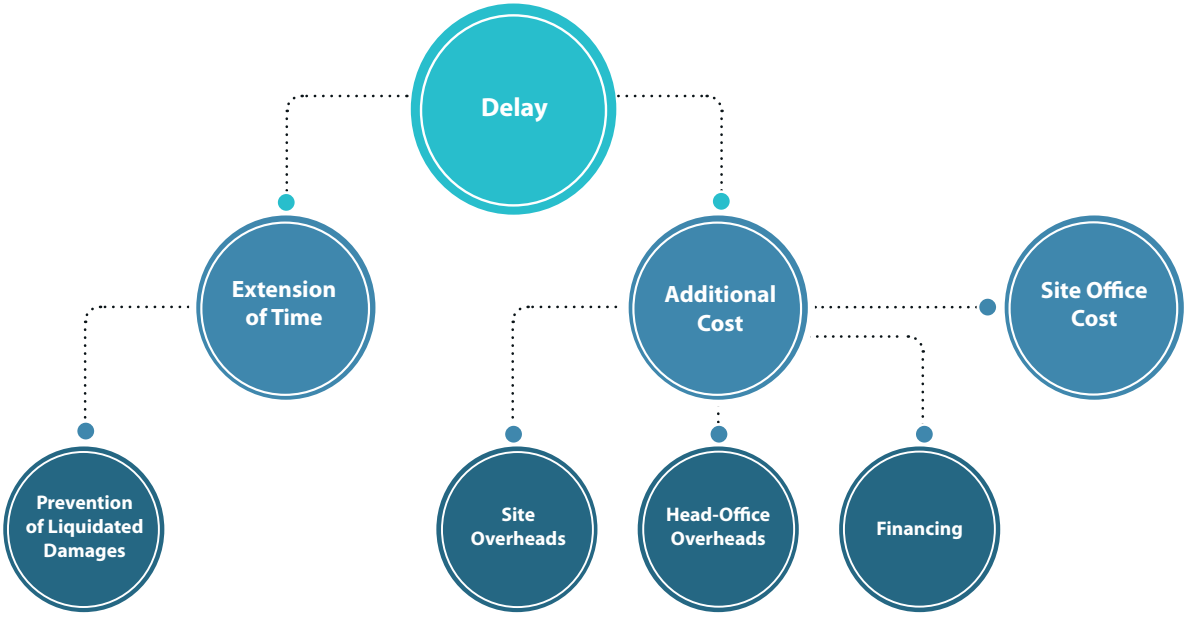
Challenges Faced

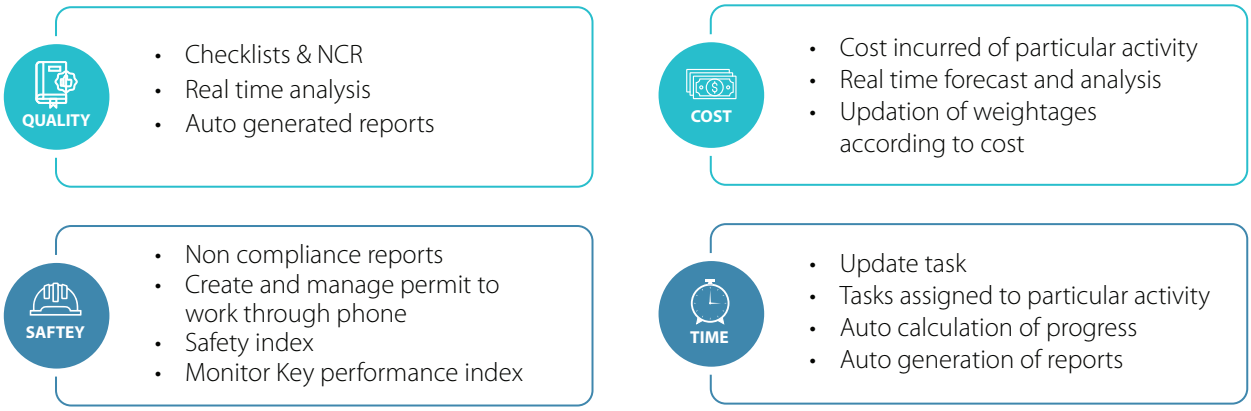
The project faced multiple challenges that tested the robustness of its management systems. The global pandemic caused disruptions in supply chains, workforce availability, and logistics. This led to delays and cost overruns that were beyond the control of the stakeholders.

There were also changes in the administrative and academic management of the institution, which brought new priorities and perspectives. The academic departments introduced new functional requirements, resulting in unavoidable scope expansions.

Furthermore, towards the completion stage, end users decided to integrate advanced technologies such as data networks, audio-visual systems, and smart classroom features that were not part of the original scope.

Each of these developments required fresh design inputs, procurement planning, cost estimation, and approvals, which increased the complexity of coordination among all parties.





Strategic Responses and Adaptive Management

To address these challenges, TCE adopted a structured and proactive strategy led by the PMC Core Management Team. The team carried out a detailed SWOT analysis to identify internal strengths, external opportunities, and potential risks. Based on this, clear strategies were defined for stakeholder management, schedule recovery, and contract variation management. During the lockdown, TCE continued to progress work digitally. The team prepared and approved method statements, bill of materials, and vendor documentation online. This ensured that all preparatory approvals were ready once construction activities could restart, reducing overall time loss.

For scope changes and academic modifications, the PMC team conducted market rate analyses, resource assessments, and prepared detailed cost estimates. These were submitted to the client and the competent authorities for timely approval. The proactive documentation helped secure approvals for both additional costs and extensions of time under contract provisions. Through this process, TCE successfully converted challenges into opportunities. What began as potential risks became instances of value creation and efficiency improvement.

Results and Impact

The structured stakeholder engagement and effective coordination practices adopted by TCE produced measurable results. The project demonstrated improved overall performance and greater alignment among all parties. Conflicts were minimised, efficiency was maximised, and activities were completed within the revised timelines and approved budget. Digital tools and transparent reporting created confidence among stakeholders and ensured that decisions were based on data rather than assumptions.

Most significantly, the project's adaptive management approach led to approximately twenty-five per cent additional revenue for the PMC over the original contract value. This increase reflected the organisation's ability to manage risks effectively while delivering additional scope with quality and accountability. The IIT Hyderabad project has now become a reference model within TCE for managing large, multi-stakeholder assignments through structured communication and digital collaboration. The IIT Hyderabad Campus Development Project is a strong example of how coordination, collaboration, and adaptability can determine the success of a complex engineering assignment.

Tata Consulting Engineers demonstrated how a well-structured governance model, supported by clear communication and digital technology, can overcome disruptions and deliver sustained results. Through early stakeholder engagement, transparent processes, proactive risk management, and continuous learning, TCE turned challenges into opportunities for improvement and innovation. The project stands as a testament to TCE's commitment to engineering excellence and its belief that true success lies in the collective efforts of people, systems, and technology working together for a common purpose.

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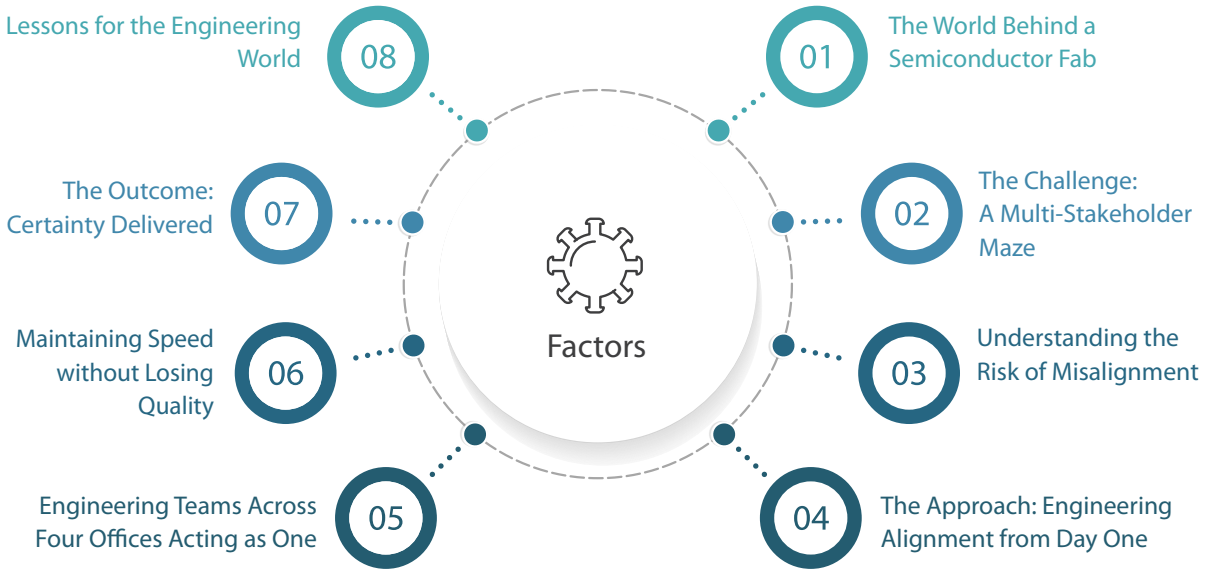
Engineering Complexity Delivering Excellence in Semiconductor Manufacturing Projects

Semiconductor manufacturing sits at the heart of modern progress. Every electronic device, every communication network and every intelligent system depends on the tiny yet powerful chips that flow through these fabs. These chips represent precision, certainty and perfection. Yet behind this precision lies a world of extraordinary complexity, where hundreds of interlinked activities must move in harmony, where design and construction blend seamlessly and where a single delay can ripple across the globe.

Engineering at the Edge of Innovation

Semiconductor manufacturing sits at the heart of modern progress. Every electronic device, every communication network and every intelligent system depends on the tiny yet powerful chips that flow through these fabs. These chips represent precision, certainty and perfection. Yet behind this precision lies a world of extraordinary complexity, where hundreds of interlinked activities must move in harmony, where design and construction blend seamlessly and where a single delay can ripple across the globe.

The growing demand for high-performance chips, the race for technological independence and the immense pressure on global supply chains have transformed semiconductor fabrication into one of the most demanding engineering spaces of our time. Projects must be planned and executed with exceptional speed. They must maintain absolute accuracy. They must integrate the needs of owners, engineers and construction teams. They must adapt to constantly evolving process equipment.



Above all, they must deliver certainty in an uncertain environment. This article explores how Tata Consulting Engineers, through its United States subsidiary, supported one such high-stakes semiconductor project. It highlights how complexity was converted into confidence through collaboration, discipline and agility.

The World Behind a Semiconductor Fab

A semiconductor fab is not just a building. It is an ecosystem. It is an environment where cleanrooms, process tools, utility networks, safety systems and precision engineering must come together without a single error. The architecture of a fab is controlled by the smallest detail. Air purity must remain stable. Temperature must not fluctuate. Utility lines must be routed with absolute precision. Equipment layouts must be adjusted repeatedly as process technology evolves.

In such an environment, engineering excellence depends on three abilities to understand complexity, to coordinate across multiple groups, and to deliver outcomes on time and on specification.

The fab project described in the uploaded document demanded all three. It required coordinated engineering from four regional hubs across the United States. It required alignment with the owner's changing requirements. It required daily communication with the construction partner. It required continuous updates, rapid decision-making and steady collaboration.

The Challenge: A Multi-Stakeholder Maze

The technical complexity of the fab was significant. High-purity utilities, complex cleanroom systems, precise layouts and controlled environments were only part of the challenge. The larger complexity lay in the collaborative landscape.

The project involved three primary groups:

- The Owner, who defined requirements and guided the business case.
- Tata Consulting Engineers, through its US operations, handled detailed design, field queries and ongoing design modification.
- The Construction Partner, who led procurement, installation and daily site execution.

Each group had its own priorities, pressures and dependencies. The owner was focused on performance and business timelines. The engineering team was focused on design accuracy and rapid integration of changes. The construction team was focused on sequencing, labour availability and installation logistics.

At the same time, Tata Consulting Engineers' teams were spread across Midland, Charleston, Baton Rouge and Houston. Each office carried discipline-specific responsibilities.

All were required to collaborate in real time, with no room for delay or misalignment. Engineering had to move at a pace that aligned with construction. Field updates had to be sent back to designers instantly. Every drawing, revision and clarification had to be aligned. This created a challenging but exciting engineering environment.

Understanding the Risk of Misalignment

In semiconductor projects, even minor misalignment can cause significant disruption. A shift in HVAC routing can delay ceiling grid installation. A minor coordination issue can push the tool installation. A one-day delay can affect commissioning windows. Lost commissioning time means lost production, and lost production means lost opportunity. The team recognised early that the most significant risk was not technical failure but communication failure. Without a unified rhythm across all stakeholders, design changes could clash with field needs. Schedules could slip. Construction could pause. Rework could increase. The path to excellence required proactive coordination before problems surfaced. This understanding shaped the team's approach.

The Approach: Engineering Alignment from Day One

The project team did not wait for conflict to arise. It created alignment from the beginning. Weekly integrated planning meetings brought the owner, engineering team and construction partner together. These sessions did more than update progress. They created shared ownership. Everyone had visibility. Everyone had a voice. Everyone understood the next steps. Design updates were aligned to construction milestones. Engineering packages were not simply produced. They were structured to support construction sequencing. Real-time collaboration became a habit. Questions from the field were addressed immediately. Plans were adjusted to avoid delays. Information moved at the pace demanded by the project. A cloud-based project management platform became the single source of truth. All stakeholders had immediate access to drawings, updates, schedules and field reports. This eliminated confusion. It prevented version issues. It allowed design and construction to move in tandem. The engineering team often issued drawing updates at night so that the construction crew could install by morning. This level of responsiveness was not accidental. It arose from shared discipline and an unwavering focus on progress.

Engineering Teams Across Four Offices Acting as One

The uploaded document highlights a key achievement: despite operating from four separate regional hubs, the engineering teams functioned as a single unit. This required a blend of discipline, humility and clarity. Midland, Charleston, Baton Rouge and Houston each carried a part of the design. Cleanroom systems flowed from one hub. Mechanical and utility coordination came from another. Electrical expertise came from another. Field coordination and rapid updates came from multiple offices at once. The team created a unified workflow so that all these contributions came together without conflict.

This multi-location alignment became a strategic capability. The project proved that distance is not a barrier when teams share a familiar rhythm and purpose.

Maintaining Speed without Losing Quality

Speed is essential in semiconductor projects. But uncontrolled speed can lead to mistakes. The team created a discipline of daily momentum. They avoided unnecessary pauses. They ensured that decisions in the morning influenced action in the afternoon. They did not wait for perfect information if progress required controlled clarity. The engineering response time became a crucial advantage. During critical phases, design changes were completed in less than two days. This allowed construction to maintain flow and avoid downtime. The owner received clarity at every step. The construction team received field-ready deliverables. This speed was a result of trust. Trust between offices, trust between stakeholders and trust in the shared workflow.

The Outcome: Certainty Delivered

The results speak clearly. Despite the scale and complexity of the project, the team delivered on time and on specification. Engineering packages were issued to support construction and avoid idle time. Coordination between Tata Consulting Engineers' regional offices allowed continuous progress. Construction began with complete and vetted designs. Commissioning progressed smoothly. Most importantly, the owner achieved schedule certainty. The fab building, with full utilities including water, glycol, cooling tower systems, compressed air, industrial gases, and electrical hook-up, moved from site acquisition to production readiness in less than one year. This is the heart of engineering excellence: turning complexity into predictable outcomes.

The modern world demands rapid progress, flawless coordination and predictable outcomes. Semiconductor manufacturing represents the highest standard of precision. The project described here shows that certainty does not emerge naturally. It must be engineered

Lessons for the Engineering World

The semiconductor project offers lessons for engineering organisations everywhere:

1. **Build alignment early and maintain it continuously.** Clarity at the beginning prevents rework later.
2. **Allow field feedback to shape design.** Design must evolve with real site conditions.
3. **Treat distributed teams as one team.** Shared tools, shared rhythms and shared understanding create unity.
4. **Recognise that speed requires trust.** Fast decisions depend on confidence between partners.
5. **Value momentum over perfection.** Progress builds confidence. Confidence builds outcomes.

Conclusion: Certainty Is Engineered, Not Assumed

The modern world demands rapid progress, flawless coordination and predictable outcomes. Semiconductor manufacturing represents the highest standard of precision. The project described here shows that certainty does not emerge naturally. It must be engineered.

It is created by teams that step beyond their functional boundaries. It is created through alignment among the owner, engineering, and construction. It is made by a rhythm of communication that becomes stronger with each interaction. It is produced by the belief that complexity is not a barrier but an opportunity to demonstrate excellence. This is the essence of Engineering Complexity: Delivering Excellence.

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Delivering Excellence through Risk Management and Resilience

Engineering today functions in a world that is constantly shifting. Projects move at a fast pace, with planning, design and execution happening in shorter cycles than ever before. Teams must make decisions quickly. Stakeholders expect timely outcomes. Conditions change without warning. In this environment, risk becomes a constant companion. Some risks are known from the beginning. Many more emerge as the project progresses. They may come from the site, the market, the design process, the environment, or even decisions made by external bodies.

Delivering Excellence in an Uncertain Engineering World

Despite these challenges, projects continue to grow in scale and ambition. They succeed because engineering teams can manage uncertainty with clarity and respond to it with strength. They use disciplined risk management to understand the nature of uncertainty. They use resilience to recover quickly and continue without losing direction. Together, these two abilities help organisations deliver excellence even amid complexity.

They support the broader belief that complexity can be handled professionally and that excellent engineering outcomes can be achieved with confidence. The following sections explore how a structured approach to risk, combined with resilient behaviour, becomes a robust foundation for modern engineering success.

Understanding Risk in Fast-Moving Projects

Risk is an uncertain event or condition that may affect a project's goals. It can have a positive or negative impact. A delay in material delivery can increase cost and affect deadlines. A new technology introduced during execution may speed up work or improve quality. Both represent uncertainty. For this reason, risk is always present in modern projects.

Today, projects are planned at a rapid pace. Many activities overlap. Designs evolve even while early construction begins. Stakeholder expectations change as the project moves forward. This environment creates both opportunities and threats. It demands a close understanding of how risks evolve through the project lifecycle. At the start, risks may be easier to identify. As work progresses, new information appears. Site conditions change. Regulations are updated. Technologies shift. Market conditions fluctuate. Each of these changes affects the risk environment. For this reason, risk management is not a single exercise performed at the beginning. It is a continuous practice.

Why Fragmented Risk Practices Do Not Work

A significant challenge for organisations is the fragmented way risk is often managed. Different departments may maintain their own risk lists. They may use different templates, classifications, and assessment methods. Information may be recorded separately by engineering, procurement, construction, quality and finance. When these lists are not connected, organisations lose the ability to form a complete understanding.

Fragmented systems create silos. Silos prevent the sharing of data. They also prevent teams from recognising how one risk may influence another. For example, a technical risk in one discipline may delay procurement. A change in specification may affect safety. A regulatory change may influence several cost items.

Without integrated visibility, teams struggle to anticipate these connections. This is why modern engineering environments require a unified risk management approach.

A shared platform, shared vocabulary, and shared information allow the organisation to see the project as a whole. This clarity supports collaboration. It improves decision-making. It will enable the team to act before a minor issue becomes a significant setback.

Overall Project Risk: Seeing the Entire Picture

While individual risks matter, engineering teams must also understand the overall project risk. This refers to the combined effect of all uncertainties. It represents how much the outcome may change. It includes risks across design, execution, environment, supply chain and stakeholder expectations. It is a measure of exposure.

To manage overall project risk, teams must understand risk appetite and risk threshold. Risk appetite is the level of uncertainty a client or organisation is willing to accept in exchange for a reward. Risk threshold is the point beyond which they are no longer comfortable. When teams understand these limits, they can make decisions that remain aligned with stakeholder expectations. Overall risk also changes throughout the project. As work is completed, some risks naturally reduce. As new phases begin, new risks appear. For this reason, overall project risk must be reviewed regularly.

Creating Effective Risk Responses

Risk responses represent the actions taken to address uncertainty. A good response reduces negative risks and enhances positive ones. Responses include reducing the likelihood of a risk, avoiding the risk entirely by changing scope or method, transferring the risk to another party, sharing it with partners or accepting it when the impact is manageable. To apply these responses effectively, the organisation must have clear responsibilities.

Each risk must have an owner. The owner must track the risk, review its status and ensure that actions are taken at the right time. Without ownership, responses lose their strength. As projects progress, responses may need to be adjusted. A response that worked early in the project may no longer be sufficient later in the project. Regular monitoring allows teams to update responses and maintain control over the evolving risk landscape.

Resilience: The Strength Behind Successful Projects

Risk management provides structure. Resilience provides the ability to respond. Resilience is the capability of individuals, teams and organisations to absorb impact, recover quickly and continue towards the goal. It is needed when plans fail, when assumptions break down or when external events cause disruption. Modern projects rarely follow the exact path expected at the beginning.

External factors, such as weather, technology performance, and supply chain issues, can alter plans. In some cases, a design that works perfectly in a computer model behaves differently on site. In others, a delay caused by an external partner forces a reorganisation of schedules. In these moments, resilience becomes essential.

Resilience helps teams reassess, reorganise and move forward. It prevents the project from losing direction. It keeps momentum alive even when setbacks occur. It also builds confidence among stakeholders, who see that the team can manage challenges without losing purpose.

Adaptability as a Partner to Resilience

Adaptability is closely linked to resilience. Adaptable teams respond to changing conditions with clarity. They do not rigidly hold on to old assumptions. They explore options. They evaluate alternatives. They find new solutions. They make thoughtful decisions that protect the project outcome.

Adaptability does not mean uncontrolled change. A proper change control process must be followed to prevent unnecessary scope expansion. When applied correctly, adaptability helps improve results. It encourages innovation and allows the project to take advantage of new opportunities. Adaptability is critical in technology-driven projects. As new tools, digital models or methods emerge, the team must be willing to adjust plans. This flexibility helps create better designs and execute them more effectively.

Unexpected Events as Opportunities for Growth

Not all unexpected events are adverse. Many create openings for improvement. A last-minute design update may allow a superior solution. A new technique may reduce time or cost. A fresh insight may lead to better performance. Resilient teams recognise these moments and present them to stakeholders for consideration. To capture such opportunities, teams must remain observant. They must evaluate each situation carefully. They must be willing to rethink earlier decisions when a new path offers better value. This approach strengthens the project and enhances the outcome.

How Resilience Builds Organisational Strength

Resilience does not benefit only one project. It strengthens the entire organisation. When teams practise resilience, they develop habits that support long-term growth. They learn from challenges. They document lessons. They share experiences with other teams. Over time, resilience becomes a natural part of the organisation's culture. A resilient organisation is better prepared for future projects.

It can manage complexity with confidence. It can support clients through challenging conditions. It can respond to changing markets. It can continue to grow even when external conditions are unstable. This capability becomes a competitive advantage. It allows organisations to take on more complex work and deliver successful outcomes.

Leadership Behaviour That Supports Resilience

Resilience grows strongest under supportive leadership. Leaders must create an environment where teams feel safe to share concerns early. They must encourage open communication. They must guide teams during uncertainty without placing blame for unexpected changes. They must show confidence in the team's ability to respond. Leaders also play a significant role in promoting adaptability. When leaders encourage innovation, teams feel empowered to explore new solutions. When they provide clarity on priorities, teams make better decisions. When they show patience during necessary adjustments, teams gain confidence. In this way, leadership behaviour becomes a powerful influence on organisational resilience.

The Human Side of Risk and Resilience

While systems and processes are essential, the human element remains central. Engineers, designers, managers and field teams are the ones who identify risks, create solutions and handle challenges. Their experience, judgement and communication influence the project's outcome. Strong teamwork, continuous learning and shared responsibility help create a resilient environment. When individuals support each other, the team becomes stronger. When expertise is respected, decisions improve. When experiences are shared, the entire organisation grows. This human element brings life to risk management and resilience. It converts theory into action.

Risk, Resilience and the Pursuit of Engineering Excellence

Risk is present in every project, every organisation and every programme. Some risks influence cost. Others influence schedule, quality or reputation. The ability to manage these risks with discipline becomes a core capability.

Resilience supports this capability by enabling teams to recover from setbacks. Together, these two abilities help organisations deliver excellence even in uncertain conditions. They allow teams to remain focused on outcomes. They improve the organisation's ability to operate under pressure.

They strengthen the belief that complexity can be navigated with confidence. This is the essence of modern engineering excellence. It is not simply the ability to design or construct. It is the ability to adapt, respond and succeed in dynamic environments. It is the ability to convert uncertainty into informed action and complexity into meaningful progress.

Conclusion: Delivering Excellence through Strength, Insight and Stability

The engineering world today requires more than technical expertise. It requires the ability to understand risk, respond to uncertainty and remain resilient through change. It requires teams that anticipate challenges and leaders who guide them through shifting conditions. It requires organisations that treat risk as a strategic tool and resilience as a core value.

When risk management and resilience work together, they create a strong foundation. They allow organisations to manage pressure, respond to surprises and deliver outcomes with clarity and confidence. They embody the belief that engineering complexity can indeed deliver excellence.

This is how modern engineering organisations succeed. This is how they create trust. This is how they meet expectations even in uncertain times. This is how they continue to grow. And this is how they uphold the spirit of Engineering Complexity Delivering Excellence.

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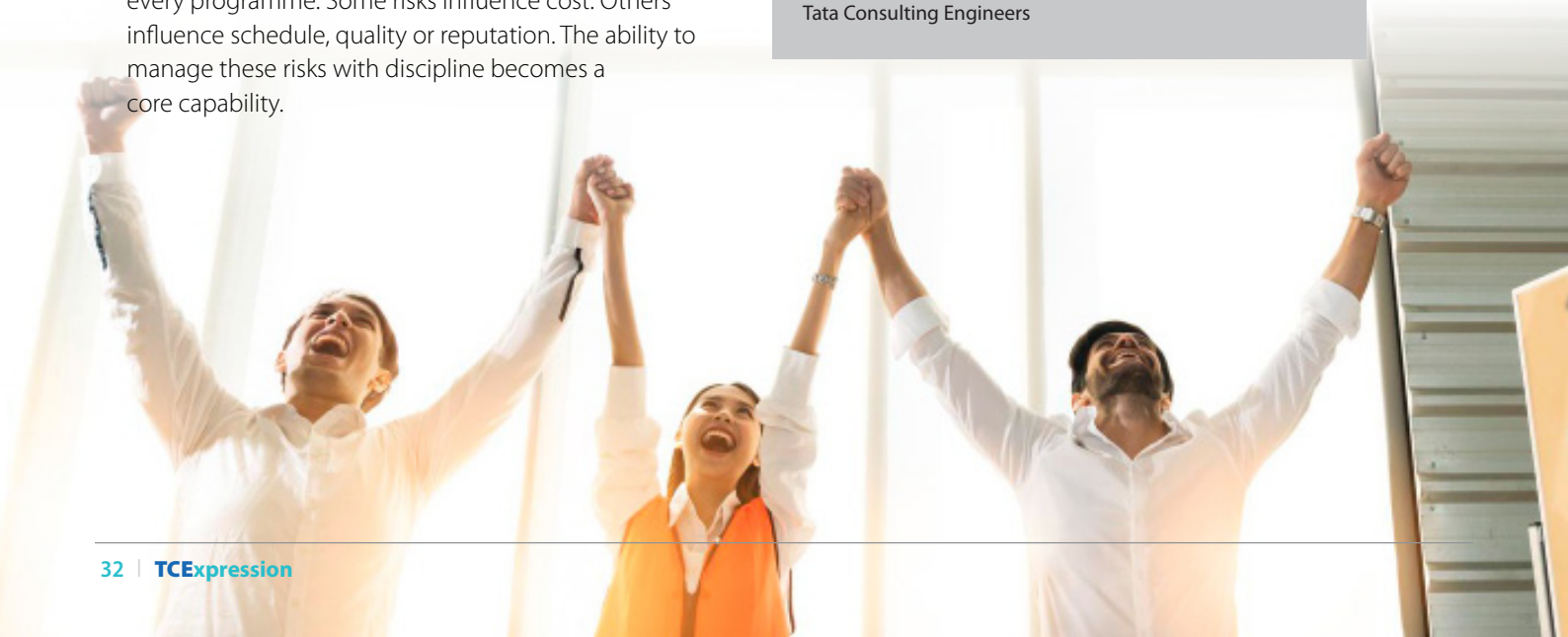


Case Study on Fast Construction Methodology for Mass Housing

India is experiencing one of the most significant movements of people into cities in modern history. Urban centres are expected to generate more than 80 per cent of global GDP by 2050, with nearly 70 per cent of the population living in cities. As the country's population grows and its aspirations rise, the demand for safe, affordable and well-planned mass housing has become an urgent priority. Each year, India requires the creation of nearly 600 to 800 million square metres of new built space. To meet this need, the Government launched the PMAY Urban initiative with the aim of delivering 3 crore houses within 5 years. This target translates to a remarkable requirement of 16,432 homes every single day.

Over the past two decades, India's infrastructure development has matured rapidly. However, conventional construction methods cannot keep pace with current demand rates. Large-scale projects need rapid delivery models. Fast construction methodologies have therefore become essential. Among the various techniques available, precast and modular construction have emerged as the most scalable solutions for mass housing. Within this space, Precast Large Concrete Panels have become particularly significant because they combine engineered quality with rapid on-site assembly.

Precast construction relies on standardised and carefully engineered structural components. These are produced in controlled factory environments to achieve a consistent finish, dimensional accuracy and excellent strength characteristics. They are then transported to the site and assembled using planned sequences. This approach reduces labour requirements, optimises material usage, minimises wastage and significantly shortens delivery timelines.

When a precast yard is located close to the site, the advantages grow even further, often resulting in completion speeds that conventional systems cannot match. Though the initial investment in creating a precast yard is substantial, the overall efficiency and rapid return on investment make it a decisive option for mass housing programmes.

The case study that follows showcases the construction of fifty high-rise towers using this method. The towers range from ground plus 12 to ground plus 19 floors. Precast techniques enabled precision production, mass manufacturing, and seamless assembly to meet the project's stringent delivery requirements. Every stage of the process, casting, stacking, transportation and erection, was designed to achieve maximum productivity and quality.

Mission Ninety-Six
Ultra-rapid delivery of ninety-six flats within ninety-six days
PMAY Housing Project, Navi Mumbai

India's quest for affordable housing is shaped by its rising population and the corresponding rise in quality-of-life expectations. The gap between demand and supply has been widening for years and has been further challenged by the nationwide shortage of skilled construction labour. To address this need, the Government introduced the Pradhan Mantri Awas Yojana Urban Mission in 2015, with the vision of creating permanent homes for the economically weaker sections, low-income groups, and middle-income groups. This mission placed a strong expectation on the construction ecosystem to deliver high-quality homes within very tight timelines.

In recent years, the Indian industry has been moving steadily towards mechanised, modular and digital methods of construction. High-rise residential buildings lend themselves naturally to these approaches. Cast-in-place aluminium formwork systems and Precast Large Concrete Panels have therefore become meaningful alternatives to older construction practices, combining cost efficiency with durability and speed. They also reduce dependence on skilled labour and minimise site activities, while ensuring high standards of quality and safety.

PMAY Housing – Navi Mumbai (Package IV)

Under the Housing for All programme, the City and Industrial Development Corporation developed more than 23,000 houses under Package Four of the PMAY scheme in Navi Mumbai. The project covered the locations of Bamandongri, Kharkopar and Taloja. Tata Consulting Engineers served as the lead Project Management Consultant for the project in association with Hiten Sethi and Associates. Out of a total of one hundred and thirty-five towers, fifty towers in Kharkopar were selected for construction using the Precast Large Concrete Panel system. This system represented one of the most suitable technologies for mass housing due to its engineered quality, delivery speed, and compatibility with Indian high-rise residential planning.

Precast Large Concrete Panel System:

The PLCP system is based on the creation of modular superstructures composed of precast walls, slabs, 3D toilet pods, staircases and corridor cores. The entire structural shell of each floor is assembled from these factory-produced elements.

Overview of Residential Towers using Precast Large Concrete Panel System

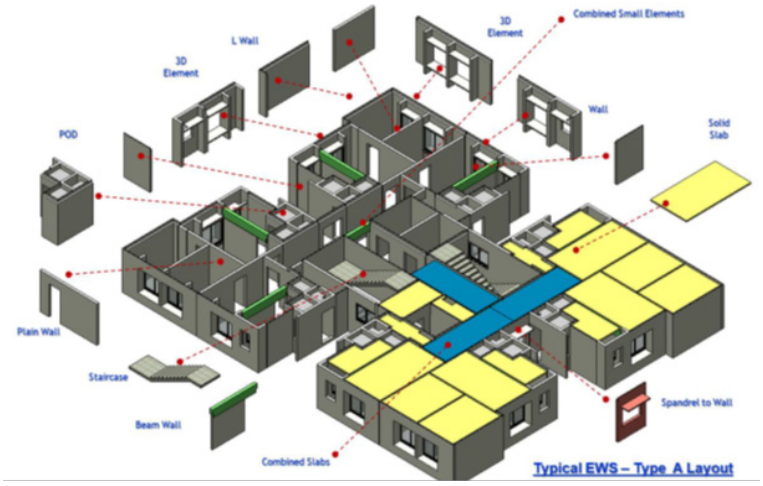
To increase efficiency, specific components were combined into larger volumetric units. For example, toilet-and-bath units with service shafts were combined into a single pod. External walls of two adjoining rooms were also cast together, along with sunshades and wardrobe spaces. These combinations reduced the number of joints, increased construction speed, and improved the overall finish quality.

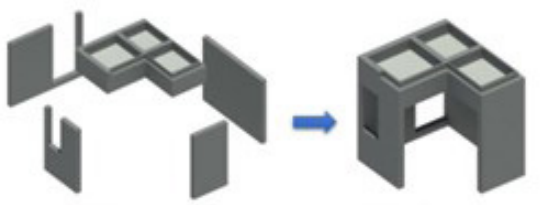
This system removes several time-consuming activities, such as blockwork and plastering. The design philosophy ensures structural performance equivalent to conventional reinforced concrete shear wall buildings. The structural detailing caters to strength, serviceability and ductility requirements for both seismic and wind behaviour. Validation studies were conducted at IIT Bombay to verify compliance with the prevailing building codes. Once placed on site, all elements are connected using carefully designed emulative joints. A cast-in-place concrete topping is then laid to create a structural diaphragm.

Mission Ninety Six Concept and Planning

To demonstrate the full potential of the PLCP system, the project partners undertook an ambitious challenge titled Mission Ninety-Six. The objective was to complete the superstructure of a stilt plus 12 storey tower containing 96 flats within a period of 96 days. The scope included the production and installation of 1,985 precast elements, as well as architectural finishes and MEP work for a built-up area of 64,000 square feet.

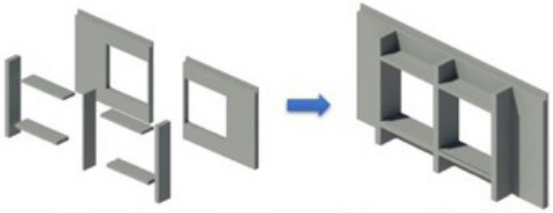
Planning for this mission was completed within 15 days. The available construction footprint was only 450 square metres, requiring precise sequencing and intelligent crane placement. Two heavy-duty tower cranes were deployed with advanced anti-collision technology. A 100 metric tonne mobile crane was positioned to manage unloading operations so that the tower cranes could focus exclusively on installation.





Toilet Pod 2D elements - 5 Panels

Toilet Pod 3D element - 1 Panel



2D elements for 2 rooms - 9 Panels

3D element for 2 rooms- 1 Panel

Typical Precast Element Framing Plan

Typical Precast Elements

A continuous supply of precast elements was essential for success. Therefore, a stockyard was created to hold elements for two complete floors at all times. The yard could store nearly three hundred elements simultaneously. This ensured uninterrupted crane utilisation and eliminated delays caused by transport scheduling or traffic conditions.

The precast production facility at Ulwe, spanning 11,000 square metres, met this requirement with a capacity of more than 2 million square feet per year. At its peak, it produced about 180 elements per day. Close to twenty transport trips were made to the site every day to maintain a uniform supply. Extensive training sessions were arranged for site workmen. These sessions covered every step of the activity sequence to ensure perfect coordination between trades. Safety protocols were reinforced through toolbox talks conducted before every shift. Digital tools, including the Concrete Maturity Method and a BIM-based Digital Twin, were integrated into the project to enable real-time tracking of concrete strength and construction progress.

Mission 96 –Day 42

Execution and Achievements

Mission Ninety-Six commenced on 4th April 2022 and was scheduled for handover on 9th July 2022. The first milestone was achieved immediately when the first floor was completed within three days, as planned. This rhythm continued throughout the project. Even the refuge floors, which had additional overhang elements and complex installation requirements, were completed within the three-day cycle.

The tower cranes installed up to ninety-one elements per day during peak performance. Twelve floors were completed in 36 days, setting a new global benchmark for residential RCC construction. Conventional systems usually require 8 to 12 days per floor. For the first time in a residential project, delays were monitored in hours rather than weeks.

Precast construction enabled the commencement of internal finishing works immediately after the third floor was completed. This approach differs from traditional construction, where finishing teams wait until most of the structural work is complete. The team also introduced a fully precast overhead water tank for the first time. Innovative engineered connections were developed so that the tank would behave structurally like a conventional cast-in-place tank. All four terrace tanks were completed in seven days, followed by the parapet walls, allowing the entire terrace to be finished in ten days. Such work typically spans several months in conventional systems.

Architectural features such as external grooves were integrated into the precast elements at the factory stage. This ensured an excellent finish and reduced the need for plastering. Finishing works, such as waterproofing toilets and baths and installing lifts, were planned at a micro level to eliminate idle periods. The overall finishing scope was completed in eighty-six days.

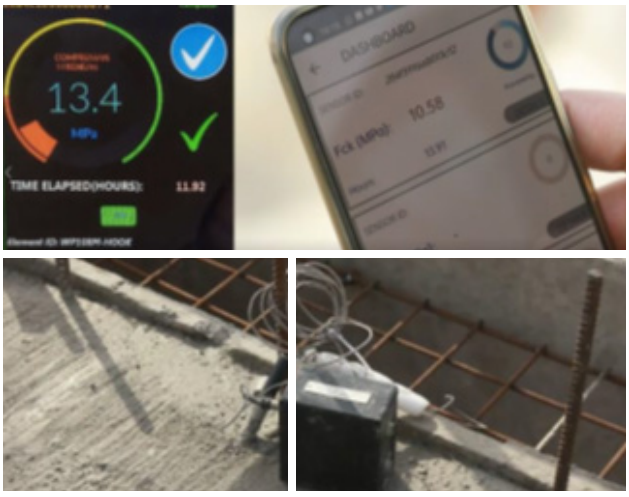
Precast Factory

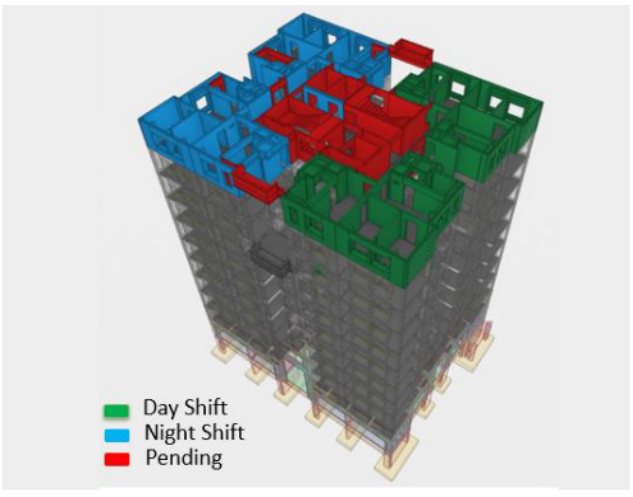
The Concrete Maturity Method played a crucial role because the topping concrete's strength determines when the next stage can begin. Traditional cube testing has limited capacity, forcing teams to add generous buffer time. The digital sensors installed for Mission Ninety-Six allowed real-time monitoring. As soon as the required strength was observed, the activity above was initiated without delay.

By the end of the project, 145,795 safe man-hours were recorded, with an average workforce of 170 people. Daily safety observations were tracked and closed out. Quality checks were carried out throughout the supply chain and at every stage of work.

Day 36 – Terrace Topped Out Celebration

Day 71 – External Finishing Completed





Concrete Maturity Method for Realtime Strength Development Tracking & Digital Twin Approach for Progress Tracking

Key Enablers

Several planned enablers powered the success of Mission **Ninety-Six**. These included two dedicated tower cranes, a 100-tonne mobile crane for unloading, separate logistics planning, dedicated housekeeping teams, a shift-wise erection strategy, precise casting and transport schedules, and the widespread use of digital tools for safety and quality. External finishing was accelerated with eight suspended platforms operating in parallel. Dedicated engineers monitored hourly progress to ensure momentum throughout the schedule.

Highlights

The project achieved **a three-day floor cycle,** compared to the conventional cycle of twelve to fifteen days. Factory capacity enabled the production of an entire floor containing eight flats in one day. The tower cranes averaged 75 panel installations per day, with a peak of 91. The terrace water tanks were completed in seven days compared to the traditional cycle of twenty-five to thirty days. Architectural finishes and services were completed in sixty days. Lift commissioning was completed in eighteen days, and corridor finishing was completed in thirty-two days. Digital monitoring through BIM provided complete visibility across the project lifecycle.

Way Forward

Mission **Ninety-Six** has demonstrated that rapid, high-quality residential construction is not only achievable but also scalable across India's housing sector. Earlier towers in the same project had cycles of 6 to 8 days, which were already superior to those of conventional methods. Mission Ninety Six has now shown that three to four days per floor is a practical and proven reality. With careful planning, appropriate technology and disciplined execution, the PLCP system can offer India a reliable and efficient model for meeting its mass housing requirements in the coming decade.

Finishing of Flat inside and Common area

Author

Sunil Kumar Samantaray
General Manager
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Project Management in Pictures



Construction







Inauguration

Millions of Safe Work Hours

Recognition

Our Women Engineers

World Environment Day'25

Engineering Complexity in Urban Water Management

Urban India stands at a defining moment. Cities are expanding at an extraordinary pace. Populations continue to rise. Economic activity is intensifying. With this growth comes immense pressure on one essential resource: water. Water sustains health, supports industries, maintains sanitation, protects ecosystems and shapes the very quality of life in urban communities. Yet, in many parts of India, water infrastructure is strained, ageing, or insufficient to meet rising demand.

Water as the Foundation of Urban Life

Supply remains intermittent in several cities. Pressure levels fluctuate. Non-revenue water losses remain high. Wastewater often flows untreated into rivers and lakes. Rapid urbanisation continues to stretch already limited resources. The Central Pollution Control Board has reported that India generates more than seventy thousand million litres of sewage every day, of which only a fraction is treated. Demand continues to rise while natural sources continue to shrink.

These challenges have placed urban water management at the heart of India's development agenda. It is no longer enough to expand supply. Cities must adopt a holistic, resilient and integrated approach that supports long-term sustainability. This is where engineering plays a transformative role. Through thoughtful design, advanced technologies, scientific analysis and strong planning, engineering organisations can help India reimagine its water future.

Among these organisations, Tata Consulting Engineers has contributed significantly to the urban water sector across the country. Through its presence in multiple regions, engagement with government agencies, and involvement in complex projects, the organisation has shaped modern concepts in water supply, wastewater treatment, stormwater management, and integrated resource planning. This article presents the organisation's ideas and illustrates them through selected case studies, demonstrating the belief that actual progress emerges when complexity is managed with clarity and responsibility.

India's Urban Water Challenge

The challenges facing urban water and wastewater systems in India are multifaceted. Many cities struggle with inconsistent supply, poor pressure and declining water quality. Infrastructure is often old and inadequate. Leakage in distribution networks leads to high levels of non-revenue water. Groundwater extraction continues without sustainable limits, leading to falling water tables.

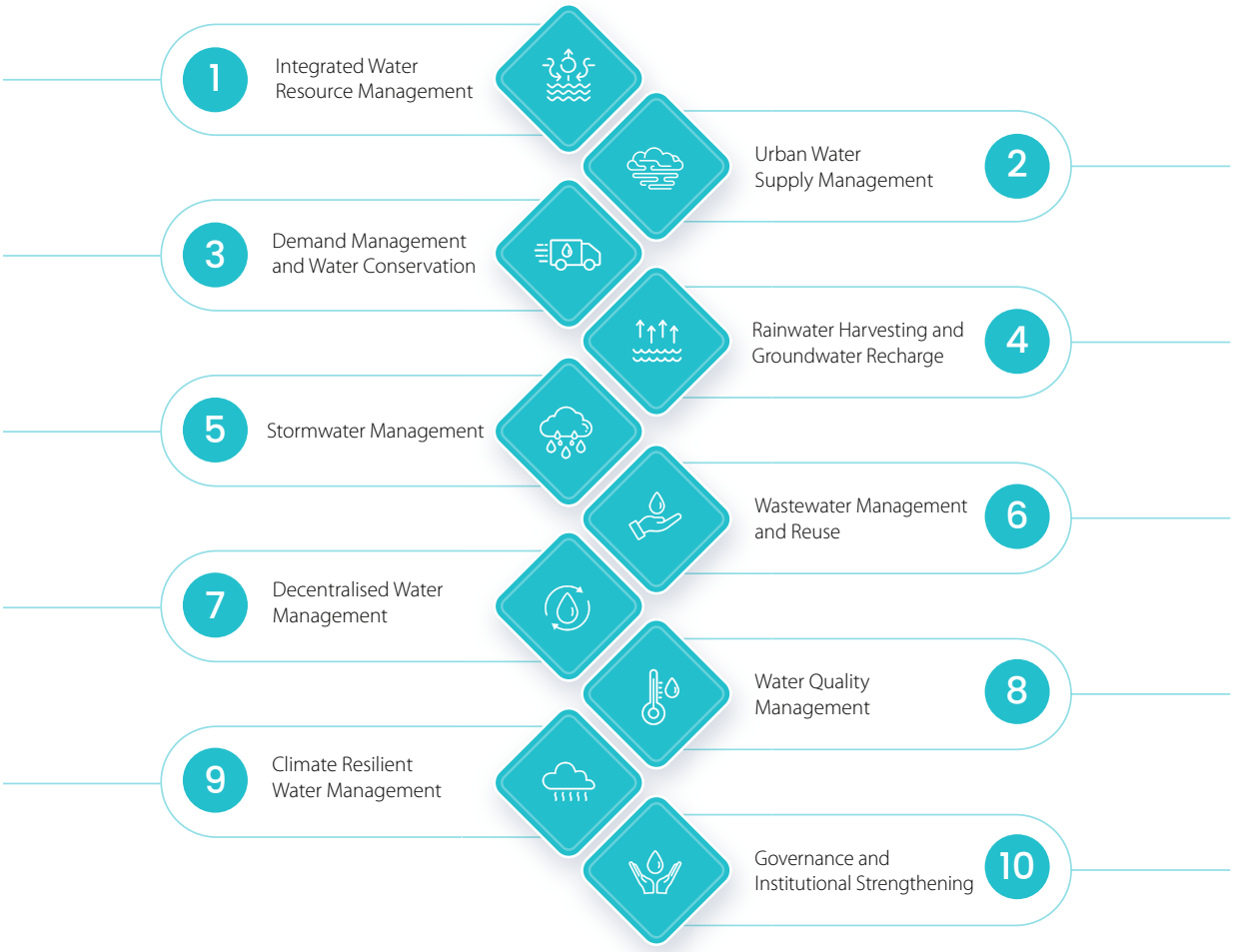
Wastewater treatment capacity remains far below the volume generated. More than seventy per cent of sewage is discharged untreated, contaminating rivers, lakes and groundwater. Urbanisation deepens these challenges.

According to global assessments, India's urban population in water-scarce regions is projected to rise sharply by 2050. This will place significant pressure on existing water systems and create new demands for investment, planning and innovation. Climate change adds further complexity. Cities are increasingly exposed to floods, droughts, heatwaves and extreme weather events. This makes resilience central to the planning of water infrastructure. Without resilience, gains can be quickly lost.

These challenges highlight the need for a comprehensive and integrated approach. Water cannot be treated as a standalone activity. It must be managed across the entire cycle: source, treatment, distribution, consumption, collection, recycling and environmental discharge. This is the principle behind the concepts championed by Tata Consulting Engineers.

Concepts Promulgated by Tata Consulting Engineers

Urban water management requires a holistic view. Tata Consulting Engineers promotes a series of interconnected concepts that address the complexity of India's urban water needs. These concepts are not isolated practices. They form a complete framework that integrates science, design, environmental responsibility and long-term resilience.



1. Integrated Water Resource Management:
   Integrated Water Resource Management encourages coordinated development and sustainable use of water, land and related resources. It recognises that water is linked to ecosystems, social needs and economic activity. It promotes efficiency, equitable distribution and preservation of water quality. It helps cities make informed decisions about supply, treatment, reuse and environmental protection.

2. Urban Water Supply Management:
   Urban water supply depends on multiple sources: rivers, lakes, groundwater and desalinated water in coastal regions. Treatment systems range from conventional clarifiers to advanced technologies such as membrane filtration and ultraviolet disinfection. Distribution networks must be well designed to minimise losses. Non-revenue water control becomes essential, involving leak detection, pressure management and metering. Tata Consulting Engineers supports urban water supply through hydraulic design, treatment plant engineering, pump house planning, automated monitoring systems and strengthened operational practices.

3. Demand Management and Water Conservation:
   Supply must be supported by careful management of demand. Water conservation helps cities reduce wastage and use resources responsibly. Public awareness campaigns, affordable water-saving devices, and meter-based billing foster responsible water use. These measures extend available resources and reduce pressure on infrastructure.

4. Rainwater Harvesting and Groundwater Recharge:
   Rainwater harvesting provides an opportunity to capture water that would otherwise be lost as runoff. Rooftop systems, percolation pits and recharge wells help replenish groundwater. Municipal policies in many states now promote or mandate rainwater systems. In water-stressed regions, these systems play a significant role in ensuring local water security.

5. Stormwater Management:
   Stormwater management reduces urban flooding and prevents contamination through controlled drainage. Sustainable urban drainage systems use green roofs, permeable pavements, detention ponds and natural channels to absorb rainfall. These systems mimic natural hydrology and enhance resilience during extreme rainfall events. They also contribute to groundwater recharge and ecological health.

6. Wastewater Management and Reuse:
   Wastewater should not be seen as waste. It is a valuable resource. Modern wastewater treatment includes primary, secondary and tertiary processes. Treated water can be reused for landscaping, agriculture and industrial applications. Sludge can be treated to produce energy or be processed into safe byproducts. Cities that adopt reuse reduce dependence on freshwater sources.

7. Decentralised Water Management:
   Decentralised systems reduce pressure on large, centralised networks. They allow treatment and reuse closer to the point of consumption. Modular treatment units and local networks support peri-urban and rapidly growing areas. They also improve resilience by preventing complete system failure in the event of local faults.

8. Water Quality Management:
   Clean water requires constant monitoring. Sensor-based systems and digital platforms now allow real-time measurement of water quality from source to tap. Alerts can be generated when any parameter deviates from expected standards. This protects public health and builds trust in the water supply.

9. Climate Resilient Water Management:
   Cities must prepare for climate variability. Resilience is achieved through nature-based solutions, robust engineering and predictive modelling.

Infrastructure must be designed to handle floods, droughts and extreme temperatures. Combining environmental sensitivity with engineering strength helps cities prepare for future uncertainties.

10. Governance and Institutional Strengthening: Infrastructure cannot function without capable institutions. Strengthening municipal agencies, building technical skills, creating accountability systems and improving revenue models support long-term performance. Public-private partnerships and stakeholder participation ensure shared responsibility.

Together, these concepts create a complete framework for sustainable and resilient water management.

Case Studies Demonstrating Engineering Excellence

The following case studies illustrate how Tata Consulting Engineers has applied these concepts across India. They represent diverse terrains, climates, social needs and technical challenges. They show how complexity can be navigated through strong design, careful planning and disciplined execution.

Case Study 1: Bangalore Water Supply and Sewerage Project (JICA Funded)

Bangalore, one of India's fastest-growing metropolitan regions, faces continuous pressure on its water infrastructure due to population growth, urban expansion, and increasing commercial demand. To address these needs, an ambitious project was initiated to augment the city's water supply by 775 MLD and extend services to 110 surrounding villages. In parallel, the project strengthened the wastewater collection and treatment network to support long-term environmental sustainability.

Tata Consulting Engineers played a wide-ranging role spanning design, detailed engineering, bid management, vendor inspection, construction supervision, safety oversight, environmental management, and full commissioning support. This created a seamless chain from concept to commissioning.

At the heart of the project is one of India's largest water treatment facilities at TK Halli. This plant uses high-rate clarifiers, advanced filtration systems with 20 per cent bed expansion, and sludge recycling technologies that reduce waste and support long-term sustainability. From TK Halli, treated water is conveyed to the city through a sophisticated three-stage pumping system. Each pumping station handles the entire 775 MLD flow, powered by single-stage, double-suction, horizontal split-casing pumps driven by 11 kV, 3.5 MW water-cooled motors. These systems are among the largest of their kind in India.

The transmission system is equally complex. A 3,000 mm diameter mild steel pipeline stretches 70 km from TK Halli to Vajarahalli. From there, a series of trunk mains ranging from 400 mm to 2,200 mm cover 120 km within the city. These pipelines feed multiple ground-level reservoirs with capacities ranging from 11 ML to 65 ML, ensuring water availability and stable pressure across the city's distribution zones. The wastewater component of the project includes 213 km of sewer networks, 14 sewage treatment plants with a combined capacity of 124 MLD, and 7 intermediate pumping stations. All plants include advanced biological nutrient removal systems to meet stringent environmental regulations.

The project demanded engineering creativity at many stages. At river crossings over the Suvarna Mukhi and Bhima rivers, the proposed alignment required new pipe bridges and demolition of existing culverts. Following rigorous site visits and discussions with stakeholders, Tata Consulting Engineers proposed laying the 3,000 mm pipeline below the riverbed. This avoided structural demolition, saved considerable time and reduced costs by approximately INR 10 crore.

Another challenge arose at Gotti Gere, where the terrain included steep gradients and rock formations. Engineers designed an innovative plum concrete grading system that created a level base for constructing a 50 ML reservoir.

Space limitations created yet another challenge at Lingadernahalli. To accommodate a 10.5 ML reservoir in a constrained area, Tata Consulting Engineers designed a unique two-tier reservoir system, with 4.5 ML in the lower level and 6 ML in the upper level. The space between the two levels was ingeniously used for office facilities. The water supply component has been commissioned successfully, and the sewerage component is nearing completion. This project remains one of India's most significant and complex water supply interventions, demonstrating the ability to deliver excellence in challenging urban conditions.

Case Study 2: Wastewater Treatment Facilities for Mumbai

Mumbai generates an enormous volume of sewage due to its population density, industrial activity and coastal geography. To improve water quality, protect natural habitats and ensure long-term environmental security, the city initiated a transformative wastewater management programme comprising 4 major treatment facilities with a combined capacity of 1,150 MLD.

Tata Consulting Engineers is involved throughout the entire project lifecycle, supporting concept development, detailed design, technology evaluation, and commissioning. The goal is to achieve 100 per cent treatment of raw sewage before discharge, in line with stringent National Green Tribunal guidelines. Each plant includes nutrient removal systems for nitrogen and phosphorus, tertiary treatment units capable of producing 577 MLD of reusable water, and sludge treatment processes that convert waste into Class A biosolids.

The anaerobic digestion system generates methane, which is used for power generation, reducing operational energy costs. Due to severe land constraints, one site required a multi-level SBR arrangement with vertically stacked treatment basins. The project also incorporates innovative technologies, such as CSBR, introduced in India for the first time with support from Tata Consulting Engineers.

Advanced PLC and SCADA systems monitor all critical units, ensuring automation, efficiency and operational reliability. The outcome will significantly reduce Mumbai's environmental footprint, increase the reuse of treated water, and strengthen resilience against water scarcity.

Case Study 3: Continuous Pressurised Water Supply Project for Shimla

Shimla, a historic hill city, relied on an old distribution network for many years, which caused frequent leaks, low pressure, and intermittent supply. With a growing population and increasing tourism, the city needed a modern solution to deliver a 24/7 water supply under all conditions.

The project transforms Shimla's entire water distribution system through new transmission mains, upgraded distribution pipelines, modern water storage tanks, smart metering and pressurised networks. Tata Consulting Engineers contributed through detailed engineering, technology evaluation, drone-based mapping, community engagement and system optimisation.

Smart metering is a key feature of this programme. Ultrasonic meters with advanced metering infrastructure allow automated billing, leak detection, tamper alerts and real-time monitoring. This reduces water wastage and increases revenue accuracy. A remarkable innovation in this project is the use of drones for mapping. For the first time in Shimla, drones helped designers identify optimal reservoir locations, assess terrain and visualise pipeline routes that minimise disruption. Public awareness initiatives supported the technical solution. Campaigns in schools, citizen forums and residential communities helped create responsible usage behaviours. Competitions and pledges encouraged water conservation across wards. The project ensures a reliable supply, significantly reduces waste, and improves public trust in the city's water system. It stands as a model for other hill towns in India.

Case Study 4: Climate Resilient Water Supply System for Leh City

Leh is a cold desert region with winter temperatures falling to minus 30 degrees Celsius. Water systems must withstand extreme freezing, harsh terrain and fluctuating weather patterns. The Government of Ladakh launched a visionary plan to achieve a sustainable 24/7 water supply through climate-resilient engineering. Tata Consulting Engineers prepared the detailed project report and guided technical planning for intake systems, treatment facilities, insulated pipelines, distribution networks, reservoirs and zone-based metering.

A 23 MLD intake system near the Indus River feeds into a new water treatment plant designed for 5.7 MLD of high-quality potable water. The transmission network includes 34.17 km of mains and 72.34 km of distribution pipelines across 14 zones and 32 district metered areas. Extreme cold conditions required special techniques. Pipelines were laid 1.5 to 2 metres below the frost line. Self-regulating heat tracing cables were installed for above-ground pipes and household connections.

The roofs of treatment units were insulated with PUF panels, and the buildings were equipped with electric heating panels. Solar power supports pumping stations through net metering. Gravity-based distribution reduces energy use and increases reliability. This project brings reliable water to households, improves health conditions and demonstrates how engineering can adapt naturally to local climatic challenges.

As cities continue to expand, the responsibility to create sustainable and resilient water systems becomes even more critical. Through continuous innovation, technical excellence and collaborative engagement, organisations can support this transformation

Case Study 5: UUSDIP Project in Uttarakhand (ADB Funded)

The Uttarakhand Urban Sector Development Investment Programme aimed to improve water supply, sewerage, sewage treatment and solid waste management in the Garhwal region, particularly Dehradun and Roorkee.

Tata Consulting Engineers provided master planning, engineering design, procurement support, institutional strengthening and awareness programmes. The programme introduced modern water treatment, upgraded sewer networks and developed advanced sewage treatment plants with SBR and BNR technology. Centralised SCADA-based district metered areas helped reduce non-revenue water and supported 24x7 supply goals. Upgradation of existing water treatment plants enhanced quality and reliability. Capacity building was an essential part of the programme, helping municipal agencies adopt better operational practices and strengthen long-term governance.

Case Study 6: UIRUDP Project for Uttarakhand (ADB Funded)

This integrated programme covered 4 towns: Dehradun, Nainital, Haldwani and Tanakpur. It included water supply, sewerage systems, sewage treatment plants, solid waste management and urban road improvements. Tata Consulting Engineers supported design, drawings review, procurement assistance and construction supervision. Innovations included double-decker overhead tanks for land-constrained areas, two-tier sewage treatment plant layouts with 11 MLD basins, odour control systems and energy-efficient equipment.

Cured-in-place pipe technology was used to rehabilitate old sewer networks in Nainital. Rainwater harvesting was integrated into the conversions of soak pits. Reuse facilities allowed treated water to be used for landscaping and non-potable needs. This project strengthened urban resilience and improved essential services across multiple hill towns.

Case Study 7: River Ganga Pollution Abatement Programme (NMCG)

Under the National Mission for Clean Ganga, a comprehensive programme was launched across 5 states and 119 towns. Tata Consulting Engineers supported conceptual review, detailed project report appraisal, programme monitoring, institutional development and long-term operation planning.

The programme includes 5,213 km of sewer networks, 188 riverfront development projects, 3,913 MLD of sewage treatment capacity and structured operation and maintenance models with 15-year contracts. Hybrid annuity models support performance-based payments.

Extensive value engineering helped reduce project costs by more than INR 4,000 crore while improving design quality. The organisation contributed to changes in concepts, design structures and policy frameworks. It also represented the programme on national and international platforms. The NMCG initiative is among the world's most significant river restoration efforts. It demonstrates how engineering, policy and community participation can work together to protect an ecosystem of national importance.

Conclusion: Engineering a Sustainable Urban Water Future

Urban water management in India is a complex challenge. It involves technical, social, environmental and institutional dimensions. It requires strong planning, scientific understanding, modern technology and resilience. This article shows that Tata Consulting Engineers brings all these elements together through integrated concepts and real-world projects.

Each case study demonstrates how engineering can rise above complexity. Each project shows how thoughtful design and steady execution can deliver lasting value. As cities continue to expand, the responsibility to create sustainable and resilient water systems becomes even more critical. Through continuous innovation, technical excellence and collaborative engagement, organisations can support this transformation.

This is the essence of Engineering Complexity Delivering Excellence. It reflects the belief that complex challenges can be turned into opportunities for national progress. It shows that engineering, when approached with responsibility and insight, can support healthy, vibrant and sustainable urban communities.

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Managing Water Loss for Sustainable Urban Water Systems

Unaccounted for Water remains one of the most persistent and costly challenges faced by water utilities across the world. It represents the difference between the volume of water entering the distribution network and the volume billed to consumers. In many cities, this difference is substantial, and the scale of wastage threatens both financial health and long-term water security. In several developing regions, more than 40% of treated water never reaches the end user. This loss reflects the pressure on growing cities, ageing networks, and the urgent need for sound engineering interventions.

As the population grows and climate change becomes more unpredictable, cities' ability to manage water efficiently will define their resilience. When a town struggles to produce water, every litre saved is valuable. The reduction of Unaccounted for Water becomes an essential strategy that brings together engineering precision, operational discipline and thoughtful planning. It demonstrates how engineering complexity can truly deliver excellence by improving efficiency, conserving resources and strengthening public trust.

This article discusses the components of Unaccounted for Water, the reasons behind leakage, the impact on consumers and utilities, the methods used for measuring and locating leaks, and the role of water audits. It also presents a detailed case study from Bangalore that shows how a structured effort can significantly reduce losses in an urban water system.

The Challenge of Unaccounted for Water

The responsibility of providing safe and adequate drinking water lies with municipalities and designated water authorities. This involves long-term planning, identifying future resources, and anticipating growing demand. Cities near perennial water sources generally find this task manageable. Cities dependent on seasonal rainfall face far greater challenges and must make every effort to conserve what they have.

Conservation of water is usually approached in three significant ways.

1. The first is the reduction of Unaccounted for Water.
2. The second is the recycling of wastewater.
3. The third is rainwater harvesting.

Among these, reducing Unaccounted for Water is often the most immediately impactful because it improves both revenue and resource efficiency.

Studies have shown that forty to fifty per cent of the water supplied in many Indian cities is lost before it reaches the user. Such high levels of loss create immense financial pressure because utilities spend money on pumping and treating water that generates no revenue. Reducing these losses is therefore a critical requirement for improving the sustainability of the water sector.

Understanding the Components of Unaccounted for Water

Unaccounted for Water has two main components, physical losses and non-physical losses. Both must be identified clearly for a meaningful reduction programme. Physical losses refer to leakage from reservoirs, trunk mains and the distribution network. Bursts, cracks, corrosion, misaligned joints or worn-out fittings may cause these losses. While some leaks are visible on the surface, many remain hidden underground and persist for months before being detected.

Non-physical losses arise from errors in supply measurement, inaccurate consumer meters, incorrect estimation of unmetered consumption, unmeasured authorised use, illegal withdrawals, administrative mistakes and waste that is not recorded. These losses require improvements in metering, better record keeping and stronger operational controls. To estimate Unaccounted for Water correctly, engineers must measure the inflow and outflow of water in the system over a defined period. Flow meters at inlet and outlet points provide information on physical losses. Metering at the consumer end helps validate consumption patterns. For non-physical losses, calibrated meters, sample testing, and accurate assessment of unmetered use are essential.

Why Leakage Occurs in Water Distribution Systems

Leakage is influenced by a combination of engineering, operational and environmental factors. Large bursts cause sudden, high-volume losses, while small leaks from joints, fittings, and service pipes go unnoticed and collectively account for a significant proportion of total loss. The amount lost depends on system pressure and the time taken to carry out repairs.

Four major factors influence leakage. The first is the condition of pipes. Ageing networks with corroded or weakened pipes are more prone to leaks. The second is the quality of materials, fittings and artistry. Poor quality installation leads to early failure. The third is pressure within the system. Higher pressure forces water through even small gaps and increases the volume lost. The fourth is soil characteristics and traffic load. Certain soils corrode pipes faster, and heavy traffic above buried pipelines adds mechanical stress.

Understanding these factors helps engineers design better networks, plan maintenance more effectively and respond quickly to emerging issues.

Impact of Leakage on Urban Systems

Leakage has many consequences beyond simple water loss. Continuous leakage weakens the surrounding infrastructure. Roads, foundations and adjacent structures deteriorate over time when water seeps through the soil. Consumers experience reduced pressure and irregular supply, which affects daily life and leads to dissatisfaction.

There is an apparent financial loss for utilities, as they incur the full cost of treating and pumping water that does not generate revenue. There are also health risks. If pressure drops in a leaking pipe, contaminants from surrounding soil can enter the system, compromising water quality. These combined impacts make leakage control a central element of sustainable water management.

Methods for Measuring Leakage

Leakage can occur at multiple points in the system. The approach to measurement varies depending on whether the supply is continuous or intermittent and on the network layout. Leakage in reservoirs is measured using a water-level drop test. Engineers observe changes in water level over a period to estimate the volume lost. For trunk mains, flow meters are installed at the inlet and outlet. Comparing the two readings gives an estimate of the loss along the pipeline.

The distribution system requires more detailed methods because most leaks occur here. Two standard methods are used. The tanker method is suitable in some situations, but the District Metering Area method is more widely adopted. This method divides the network into smaller zones, where water entering and leaving each zone is continuously measured. It allows engineers to detect unusual flow patterns and identify leakage zones more accurately.

Studies show that nearly 80% of total water loss occurs in the distribution network. This explains why the District Metering Area method has become central to modern leakage management.

Locating Leaks

Once a leak is detected in a particular area, engineers must identify its exact location.

Three primary methods are used.

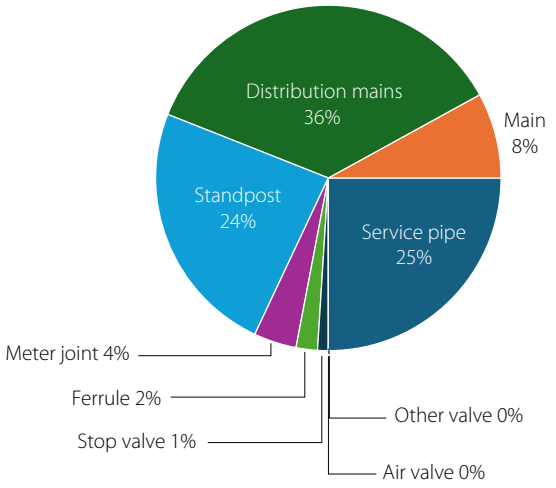
- Step testing involves isolating sections of the network and checking flows in each section to narrow down the area where the leak might be.
- Sounding uses specialised listening equipment to detect the noise generated by escaping water.
- Leak noise correlation uses advanced devices that analyse sound signals at two points on the pipe and calculate the exact position of the leak based on the time difference.

These methods reduce the need for unnecessary excavation and speed up repair.

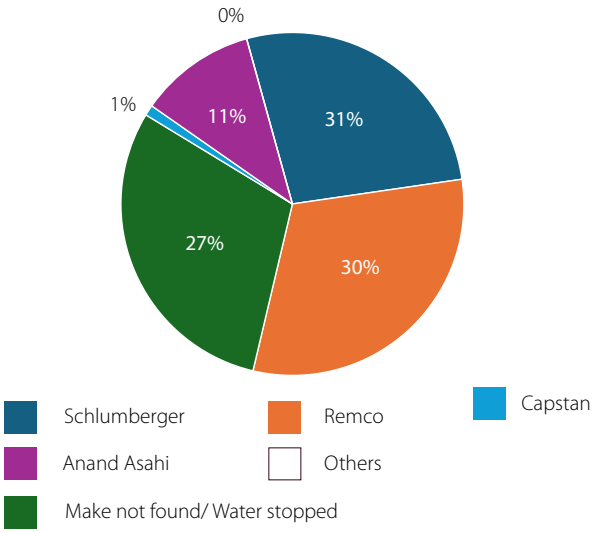
The Role of Water Audits

A water audit is a systematic review of the entire supply system. It measures the volume of loss, estimates the financial impact and checks all data, records and control equipment for accuracy. An audit is essential for understanding where losses occur and for establishing a baseline against which progress can be measured.

Water audits should be carried out annually. They help managers evaluate the effectiveness of previous interventions, identify new problem areas and set new targets. Updating an audit is usually less time-consuming and less expensive than conducting the first one.



Type of Leaks in the Project Area



Classification of Consumer Meters

Case Study: The Bangalore Experience

The Bangalore Water Supply and Sewerage Board is responsible for providing drinking water and managing wastewater across an area of about 800 square kilometres. The city depends almost entirely on the Cauvery River for its water supply. The river is about 100 kilometres from the city, and the average elevation difference is 300 metres. Water must be pumped at a head of about 450 metres, which makes energy costs the most significant part of operating expenses. Parts of the distribution network in Bangalore are nearly a century old. The level of Unaccounted for Water was about 38%.

In response to this challenge, the Board implemented a pilot project on reducing water loss. The project formed part of the Cauvery Water Supply and Sewerage Project, Stage Four, Phase One, and covered 20 square kilometres in the city's central area. It included more than thirty-two thousand consumer connections. The District Metering Area method was adopted. Twenty-one District Metering Areas were created. The number of connections in each area ranged from 500 to 2,500, depending on the network layout. Water entering and leaving each

District Metering Area was measured continuously. During the first phase of the project, which lasted 22 months, 7,000 leaks were repaired. During the second phase, which lasted 18 months, a further 6,500 leaks were repaired. Leaks were found in service pipes, main valves, stand posts, meter joints, ferrules and other parts of the network. All consumer meters were surveyed, and many Class A meters were replaced with Class B meters to improve accuracy. District Metering Area meters were full-bore electromagnetic meters, which provided reliable flow data. The results were substantial.

Leakage was reduced by 26% from an original average of 56%. Average billing increased by almost 9 per cent, rising from 936.26 million litres per month to 1,027.75 million litres per month, as per data for the years 2008 to 2009. This case study demonstrates the effectiveness of systematic engineering methods. It shows that even in ageing networks with high operating pressures and complex urban conditions, Unaccounted for Water can be significantly reduced through careful monitoring, planned interventions and continuous measurement.

Conclusion

The reduction of Unaccounted for Water is a significant priority for all water authorities. The choice of technology and method varies from system to system and depends on financial constraints and available resources. In areas with plentiful, inexpensive water, a limited approach that focuses only on visible leaks may be sufficient. In regions where production and supply costs are high, a more active approach is required, including detailed flow monitoring and advanced leak-detection systems. The challenge of reducing water loss brings together engineering design, scientific investigation, data analytics, field operations, and community expectations. It reflects the broader idea of engineering complexity to deliver excellence. Through structured engineering and continuous improvement, water utilities can protect resources, reduce costs and provide reliable service to the people they serve.

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Frameworks That Strengthen Efficiency, Accuracy and Execution in Large Projects

Engineering today is central to national progress and industrial advancement. As societies expand and demand for infrastructure grows, projects have become larger, more interconnected and more technologically intensive. They involve thousands of activities, multiple agencies, global supply chains and diverse regulatory frameworks. To succeed in this environment, organisations need systems and practices more than technical expertise; this demands strategic clarity and robust governance.

Delivering large-scale projects on time and within budget is increasingly challenging amid evolving technologies, stringent regulations, and rising stakeholder expectations. Success hinges on frameworks and practices that ensure execution certainty, cost predictability, and organisational alignment. This article explores techniques and structured approaches that strengthen project delivery. Specifically, Techniques that enhance execution certainty; project management frameworks for structured governance; core project controls and digital transformation enablers; execution best practices; common pitfalls and modern mitigation strategies; and emerging trends shaping the future of project execution.

With the proper foundation, integrating disciplined planning, stakeholder engagement, and digital tools that provide real-time visibility, organisations can deliver even the most sophisticated programs with consistency and precision.

A Changing Landscape of Engineering Projects

Modern engineering projects reflect the pace and diversity of global development. Airports, metro networks, data centres, semiconductor fabrication units, hospitals, and energy facilities are built to meet far greater demands than in the past.

These demands arise from population growth, urbanisation, climate considerations, customer expectations, and technological innovation. Engineering projects today span multiple geographies, industries, and regulatory frameworks, making them inherently complex. They involve coordination across disciplines and integration of advanced technologies under stringent timelines and stakeholder scrutiny. For example, an airport terminal is an integrated system combining civil, structural, mechanical, electrical, and plumbing (MEP) works with IT infrastructure, sustainability features, and digital control systems. It must manage passenger flow, energy consumption, digital control, security, baggage-handling automation, and airside movement seamlessly. Similarly, a semiconductor plant must operate in carefully controlled environments where even microscopic variations can impact quality. Metro lines traverse varied soil conditions, requiring intricate design and precise construction.

Four forms of complexity influence such projects.

1. **Technological complexity** arises when advanced design systems, equipment automation and interconnected digital networks must function together.
2. **Stakeholder complexity** grows when multiple agencies, consultants, contractors, regulatory bodies and investors contribute to a single programme.
3. **Regulatory complexity** increases as environmental approvals, safety protocols and cross-border standards become more detailed.
4. **Execution complexity** expands when global supply chains, labour markets, weather conditions and owner timelines interact throughout the project cycle.

Successful delivery requires early clarity and workflows that reduce uncertainty. Today's projects demand agile, transparent, and resilient systems. Further, adaptive, data-driven frameworks enable quick responses, clear communication, and predictable outcomes, thereby building stakeholder trust.

Governance principle: Always inform Sponsors of any plan deviation to ensure alignment, accelerate decisions, and protect strategic goals.

Techniques That Improve Predictability in Execution

Achieving execution certainty demands meticulous planning combined with the flexibility to adapt. This balance is essential for navigating the complexities of modern engineering and ensuring that projects are delivered on time, within budget, and to the highest standards. Project execution benefits greatly from structured techniques that align teams, enhance predictability, and minimise avoidable delays. The following practices have been widely adopted in large and multidisciplinary projects, enabling organisations to maintain control while adapting to dynamic conditions.

Concurrent Engineering

Modular Project Planning

Rule of Credit for Progress Measurement

CSI Format and Room Book Hybrid

1. Concurrent Engineering:

Concurrent engineering is an approach that enables design and procurement processes to run in parallel, thereby significantly reducing the critical path of a project. Unlike traditional sequential approaches, it integrates multiple disciplines and phases to operate in parallel, accelerating schedules without compromising quality. Instead of waiting for the entire design to be completed, teams freeze specific critical deliverables early, thereby enabling procurement and early construction to begin. For example, civil foundation work can start while piping loads are still being refined, provided conservative assumptions are applied. This approach saved several months on a recent project, where modest rework was far outweighed by the revenue gains from early completion.

The success of Concurrent Engineering depends on the early freezing of long-lead deliverables, thereby enabling procurement and construction to commence without delay. Progressive detailing of remaining designs maintains momentum, while accepting limited rework as a cost–risk trade-off ensures time savings far outweigh incremental design costs.

Concurrent engineering is not just a technique; it is a strategic enabler for schedule certainty in complex projects. When applied thoughtfully, it minimises delays, optimises resource utilisation, and strengthens competitive advantage.

Key Success Factors

- **Early Freezing of Deliverables:** Identify and freeze long-lead packages and elements essential for early construction phases.
- **Progressive Detailing:** Continue refining non-critical design elements while maintaining momentum on work fronts.
- **Cost–Risk Trade-off:** Accept limited rework as a strategic trade-off; time savings often deliver far greater value than incremental design costs

2. Modular Project Planning:
Modular execution divides a large project into smaller self-contained modules that can be fabricated and evaluated independently in controlled environments. This method reduces pressure on on-site activities, which are often affected by weather conditions, contractor availability, and supply variations, while improving quality and schedule certainty.

In a modular approach, each unit or section is fully designed, manufactured and tested in a controlled environment before being transported to the project site. This improves quality, reduces rework and accelerates installation. The method is widely used in oil and gas infrastructure, renewable energy, healthcare buildings, and high-tech manufacturing. In the oil and gas industry, it improved schedule predictability and installation quality. In semiconductor manufacturing, it reduced contamination risks and ensured precision standards. Similarly, renewable energy and healthcare projects leverage modularisation for speed, quality, and cost efficiency. It offers predictability because controlled environments can maintain stable productivity and stringent quality checks.

Key Success Factors

- **Detailed Planning & Standardisation:** Modules are planned with precision, reducing uncertainty.
- **Controlled Environment Fabrication:** Improves quality and mitigates site-related risks.
- **Parallel Execution:** Shortens project duration significantly.
- **Simplified Interfaces & Reduced Rework:** Isolated scopes streamline integration.

Industry Applications and Benefits: Refer to Figure 1

3. Rule of Credit for Progress Measurement:
Accurate progress tracking is essential for project performance & governance. The Rule of Credit system divides work into milestones, each with an assigned percentage of credit to objectively reflect progress. This ensures that progress is recorded in meaningful stages rather than only when a task is fully completed. This structured approach enhances visibility, objectivity, and predictive accuracy across the project life cycle. For engineering works, credits may be distributed as follows: 10% at the start of BD review; 35% upon completion of the discipline document; 45% upon IDC closure; 55% upon completion of approval; 60% upon first submission; and 100% upon approval. In procurement, credits typically include 10% for inquiry, 30% for purchase order release, 30% for inspection, and 30% for delivery. Similarly, construction activities earn credits for key stages such as foundation work, structural completion, and final installation.

This structured approach ensures progress is tracked in measurable increments rather than only at task completion. The Rule of Credit system improves governance by enabling accurate earned value tracking and consistent progress measurement. It aligns billing with real progress, enhances schedule forecasting, and ensures transparency across teams.

Industry	Data Centre	Oil Refinery	Semiconductor
Module Example	Electrical and Cooling Units	Distillation Units	FAB Shells & Utility Modules
Benefit	Reduces on-site work	Improves Schedule predictability	Reduces clean room risk

Industry Application and Benefits

In projects, where the Rule of Credit system is applied, it has improved the progress visibility, enhanced schedule forecasting, and optimised resource allocation. This demonstrates its value in managing complex, multi-disciplinary programs.

Key Success Factors

- **Reliable Earned Value Tracking:** Enables quantitative performance analytics.
- **Consistent Progress Measurement:** Ensures objectivity across disciplines.
- **Aligned Billing and Payments:** Matches financials with actual progress.
- **Improved Schedule Forecasting:** Strengthens predictive capabilities and resource planning.
- **Transparency Across Teams:** Facilitates clarity when multiple contributors share deliverables

4. CSI Format and Room Book Hybrid:
Combining the Construction Specifications Institute (CSI) format with a Room Book (or Equipment Book) creates a robust tracking structure through a location-linked monitoring system for large buildings, specialised facilities and complex projects.

The CSI format standardises scope definition across disciplines (Divisions 01-49), ensuring clear documentation for mechanical, electrical, and structural works. The Room Book complements this by detailing requirements for each room or space, such as control rooms, cleanrooms, or utility blocks, capturing tools, finishes, equipment, and utilities.

Together, they provide a system that ensures scope completeness, early identification of gaps, improves drawing release and construction management, and streamlines during commissioning and handover. It enables milestone tracking, simplifies punch list management, and ensures no scope item is overlooked.

In a semiconductor FAB project, for example, CSI organised discipline documentation while the Equipment Book specified utilities and processes for each area, reducing gaps and accelerating handover readiness.

Furthermore, the hybrid method performs exceptionally well in hospitals and airports, where each environment has unique requirements. It allows teams to verify that every room receives the correct tools, finishes, equipment and utilities.

Key Success Factors

- **Clarity in Scope Tracking:** Provides discipline-wise and area-wise visibility, reducing the risk of missed tasks.
- **Support for QA/QC and Commissioning:** Offers a structured framework for quality assurance and readiness.
- **Applicability to Large Structures:** Ideal for hospitals, airports, hotels, and semiconductor plants where precision and completeness are critical.

Governance Frameworks for Structured Delivery

Project governance defines how decisions are taken, how risks are managed and how communication flows through the organisation. The choice of governance model must reflect the nature of the project.

Traditional models offer strong control when project requirements are stable. Agile methods are well-suited to environments in which requirements change frequently. Hybrid models combine both. They allow teams to manage long-horizon activities with discipline while maintaining flexibility in areas where adjustments are expected.

A strong governance framework clearly outlines roles, reporting structures, decision-making authorities, communication channels, and change-management processes. It ensures that every participating organisation understands its responsibilities and can contribute to a seamless workflow.

A tailored hybrid approach is often best for EPCM and infrastructure projects. Refer to Figure 2

Framework	Agile	Waterfall	Hybrid	Lean
Best Use Case	Design Engineering, R&D	Construction	EPC Projects	Manufacturing, Product Development
Strenght	Rapid Prototyping, Feedback	Clear Dependencies	Balanced Governance	Waste Elimination
Watchpoint	May lack Predictability	Inflexible to Change of Linkage	Complex to Administer	Culture-dependent Adoption

Project Management Frameworks

Strengthening Project Controls Through Digital Tools

Project controls form the backbone of large project execution. They provide structure for six essential dimensions: time, cost, scope, quality, risk, and resources. Effective project control systems consistently monitor each of these and provide early warning indicators when plans begin to diverge from reality. Digital transformation has significantly strengthened these controls. Today, projects use model-based design systems, integrated planning software, mobile inspection tools, real-time dashboards and automated reporting frameworks. These tools reduce manual tracking, improve accuracy, and enable managers to make decisions based on real-time data. Digital tools also support field teams by providing instant access to drawings, method statements, checklists, and records. When site engineers can submit queries, record inspections, and update progress via mobile platforms, information flows more freely, and coordination improves across departments.

Practices That Strengthen Daily Execution

Beyond frameworks and digital tools, effective project execution depends on disciplined practices that embed clarity, adaptability, and collaboration into daily operations. These principles transform plans into predictable outcomes and strengthen governance across the project life cycle.

- **Integrated Teams:** Engage procurement, design, and construction roles early to prevent late-stage changes, reduce rework, and align cost and constructability considerations.
- **Rolling Wave Planning:** Freeze near-term scopes while refining long-term plans as new data emerges, enabling flexibility without compromising timelines.
- **Flow-Based Monitoring:** Track how work moves through systems, not just tasks, to identify bottlenecks and optimise throughput.
- **Cross-Functional Collaboration:** Use shared dashboards and KPIs to ensure all teams operate from the same data, fostering transparency and accountability.
- **Knowledge Capture:** Institutionalise lessons learned to accelerate future projects and avoid repeated mistakes.
- **Data-Driven Field Execution:** Equip site teams with real-time tools for faster decisions, improved quality, and reduced delays.

These practices create consistency, enhance predictability, and encourage teams to approach problems openly and resolve them, ensuring that projects meet schedule, cost, and quality objectives before they escalate.

Engineering complexity is not a barrier; it is an opportunity to innovate and lead. As engineering projects grow in scale and sophistication, their delivery demands structured thinking, disciplined planning, and adaptive execution.

Preventing Failures Through Modern Approaches

Many project challenges arise not from technical issues but often stem from misaligned expectations, unclear communication, weak processes, and weak governance. To address these, execution strategies must go beyond traditional cost control and embed practices that ensure alignment, adaptability, and transparency.

1. **Outcome-Oriented Alignment:** Anchor projects to strategic objectives rather than mere cost focus, ensuring outputs deliver real business value.
2. **Dynamic Requirement Traceability:** Document, validate, and track requirements throughout the lifecycle to prevent scope gaps and missed acceptance criteria.
3. **Robust Business Case Development:** Define rationale, benefits, and financial parameters, including cash flow patterns, to guide realistic planning and resource allocation.
4. **Comprehensive Baseline Management:** Maintain clarity in scope, schedule, cost, and quality, while establishing communication protocols and stakeholder engagement plans to prevent breakdowns.
5. **Integrated Organisational Budgeting:** Align project budgets with enterprise priorities to avoid resource conflicts when multiple initiatives compete for shared teams.

These practices reduce rework, delays and disputes, while strengthening governance and maintaining alignment between owners and delivery teams.

Emerging Directions in Project Delivery

Digital ecosystems, predictive analytics, artificial intelligence, connected planning and sustainability requirements will shape the next generation of engineering projects. Technology will not only support project controls but also help teams anticipate disruptions, improve resource use and integrate supply chains more closely. Organisations that invest early in such capabilities will find it easier to adapt to rapid change and deliver projects with confidence even in uncertain environments.

Conclusion

Engineering complexity is not a barrier; it is an opportunity to innovate and lead. As engineering projects grow in scale and sophistication, their delivery demands structured thinking, disciplined planning, and adaptive execution. Organisations that adopt advanced frameworks, such as concurrent engineering, modular planning, and hybrid governance models, and support them with tools such as the Rule of Credit and CSI-based tracking, can achieve predictability even in the most challenging environments.

Digital transformation amplifies these methods by providing real-time visibility, analytics, and decision support, fostering a culture of continuous improvement and resilience. In a world of high expectations and tight timelines, engineering leaders must balance creativity with control, ensuring clarity, collaboration, and forward-looking decisions. With the right mindset, tools, and partnerships, large-scale projects can be delivered accurately, reliably, and purposefully, transforming challenges into opportunities and driving sustainable progress.

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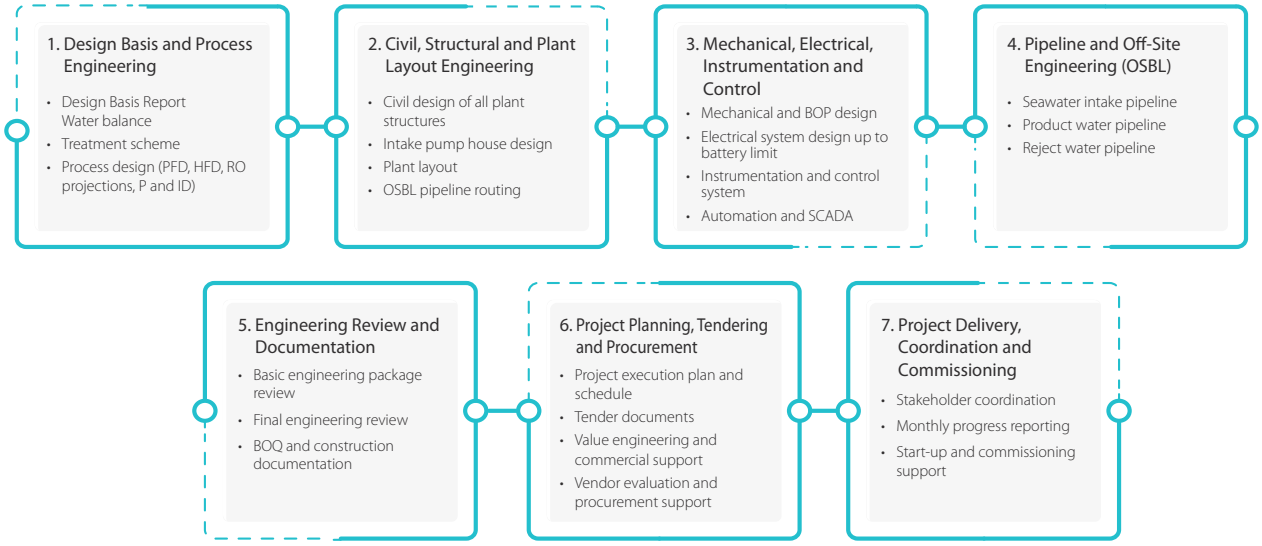
Engineering Water Security through Complex Desalination Design

Water security has become a critical requirement for industrial growth, especially in regions with harsh climates and limited access to fresh water. Mundra, situated in the arid landscape of Kutch in Gujarat, faces a persistent water shortage that affects both communities and industries. In this environment, a reliable and sustainable water supply is not simply a utility but a lifeline for industrial operations. The 33 MLD seawater desalination plant established at the Mundra site represents a significant investment to ensure an uninterrupted water supply for industrial processes, particularly for copper manufacturing. The plant demonstrates how deliberate planning, scientific engineering, and meticulous execution can deliver solutions that meet large-scale industrial demand. Tata Consulting Engineers played a central role in conceptualising, designing, and guiding the project from the earliest planning stages through to final commissioning.

This project demonstrates how complex engineering challenges can be addressed through a structured approach that brings together experience, technology, and precision. The seawater desalination plant is more than a facility for producing industrial water.

It embodies a sustainable resource management approach and demonstrates how engineering can support growth in regions with limited natural resources.



Comprehensive Scope from Concept to Commissioning

Tata Consulting Engineers undertook the entire engineering consultancy lifecycle. The assignment began with conceptual planning and extended right through to commissioning support. This comprehensive involvement ensured consistency of technical thought and design quality at every step and contributed to the timely delivery of the plant. The scope included the complete civil engineering design for the desalination plant. This involved preparing all civil construction drawings and the detailed Bill of Quantities needed to support a smooth construction process. The team then developed the Design Basis Report, which serves as the foundation for technical decisions and functional parameters.

The report included a detailed water balance and defined the treatment scheme, comprising pre-treatment, two-stage media filtration, seawater reverse osmosis, brackish water reverse osmosis, and a re-mineralisation system. Tata Consulting Engineers conducted a detailed review of the Basic Engineering Package, which covered process flow diagrams, water balance calculations, hydraulic and process design calculations, projections for the reverse osmosis systems, piping and instrumentation diagrams, hydraulic flow diagrams, plant layout, and sizing of all civil components. For seamless integration of all plant process units, detailed review of Control Philosophy was also carried out by Tata Consulting Engineers.

This review ensured that every design element met the technical standards required for a plant of this scale. In addition to the core treatment facilities, the project required a robust seawater intake infrastructure. Tata Consulting Engineers designed and engineered the entire seawater intake pump house. Off-site pipeline engineering was also included in the scope.

This covered the intake pipeline that brought seawater to the plant, the product water pipeline that transferred treated water to the point of use, and the reject water discharge line that carried the brine outflow. The team was also responsible for the final engineering review across the entire project. This final validation ensured that every component was checked thoroughly and that the design met all process structural, hydraulic, mechanical, and operational requirements. The plant layout and final routing of off-site pipelines were optimised to enhance operational efficiency and ease construction. The electrical system design included the entire configuration from the incoming power connection to the plant boundary. Instrumentation and control design included creating a fully automated environment for consistent plant performance and ease of operation.

In addition to civil engineering and vendor-engineered packages, the team provided Balance of Plant design for all components not covered under vendor or civil contracts. This included complete documentation and a Bill of Quantities. To ensure efficient project execution, Tata Consulting Engineers prepared a project execution philosophy and a detailed schedule. These helped to coordinate construction activities, vendor execution, and commissioning timelines. The team also prepared tender specifications for the desalination plant and the seawater intake pump house. During vendor evaluation and procurement, the team provided technical and commercial support. This included value engineering, clarifications during bid evaluation, negotiation support, and cost optimisation. Procurement support extended to site visits, vendor discussions, and technical reviews. Coordination with vendors and the site team was critical to managing the project's complexity and ensuring timely progress.

The team monitored the overall execution and prepared regular monthly progress reports that helped the client track work status. During commissioning, Tata Consulting Engineers provided continuous technical supervision to ensure each plant section operated as intended. The facility is automated via a SCADA system that provides real-time data, smooth operation, and minimal need for human intervention.

Desalination Process and Its Significance for the Region

Desalination is a scientific process that removes dissolved salts and impurities from seawater or brackish water to make it suitable for drinking or industrial use. It is a vital technology for water-scarce regions with easy access to seawater but limited freshwater sources. The Mundra project addresses a clear need. The copper plant in the region requires high-quality, low-total-dissolved-solids water for its operations. Without a secure and consistent water supply, industrial operations would face frequent interruptions. The 33 MLD desalination plant ensures an uninterrupted supply and contributes significantly to the sustainable use of water in the Kutch area. The process begins with seawater intake from the Arabian Sea. This water can have total dissolved solids ranging from 35,000 to 42,000 parts per million. At times, the water may have a turbidity of up to 100 NTU. The temperature ranges from 20 to 35 degrees Celsius across seasons. High-capacity pumps, specifically designed for seawater conditions, draw water into the plant.

Multi-Stage Treatment Scheme

The desalination facility follows a carefully designed sequence of processes. Each stage of treatment has a specific purpose, and together they ensure that the final output meets industrial quality requirements.

Pre Treatment

The pre-treatment stage begins with disinfection to control biological growth. Chemical dosing is used to enhance the removal of suspended matter. A flash mixer and a flocculator facilitate mixing and promote coagulation & flocculation. A lamella clarifier efficiently separates suspended solids, and a sludge transfer pump removes the settled sludge. The clarified water is stored in a tank before entering the filtration system.

Two Stage Media Filtration

The dual media filter and pressure sand filter remove fine suspended particles that remain after clarification. This step protects the membranes during reverse osmosis and preserves the treatment system's efficiency.

Seawater Reverse Osmosis Stage

The seawater reverse osmosis system forms the main treatment section of the plant. The water passes through a micron cartridge filter that removes particles larger than five microns. Special chemical dosing protects membranes from scaling and fouling. A high-pressure pump delivers pressure in the range of 60 to 70 bar, which is essential for seawater reverse osmosis. Multistage centrifugal pump with 1300kW motor is used to pump sea water to SWRO system. The membranes reduce total dissolved solids from about 40,000 parts per million to 500 parts per million or lower. An energy recovery device captures a portion of the pressure energy in the reject stream and transfers it to the feed water. This improves the plant's overall energy efficiency.

Brackish Water Reverse Osmosis Stage

In the next stage, the permeate generated from of the seawater reverse osmosis system is polished using brackish water reverse osmosis. The pressure required for this stage is lower, at about 15 to 18 bar. The brackish water reverse osmosis system produces water with total dissolved solids of about fifty parts per million. This is stored in a dedicated tank before undergoing re-mineralisation.

Re Mineralisation System

Re-mineralisation adjusts pH, hardness, and alkalinity to meet the water quality required for industrial use. This is achieved by controlled dosing of CO_2, with water subsequently passed through lime filters. The final output water meets the target of less than 150 parts per million total dissolved solids with positive Langelier Saturation Index (+ LSI).

Supporting Units

Additional units include the backwash system for complete RO Cleaning In Place (CIP) system media filters, the reject-water outfall system for brine management, and the neutralisation pit to ensure compliance with environmental regulations.

By using energy-efficient motors and energy recovery devices, overall consumption has been kept within an estimated range of 3.5 to 4 kilowatt-hours per cubic metre of final output.

Key Components that Enable Performance

The desalination plant incorporates several critical systems that must work in harmony to maintain reliability. These include high-capacity intake pumps; dual-media and sand filtration systems; seawater and brackish-water reverse-osmosis membrane systems; high-pressure pumps for both passes; energy-recovery devices; chemical dosing units; re-mineralisation systems; and the central SCADA-based automation system. The two passes membrane process ensures high-quality permeate generation output. The seawater reverse osmosis stage removes most dissolved salts. The brackish-water reverse-osmosis stage provides final polishing. This combination helps maintain the output water quality to meet required standards.

The energy recovery device is vital in reducing overall electricity consumption. Desalination is an energy-intensive process due to the high pressure required for reverse osmosis. By capturing pressure energy from the reject stream, the energy recovery device helps reduce the burden on high-pressure pumps and lowers operating costs with the help of ERD, up to 95% to 96% of pressure energy available in SWRO reject stream is utilized. To support water flow through various stages, different pipe materials are used based on process requirements. High-density polyethene and glass-reinforced epoxy pipes are used in seawater handling because they resist corrosion. Stainless steel and duplex steel pipes are used for high-pressure sections. For low-pressure chemical dosing systems, cPVC pipes are used.

Water Quality, Power Consumption and Use

The plant produces seawater reverse osmosis permeate with total dissolved solids of less than 500 parts per million. The brackish water reverse osmosis stage further reduces the total dissolved solids to fifty parts per million. After re-mineralisation, the final water quality is maintained below 150 parts per million. The copper plant uses this water in several industrial processes where scaling must be avoided.Consistent water quality ensures reliable operations and reduces maintenance requirements. The plant has been designed to optimise power consumption.

By using energy-efficient motors and energy recovery devices, overall consumption has been kept within an estimated range of 3.5 to 4 kilowatt-hours per cubic metre of final output.

Commissioning and Cost Structure

The desalination plant was commissioned within one year. This achievement highlights the effectiveness of planning, project management, and close coordination between Tata Consulting Engineers, vendors, and the site team. The total cost for the 33 MLD capacity is 267.75 crore rupees. This includes civil works for the desalination plant; civil works for the intake; intake pipeline; miscellaneous work; Electrical, Mechanical and Instrumentation packages; intake electrical and mechanical instrumentation; and the electrical substation. The cost per million litres per day is approximately 8.1 crore rupees.

A Model of Engineering Excellence

The 33 MLD seawater desalination plant at Mundra demonstrates how engineering complexity can be addressed with clarity, precision, and foresight. Tata Consulting Engineers brought together extensive experience across process design, structural engineering, electrical and control systems, mechanical design, and project management to create a facility that delivers both high performance and sustainability. The integration of two pass membrane technology, energy recovery devices, automation, and corrosion-resistant materials makes the plant robust and efficient. The seamless coordination among design teams, vendors, and site engineers ensured the project was completed within a year. This project is not only a solution to water scarcity but also an example of how advanced engineering can contribute to long-term sustainability in industrial regions. It proves that when engineering is applied with purpose, complexity becomes manageable and excellence becomes achievable. Tata Consulting Engineers continues to apply this approach across all its projects, helping industries grow responsibly, efficiently, and aligned with future needs.

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Bharat Pavilion: The Lotus of India at the Expo

The Bharat Pavilion at the Expo is more than an architectural creation. It is a story told in form, light and space. It speaks of India's heritage, its journey of resilience and its vision for the future. Inspired by the lotus, India's national flower, the pavilion reflects purity, harmony and enlightenment. Rising gracefully from mud and water, the lotus has always symbolised the ability to blossom above difficulties while remaining rooted in values. The pavilion mirrors this spirit, reminding the world that India has risen above challenges, blossomed through determination and continues to connect people, culture and nature in harmony.

Carrying the theme of "Connecting Lives", the pavilion reflects India's belief that development is not only about economic progress but also about enriching societies and weaving strong relationships. It is designed to engage communities, to foster connections and to encourage shared experiences. Visitors are invited to participate rather than merely observe. Every pathway and alcove has been created to encourage dialogue, reflection and interaction.

The theme also symbolises the intricate weave of life. Heritage, innovation, culture and nature are brought together in a way that reflects resilience, awakening and growth. The pavilion, therefore, becomes both a physical and a symbolic space where lives are connected.

Architecture and Spirit

The design of the Bharat Pavilion is an architectural expression of the lotus. Spread across eighteen thousand square feet and extending forty metres in length, the pavilion unfolds like a lotus in bloom. Petal-like forms radiate outward in rhythmic yet asymmetric patterns, creating alcoves and sheltered areas that invite pause and contemplation. The play of light and shadow across the structure mirrors India's layered and multifaceted journey.

Lightweight tensile structures give strength without heaviness, allowing the form to remain elegant. During the day the pavilion is a calm refuge where people can reflect and connect. At night it becomes a glowing cultural landmark, its silhouette instantly recognisable as the lotus in bloom.

At its spiritual centre stands Padmapani Bodhisattva, inspired by the Ajanta cave murals. Padmapani represents compassion and mindfulness and serves as a reminder that India's progress is inseparable from its spiritual and cultural roots. Together, the lotus form and the image of Padmapani embody a deeper message of harmony between tradition and innovation, heritage and future.

Building Against Challenges

The pavilion was completed within just three months from designs to delivery, an achievement made possible through discipline and teamwork. The project faced the constraints of a Type X Pavilion design, the limitations of an existing container space, foundation and the complex task of designing petals that could not touch the main given structure . All the designs and material were required to be as per Japanese standards with approvals from multiple Japanese agencies. Other the challenge of country with different language and extremely low use of English as common language, extremely constrained supply chain, non availability of workers and different construction practices posed a big challenge on timely completion of the project.

The alternate approach adopted to prepare the major components in India faced the huge challenge of transportation so that materials can be delivered on time despite. More than 180 ton of material was air lifted from India with hopping flights to reach at site saw logistic nightmare and coordination between multiple agencies across multiple borders. It was a race against time to make India proud. Never before projects with such urgency and complexities were seen by the Indian and Japanese expo authorities. Each of these challenges was resolved through careful planning, creative engineering and constant coordination.

The pavilion was completed as a symbol of determination and resilience, delivered by Ecofirst Services Limited, a Tata Enterprise, with precision and passion.

Sustainability as DNA

From the beginning, sustainability was treated as the very foundation of the pavilion. Energy efficiency was achieved with Energy Star rated equipment, occupant sensors in back of house areas and carbon dioxide sensors to ensure healthy air circulation. A central monitoring system was installed to record and manage energy use. Water conservation was supported by the use of low flow fixtures. Materials were chosen with care, favouring recycled content and local sourcing. Finishes were kept low in volatile organic compounds to improve air quality. Even the cleaning practices were considered, with only certified housekeeping chemicals being used.

Waste management during construction was handled through separation at source and disposal by registered vendors. Japanese partners worked closely with the team to ensure that sustainability remained a shared goal, overcoming language and procedural challenges. Before opening, the pavilion was flushed out completely to ensure a fresh and safe environment for all visitors.

These efforts were validated when the Bharat Pavilion was awarded the IGBC Platinum Plaque for Sustainable Interiors, one of the highest recognitions of sustainable design. The award is especially significant given the temporary nature of the structure, proving that cultural expression and environmental responsibility can work together in perfect balance.

Bharat Pavilion proved to be a tremendous success in World Expo event with more than 37 lakh visitors visiting the Pavilion. It stood as third largest visiting Pavilion in Expo and had been appreciated by local press and public. The Bharat Pavilion was awarded bronze medal by the Expo authorities. It was first ever medal for India Pavilion in World Expo Event o 150 year history.


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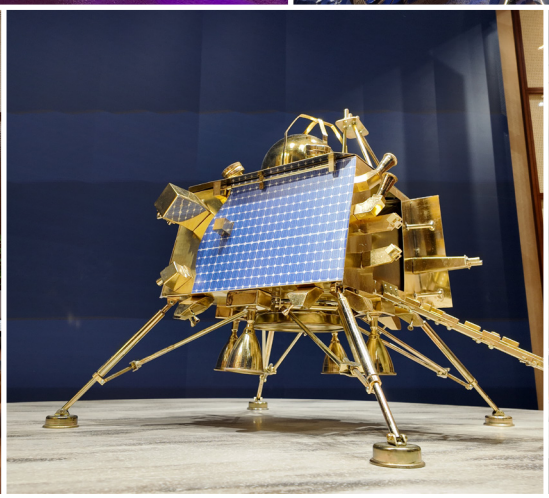


A Living Symbol

The Bharat Pavilion is more than an exhibition hall. It is a cultural and contemplative space. Its lotus silhouette makes it iconic and instantly memorable. Its design offers both activity and reflection, and its presence at the Expo is a symbol of resilience and sustainability.

The rapid completion within six months reflects India's determination, and its Platinum certification is proof that growth and responsibility can coexist. The symbolism of the lotus gives further depth to the story. For centuries the lotus has represented purity, renewal and grace under pressure.

It grows in muddy waters yet emerges untouched, embodying the ability to overcome adversity. The pavilion mirrors these qualities. Alongside it, Padmapani Bodhisattva radiates compassion, mindfulness and balance, inviting visitors to reflect on India's deeper message of harmony and inclusiveness.

India's Invitation

The Bharat Pavilion is India's invitation to the world. It is a space where heritage meets innovation, where tradition flows into modernity, and where sustainability becomes a way of life. It is not only a building but a story of resilience, progress and balance.

By blending culture, architecture and sustainability, the pavilion embodies the spirit of Engineering a Better Tomorrow, which is central to both the Tata Group and India's global role. To step into the Bharat Pavilion is to enter an experience that is timeless yet modern.

It is a lotus in bloom, rising above challenges, connecting lives and offering hope for a future that is inclusive, sustainable and harmonious. It is India's gift to the world, a creation that is meaningful, inspiring and unforgettable.

International Recognition

Bharat Pavilion proved to be a tremendous success in World Expo event with more than 37 lakh visitors visiting the Pavilion. It stood as third largest visiting Pavilion in Expo and had been appreciated by local press and public. The Bharat Pavilion was awarded bronze medal by the Expo authorities. It was first ever medal for India Pavilion in World Expo Event o 150 year history. It was a recognition for Ecofirst designs and execution at international stage where more than 150 countries participated. In addition Consulate General of India in OSAKA issued special appreciation letter for Ecofirst services to commend their efforts, technical excellence and project delivery capabilities in such challenging conditions. The project has brought significant recognition and credentials for Ecofirst, establishing them as a major market player in experience based business of Museums, exhibitions, heritage buildings etc.

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The Science of Total Installed Cost (TIC) Estimating at Tata Consulting Engineers

Every great engineering achievement begins with a clear understanding of what it will take to turn vision into reality. From conception to completion, Total Installed Cost (TIC) estimating forms the backbone of this journey. It connects the creativity of design with the discipline of execution, ensuring that complexity is managed with precision and that excellence is delivered with confidence.

At Tata Consulting Engineers (TCE), TIC estimating is not simply about predicting numbers. It is about enabling informed decisions, reducing uncertainty, and building trust between stakeholders. It represents the point where engineering intelligence meets financial clarity.

By combining technical expertise, structured methodology, and reliable market insight, TCE helps clients plan, budget, and execute projects that stand the test of time.

A Foundation of Experience

TCE's Estimating function brings together experienced professionals from multiple engineering disciplines, including electrical, instrumentation, mechanical, civil, and structural design. Collectively, they possess many decades of experience across industries such as energy, infrastructure, manufacturing, and chemicals. This depth of experience allows them to understand the relationship between design detail, construction effort, and overall project cost.

The estimating team prepares more than a hundred detailed estimates each year for projects ranging in size from small capital improvements to large-scale industrial facilities worth several billion dollars. Each estimate reflects real-world experience, technical discipline, and a culture of accuracy. Every number, quantity, and assumption is examined carefully to ensure that the result is practical, transparent, and aligned with the client's objectives.

Why TIC Estimating Matters

A Total Installed Cost estimate provides a complete view of the cost to design, build, and deliver a project. It helps project owners:

1. Establish and manage capital budgets effectively
2. Compare alternative designs and construction strategies
3. Secure funding approval from stakeholders or financiers
4. Assess return on investment and financial feasibility
5. Support planning, procurement, and scheduling decisions

For TCE, estimating is not a one-time activity but a continuous process that evolves with the project. As the design progresses, the estimate becomes more refined, reflecting greater accuracy and lower uncertainty. The ability to make informed choices at each stage of development is what transforms complexity into control and ambition into achievement.

Front-End Loading: Setting the Stage for Success

Front-End Loading, or early-stage engineering development, is widely regarded as the most decisive factor in determining project outcomes. It allows teams to define project scope, identify risks, and align design with cost expectations well before construction begins. Within this phase, accurate estimating is the single most valuable input for sound decision-making.

In the early stages of project planning, flexibility is high, and changes can be made at relatively low cost. As the project advances, the cost of change rises while the opportunity to influence total expenditure declines.

Recognising this relationship, TCE prepares precise and appropriately detailed estimates at every stage of project development. This ensures that design innovation is always matched by financial discipline.

An Integrated and Structured Approach

At TCE, the estimating process is integrated with engineering, procurement, and project management functions. Estimators work closely with design teams and planners to ensure that cost implications are understood from the earliest stages of conceptualisation. This cross-functional collaboration prevents gaps between technical intent and financial reality.

The estimating process itself is structured, methodical, and repeatable. It begins with the collection of reliable project data, including engineering specifications, material take-offs, and schedule inputs. Advanced software tools are then used to model costs, supported by continuously updated databases containing information on labour productivity, material pricing, and regional market conditions.

Every estimate undergoes detailed peer and management reviews before it is finalised. These reviews confirm that assumptions are well supported, data is current, and company procedures are followed rigorously. The result is an estimate that can be relied upon by both technical and financial stakeholders.

For Tata Consulting Engineers, Total Installed Cost estimating represents the meeting point of technical depth and professional discipline. It demonstrates how complexity can be mastered through method, collaboration, and integrity.

Six Essentials of an Accurate TIC Estimate

TCE follows a clear set of principles that define the quality and usefulness of a Total Installed Cost estimate.

Clarity of Objectives
A precise understanding of project goals is essential, whether the intent is capacity expansion, modernisation, compliance, or cost reduction.

Reliable Project Information
The accuracy of the estimate depends on the quality of the data available, including design maturity, schedules, and equipment lists.

Updated Market Inputs
Labour rates, material costs, and productivity factors are continually updated to reflect changing economic and market conditions.

Rigorous and Consistent Process Each estimate is developed through a well-defined process, ensuring uniformity across different projects and industries.

Clarity in Presentation The estimate must be easy to review and validate, allowing clients to understand how figures have been derived.

Collaborative Validation
Validation by the client ensures confidence and shared ownership of the estimate, turning it into a trusted tool for decision-making.

Tools and Techniques That Enhance Accuracy

Modern estimating at TCE combines advanced digital tools with professional experience. The use of integrated estimating software and cost databases allows the company to model complex engineering projects with consistency and speed. Market trends, such as commodity price fluctuations and labour availability, are regularly analysed and incorporated into every estimate. This data-driven approach provides clients with insight into potential cost risks and opportunities, enabling better planning and control. It also supports TCE's broader goal of using technology to enhance engineering excellence and predictability in project delivery.

Continuous Learning and Knowledge Sharing

The quality of TCE's estimating services is strengthened by its culture of continuous learning. Lessons from completed projects are reviewed and documented to improve future practices. Internal training sessions, knowledge-sharing forums, and collaborative reviews help estimators stay aligned with evolving tools and techniques. This structured knowledge management approach ensures that every new estimate benefits from accumulated experience, global exposure, and the latest market intelligence. The focus is always on improving accuracy, efficiency, and transparency.

From Complexity to Clarity

In an environment where engineering projects are becoming increasingly complex, the ability to forecast costs accurately is vital. TCE's estimating function plays a central role in bringing clarity to this complexity. By combining engineering insight with commercial understanding, the company helps clients balance ambition with practicality. A well-prepared estimate does more than predict expenditure. It provides direction, confidence, and accountability. It aligns engineering creativity with financial discipline and ensures that every decision contributes to overall project success.

Delivering Excellence through Precision

For Tata Consulting Engineers, Total Installed Cost estimating represents the meeting point of technical depth and professional discipline. It demonstrates how complexity can be mastered through method, collaboration, and integrity. Each estimate prepared by TCE embodies its guiding philosophy of quality results, sustainable solutions, and safe delivery. Through accurate estimation and informed decision-making, TCE continues to enable clients to invest wisely, plan effectively, and execute confidently. This ability to transform engineering complexity into measurable excellence is what truly defines Tata Consulting Engineers as a trusted partner in building a better tomorrow.

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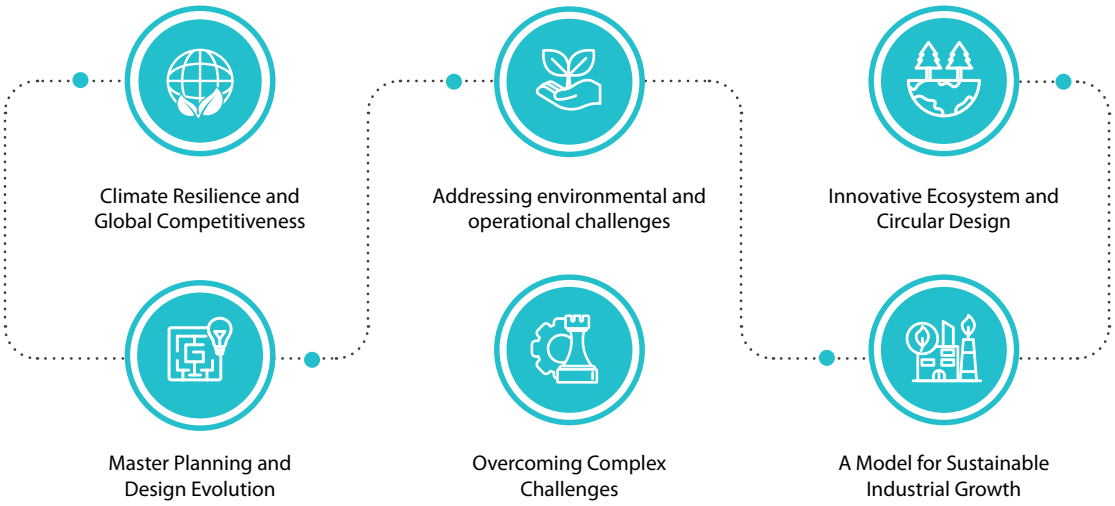
Tata OSAT Facility: Pioneering Sustainable Semiconductor Manufacturing in India

The Tata Outsourced Semiconductor Assembly and Test facility represents a defining chapter in India's effort to build a domestic semiconductor manufacturing ecosystem that is resilient, responsible, and globally competitive. Planned in Assam, a region known for its ecological richness and exposure to climate-related risks, the project demonstrates how advanced industrial infrastructure can be shaped through deliberate environmental planning and long-term thinking.

Conceived as India's first large-scale semiconductor assembly and testing campus, the OSAT facility brings together cleanrooms, research and development spaces, administrative functions, utilities, and employee wellness areas within a single, integrated master plan. This integrated approach reflects a shift away from fragmented industrial development towards a more holistic understanding of how technology, people, and natural systems interact within complex manufacturing environments. The project aligns closely with Tata Aalingana's sustainability vision, with a strong emphasis on decarbonisation, circular resource use, and ecosystem protection.

From the earliest planning stages, lifecycle assessments, net-zero energy pathways, water-neutrality objectives, biodiversity considerations, and Environmental, Social, and Governance readiness were embedded in the project framework. In a region already experiencing the effects of climate variability, the facility had to be planned not only for efficiency and performance but also for resilience, adaptability, and transparency.



Climate Resilience and Global Competitiveness

Semiconductor manufacturing requires high operational stability, precision, and resource reliability. At the same time, climate change is increasing the frequency and intensity of environmental stresses that can disrupt industrial operations. The OSAT facility addresses this dual challenge by integrating climate-resilience strategies with global performance benchmarks.

Green infrastructure and climate adaptation measures have been incorporated across the campus to address risks such as flooding, heat stress, and water scarcity. Alignment with international standards, including LEED Platinum certification targets, advanced automation protocols, and established ESG practices, ensures that the facility meets the expectations of global clients and partners while remaining responsive to local environmental conditions.

Digital enablement plays a central role in achieving this balance. AI-driven monitoring systems continuously track energy, water, and material flows, enabling real-time optimisation and rapid response to operational deviations. These systems improve efficiency while strengthening governance by providing reliable data for reporting and decision-making. In doing so, the facility serves as a reference for how India's OSAT sector can integrate sustainability and digital intelligence to support long-term competitiveness.

Located in Jagiroad near Guwahati, the project addresses the inherent environmental challenges of semiconductor manufacturing, including high energy and water demand, waste generation, thermal loads, and flood exposure. Climate-responsive master planning and flood-mitigation strategies have been integrated into the site design, while energy-efficient equipment reduces operational intensity.

Each plant building incorporates rooftop solar installations totalling 3.5 MWp, supported by battery storage, generating approximately 4.4 GWh of electricity annually. These measures achieve a 5% reduction in overall energy consumption and a 30% reduction in non-process energy compared to ASHRAE 2016 standards. A long-term roadmap aims for 100 per cent renewable energy use by 2045. Water efficiency is achieved through closed-loop systems, efficient fixtures, and reuse strategies that reduce freshwater demand by 59%. Circular and modular construction methods further support sustainability objectives by diverting 75% of construction waste from landfills. Achieving this balance between resilience and performance required a clear understanding of the environmental and operational challenges that modern OSAT facilities face, particularly in climate-sensitive locations.

Addressing environmental and operational challenges

Over the past decade, OSAT facilities worldwide have faced increasing environmental and operational pressures driven by climate change. Extreme weather events have disrupted infrastructure, strained utilities, and exposed vulnerabilities in supply chains. Recognising these realities, the OSAT project conducted a detailed climate risk assessment to inform planning and design. The assessment drew on data from the Indian Meteorological Department and state climate action plans. It was structured in line with the Task Force on Climate-related Financial Disclosures and ISO 14091 frameworks. This approach enabled the systematic identification of climate hazards, the evaluation of site and asset vulnerabilities, the prioritisation of risks, and the development of targeted resilience measures.

Rather than treating climate risk as a compliance exercise, the findings were actively used to inform design decisions across the campus. The architectural response reflects this integration of risk awareness and operational needs. The design moves away from closed, inward-looking industrial typologies, introducing openness, fluid circulation, and biophilic elements within a contemporary industrial form. Transparency and visual connectivity are carefully incorporated in non-cleanroom areas to support user well-being and productivity, while maintaining the strict environmental controls required for semiconductor manufacturing.

On-site solar generation supported by battery storage provides a reliable source of clean energy, reducing exposure to grid disruptions. Comprehensive wastewater treatment and reuse systems reduce dependence on external water sources and support water security. A zero non-process waste approach minimises reliance on landfill through segregation, recovery, and responsible disposal. Landscaped green buffers, shaded pedestrian routes, and high-performance building envelopes reduce heat gain and improve thermal comfort across the site. Passive design strategies operate in coordination with advanced mechanical systems to optimise energy performance and maintain stable indoor conditions. These combined pressures made it clear that the project could not rely on isolated sustainability measures. What was required was an integrated ecosystem approach that addressed environmental performance, operational reliability, and human experience in a single framework.

Innovative Ecosystem and Circular Design

The OSAT development has therefore been planned not as a standalone industrial plant, but as India's first fully integrated semiconductor ecosystem. Cleanrooms, research and development facilities, administrative areas, utilities, and wellness spaces are designed to function as a cohesive whole, enabling operational efficiency, workforce well-being, and sustainability objectives to reinforce one another.

This integrated approach marks a national milestone through the Tata Semiconductor Assembly and Test facility in Assam. The long-term ambitions extend beyond compliance to include net-zero operational energy, water positivity, and near-net-zero waste generation. These goals are supported by a master plan that coordinates infrastructure, landscape, and building systems across the campus. The project is located on a 175-acre brownfield site formerly occupied by the Nagaon Paper Mill. Redeveloping this site demonstrates a strong commitment to responsible land reuse, avoiding pressure on undeveloped areas while enabling environmental regeneration. The master plan balances the spatial demands of large-scale manufacturing with landscape integration, ecological sensitivity, and efficient utility planning.

Circular design principles underpin both construction and operations. The facility has been designed for net-zero energy readiness, supported by a 7 MWp solar capacity that offsets approximately 20 per cent of energy consumption, with a defined pathway to full net-zero operations by 2030. Modular cleanroom designs that meet ISO Class 6 and 7 standards reduced construction time by nearly 30 per cent while improving quality control, material efficiency, and adaptability.

Innovative HVAC systems, combined with passive design strategies, deliver energy savings of up to 25 per cent, reducing long-term operational demand. Water circularity is a central feature, with rainwater harvesting and reuse systems conserving over 50 million litres annually. Biodiversity restoration measures and landscape strategies contribute to ecological balance, while the project is expected to create more than 8,000 direct jobs and support over 25,000 employment opportunities through ongoing operations. Together, these initiatives result in an estimated annual reduction of 6,500 tonnes of carbon dioxide equivalent emissions. Translating this integrated vision into a buildable campus required several stages of design exploration and refinement.

Master Planning and Design Evolution

The master planning and design of the OSAT facility progressed through multiple iterations as the project team evaluated functional, environmental, regulatory, and contextual requirements. Early explorations considered conventional green building approaches and the use of locally familiar Assamese materials such as green facades, brick, and bamboo. These strategies offered cultural relevance and an immediate sustainability narrative.

However, a detailed assessment highlighted limitations in long-term resilience, fire safety compliance, maintenance requirements, and the strict environmental controls required for cleanroom operations. High humidity, operational precision, and safety criteria necessitated materials and systems that could perform consistently over time without compromising cleanroom integrity.

These considerations led to a transition towards contemporary sustainable materials and industrial design principles better suited to semiconductor manufacturing. The refined approach enables precise management of energy use, water systems, indoor environmental quality, and operational risk, while supporting durability and ease of maintenance across the facility's lifecycle. It also enables efficient spatial planning and the integration of complex utility networks across both plant and non-plant structures.

Importantly, this shift did not result in a purely utilitarian environment. Landscape connections were intentionally woven into workspaces and circulation areas, ensuring access to daylight, visual relief, and natural elements. This balance between technical rigour and human-centred design enhances occupant well-being while maintaining the high-performance standards required for advanced manufacturing. As the design evolved, the realities of scale, speed, and site conditions brought a new layer of complexity to the project.

Overcoming Complex Challenges

The OSAT project faced a unique set of challenges stemming from its scale, accelerated delivery timeline, remote location, and the absence of direct precedents in the Indian semiconductor context. Coordinating large plant footprints, complex utility systems, and stringent performance requirements within these constraints demanded a highly integrated planning approach. Topographical conditions played a critical role in shaping the master plan. A protected hill of approximately 70,000 square metres within the site, limited available developable land, and required careful integration into fire safety planning and access routes.

Rather than altering this natural feature, the hill was retained as a dedicated biodiversity zone. This decision mitigates habitat loss and potential human-wildlife interactions by supporting ecological corridors and environmentally sensitive infrastructure.

Climate-related risks were addressed through a combination of strategic and technical measures. Flood vulnerability is managed through elevated site grading and robust stormwater systems designed to handle extreme rainfall events. Water scarcity risks are reduced through rainwater harvesting, advanced wastewater treatment, and recycling systems that support long-term operational resilience. Passive cooling strategies, shaded circulation, and green buffers improve thermal comfort, while onsite solar generation and planned offsite green energy procurement support net zero readiness. Together, these responses demonstrate how industrial complexity can be addressed through structured planning, informed design choices, and early risk integration.

A Model for Sustainable Industrial Growth

The OSAT facility illustrates how sustainability, climate resilience, and innovative engineering can be integrated to support industrial development without compromising ecological sensitivity. Environmental considerations were embedded throughout the planning, design, and execution phases, ensuring low-carbon outcomes and operational performance. Nature-based solutions, systematic carbon accounting, and the use of Environmental Product Declarations informed material selection and construction practices, supporting measurable reductions in embodied carbon.

The Tata OSAT facility demonstrates how semiconductor manufacturing can be planned as a resilient, resource-conscious, and people-focused ecosystem. Through climate-aware planning, circular design, and digital intelligence, the project offers a clear framework for future-ready industrial development in India.

Site planning strategies, including elevation- and landscape-based interventions, reduce vulnerability to flash flooding while strengthening long-term resilience. Project delivery relied on technology-enabled collaboration and coordination among multiple stakeholders, supporting efficient execution in a complex environment.

Operational performance is supported by a data-centric management framework, with AI-enabled dashboards that monitor energy, water, and material flows in real time. These systems support water positivity, circular resource use, and progress toward net-zero goals. This combination of environmental rigour, digital intelligence, and coordinated delivery establishes the OSAT facility as a replicable reference for sustainable industrial growth.

Future Benefits and Replicability

The strategies adopted at the OSAT facility have strong potential to be applied across India's emerging industrial landscape. By integrating lifecycle planning, net-zero energy pathways, water-positive targets, and circular design principles from the outset, the project demonstrates how efficiency and resilience can be embedded rather than retrofitted. Several initiatives, including energy audits, renewable energy pilots, and water efficiency measures, are already in place, providing a foundation for further scaling and adaptation.

There remains significant scope to extend these strategies across Tata's wider network, strengthening consistency in sustainability performance and supporting long-term environmental objectives. Over the next two years, the facility is expected to reduce operating costs through improved energy and water efficiency, strengthen asset resilience against climate risks, enhance ESG performance and stakeholder confidence, and align with international ESG standards to unlock green financing and policy incentives.

Taken together, the Tata OSAT facility demonstrates how semiconductor manufacturing can be planned as a resilient, resource-conscious, and people-focused ecosystem. Through climate-aware planning, circular design, and digital intelligence, the project offers a clear framework for future-ready industrial development in India. Ecofirst, as architects and sustainability designers, supported the translation of this vision into a campus that balances technological ambition with environmental responsibility and regional development.

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Reclaiming the River, Reimagining the City - The Tunga River Front Development Project

Cities and rivers have long shared a deep, complex relationship. Rivers give birth to settlements, shape culture, support livelihoods, and quietly witness centuries of change. Over time, however, rapid urban growth often turns this relationship distant or even fragile. The Tunga River Front Development Project aims to restore that bond in a way that respects history, safeguards the future, and places people back at the heart of the river landscape.

Located in **Shivamogga,** the project draws its strength from a powerful natural and cultural context. The city itself is a classic example of how Indian towns evolved along riverbanks. The old city of Shivamogga grew along a 2.60-kilometre stretch of the left bank of the Tunga River, forming a narrow yet vibrant urban strip barely half a kilometre wide. Within this compact stretch lies the story of the city's origin, growth, and identity. This river edge is not just a physical boundary. It is a living archive of Shivamogga's heritage.

Landmarks such as the Shivappa Nayaka Palace and its fort, the Ganapathi Temple near Ramanna Shresti Park, the Kote Marikamba Temple, and the famous Mandakki Bhatti cluster are located near the river and are woven into everyday life. For generations, the river has been a backdrop to worship, trade, festivals, and informal social interaction. Yet, like many historic river cities, Shivamogga also faced the challenge of protecting its heritage from the river's seasonal fury.

From Flood Protection to Urban Opportunity

From 2009 to 2010, a high flood-protection retaining wall was constructed along the left (north) bank of the Tunga River. This intervention was essential to protect the old city and its monuments from monsoon flooding. While the wall reduced flood risk, it also had an unintended consequence. Between the new flood protection wall and the historic city edge lay a narrow strip of underused land, including a moat along the fort wall. Spread over nearly 6.5 hectares, this space remained disconnected mainly from daily urban life.

Rather than viewing this land as residual or leftover space, the riverfront development project reframes it as an opportunity. The flood protection wall itself sits between two major entry roads into Shivamogga. By transforming it into a green, active urban edge, the wall is no longer a barrier but a gateway. Symbolically and visually, it announces entry into a city that stands at the threshold of the Western Ghats, rooted in heritage and open to sustainable growth.

The project, therefore, moves beyond mere beautification. It is an example of how engineering, urban design, and landscape planning can work together to unlock value from infrastructure originally built for protection alone.

A Vision Anchored in Public Life

At the heart of the Tunga River Front Development Project is a clear, people-centric vision. The aim is to create a thriving public space along the river that enhances the city's image while becoming an essential part of everyday life for residents. Across the world, successful cities have rediscovered their rivers as active public realms. River edges that once served only industrial or defensive purposes are being transformed into promenades, parks, cultural venues, and social spaces.

What makes such places successful is their ability to adapt. They are not designed for a single activity or group. Instead, they evolve with changing social needs. In Shivamogga, revitalising the river edge is expected to improve the quality of life and catalyse broader urban development. The riverfront is envisioned not as a destination visited occasionally, but as a daily extension of the city itself.

This vision recognises that public spaces are not luxuries. They are essential urban infrastructure. They support physical health through walking and cycling, mental wellbeing through access to nature, social cohesion through shared experiences, and economic vitality through increased footfall and local activity.

Rejuvenating an Idle Strip into a Living Corridor

One of the project's most significant achievements is transforming an idle strip of land into a public, utilitarian space. The once neglected zone between the city and the flood wall is reimagined as a continuous green and blue corridor. This corridor physically and visually reconnects the city with the river, allowing people to experience water, landscape, and heritage together.

The design introduces multiple levels of promenade that respond to the river's changing character across seasons. Upper promenades remain accessible during higher water levels, while lower promenades bring people closer to the river during calmer periods. This layered approach ensures safety without sacrificing intimacy with the water.

Walking tracks and cycling paths encourage slow movement and active lifestyles. Plazas and open spaces punctuate the promenade, offering places to pause, meet, and observe the river. Carefully designed immersion ghats support traditional rituals while ensuring safety and cleanliness. Landscaped zones soften the hard edges of infrastructure and create shaded retreats within the urban fabric.

Parks, Landscapes, and Sensory Experiences

The development of park spaces along the riverfront plays a central role in shaping user experience. A thoughtful mix of hard and soft landscaping ensures durability while maintaining a strong connection to nature. Paved areas support gatherings and events, while green lawns, planted buffers, and tree lined walks offer calm and comfort.

Sensory gardens introduced along intermediate promenades add another layer of engagement. These gardens use plant textures, fragrances, colours, and sounds to create immersive experiences for visitors of all ages. For children, they become spaces of exploration. For elders, they offer restorative environments. For everyone, they provide moments of pause in an increasingly fast-paced urban life. By integrating landscaping with the city's climate and ecology, the project also contributes to urban resilience. Vegetation helps moderate temperature, manage surface runoff, and enhance biodiversity along the river edge.

Connecting Both Banks Through the Blue Corridor

While the north bank forms the primary focus of the development, the project also recognises the importance of linking both sides of the river.




A ferry service from the lower promenade on the north bank to the south bank is proposed to create a blue corridor linking points of interest across the river. This water-based connection adds a new dimension to urban mobility. It is functional, experiential, and symbolic. Functionally, it improves access between river banks. Experientially, it allows people to view the city and its landscape from the water. Symbolically, it reinforces the river's role as a connector rather than a divider. Such interventions encourage people to rediscover the river not just as scenery, but as an active participant in urban life.

Placemaking and Vibrant Public Realms

Activation of public space is central to the project's placemaking strategy. A riverfront succeeds when it feels alive at different times of day and across seasons. To achieve this, the development includes a variety of formal and informal gathering spaces. Public plazas provide venues for festivals, markets, and civic events. Viewing points are strategically placed to frame views of the river, heritage structures, and city skyline.

An open-air theatre introduces cultural programming into the riverfront, supporting performances, community events, and educational activities. Eateries and small commercial nodes are carefully integrated to enhance vibrancy without overwhelming the space's public character. These elements encourage longer stays and repeat visits, making the riverfront a shared living room for the city.

Enhancing Heritage Through Urban Design

One of the most sensitive aspects of the project is its relationship with Shivamogga's heritage assets. Rather than competing with historic structures, the riverfront design uses urban design enhancements as a backdrop to elevate the heritage experience.

The Shivappa Nayaka Palace and its surroundings benefit from improved access, views, and public spaces. Lighting, landscaping, and controlled sightlines ensure that heritage structures remain visually dominant while becoming more approachable.

The riverfront thus acts as a cultural promenade where history is not confined to museums but experienced in everyday movement. This approach reinforces the idea that heritage conservation and contemporary development are not opposites. When designed thoughtfully, they can strengthen each other.

Smart Infrastructure for a Safe and Inclusive Space

Modern public spaces must also meet contemporary expectations for safety, connectivity, and efficiency. The Tunga River Front Development Project integrates information and communication technology to support these needs. A comprehensive surveillance system along the promenade enhances safety without being intrusive. Public Wi-Fi zones are planned at regular intervals to support both leisure use and digital inclusion. Smart lighting connected to a central command-and-control system improves energy efficiency while enhancing nighttime ambience and safety.

These interventions ensure that the riverfront is not only beautiful but also functional, inclusive, and future-ready.

From Planning to Reality

All planning and engineering work for the project has been completed, and contracts have been awarded. The development is now in an advanced stage of construction. This transition from vision to reality reflects strong coordination between planning, engineering, and execution.




The project also acts as a stimulus for development in surrounding areas. Improved public spaces often attract investment, revitalise neighbourhoods, and encourage better maintenance of adjoining properties. Over time, this can lead to more balanced and inclusive urban growth.

The project demonstrates how long-term thinking, when backed by detailed engineering and stakeholder alignment, can deliver complex urban transformations. It is not a standalone beautification exercise but a carefully sequenced intervention grounded in flood protection, urban design, landscape architecture, and smart infrastructure.

Benefits That Extend Beyond the River Edge

The benefits of the Tunga River Front Development Project extend well beyond its physical boundaries. At a fundamental level, it strengthens flood protection, makes protective infrastructure part of everyday urban life, and enhances the city's image, positioning Shivamogga as a progressive, liveable city that values its natural and cultural assets. Quality of life improvements are tangible.

Citizens gain access to open spaces for recreation, relaxation, and social interaction. Health outcomes improve through increased opportunities for walking and cycling. Cultural life is enriched through new venues for expression and gathering. The project also acts as a stimulus for development in surrounding areas. Improved public spaces often attract investment, revitalise neighbourhoods, and encourage better maintenance of adjoining properties. Over time, this can lead to more balanced and inclusive urban growth.

A Model for River Centric Urban Renewal

As cities across India and beyond grapple with challenges of climate resilience, heritage conservation, and quality of life, the Tunga River Front Development Project offers valuable lessons. It shows how flood protection infrastructure can be reimagined as civic space. It demonstrates the power of integrating green and blue corridors into dense urban settings. It highlights the importance of placing people, culture, and ecology at the centre of urban design. Most importantly, it reminds us that rivers are not obstacles to be managed or edges to be fenced off. They are living systems that shape identity and community. By reclaiming the river edge as a shared public realm, Shivamogga is not just developing a riverfront. It is renewing its relationship with the Tunga River and, in doing so, reimagining the city's future.

Author

C R Indumathi
Senior General Manager - Architecture
Tata Consulting Engineers

Client Testimonials

I am writing to extend my heartfelt appreciation for the outstanding work your team has accomplished in the Electrorefinery Tank House of the 900 KTPA Captive Copper Smelter Project. Your team's dedication, expertise, and meticulous attention to detail have been instrumental in the successful commissioning of this critical project. The high standards of professionalism and technical proficiency demonstrated by your team have not only met but exceeded our expectations.

The challenges faced during this project were significant, yet your team navigated them with remarkable skill and resilience. The seamless integration and operational efficiency achieved in the Electrorefinery Tank House are a testament to your team's hard work and commitment to excellence.

Please convey my sincere gratitude to each member of your team for their exceptional contributions. Their collective efforts have played a pivotal role in the success of this project, and we are deeply appreciative of their dedication and hard work. We look forward to the opportunity to collaborate with your team on future projects and are confident that your continued excellence will lead to many more successful endeavours.

Thank you once again for your outstanding work.

The Trombay Team was faced with the mammoth task of restoring Unit 5, and we deeply appreciate and value each contribution in achieving this milestone. Your collective efforts enabled the restoration of Unit 5 in a record time of 137 days, which is truly commendable.

Special recognition goes to the team for effectively managing site activities and coordinating seamlessly with the design team to incorporate field inputs. This collaboration was instrumental in the success of the project.

Thank you all for your dedication and hard work.

We are proud to have contributed to a prestigious project of national importance. Our team showed strong dedication, professionalism, and a spirit of collaboration throughout the work. We managed complex technical tasks, adapted to changing requirements, and maintained clear communication with all stakeholders. The quality of our engineering input, timely responses, and structured approach helped the project progress smoothly. Our team's experience and ability to work across disciplines ensured that challenges were addressed quickly and practical solutions were delivered.

This recognition reflects our commitment to excellence and integrity. We look forward to continuing to deliver the same high standards on future projects.

TCE Awards

Vigyaan: Recognised for Driving STEM

Recognised as a WOW Workplace 2025

The prestigious CIDIC Vishwakarma Award 2025

Recognised as Masters of Risk-Private Company (Mid-Cap)

Won the 3rd edition of the World of Concrete Award

The prestigious Autodesk Imagine Award 2025

ENR Top 225 Design Firms 2025 – #94

Significant Impact through Competency Development Interventions

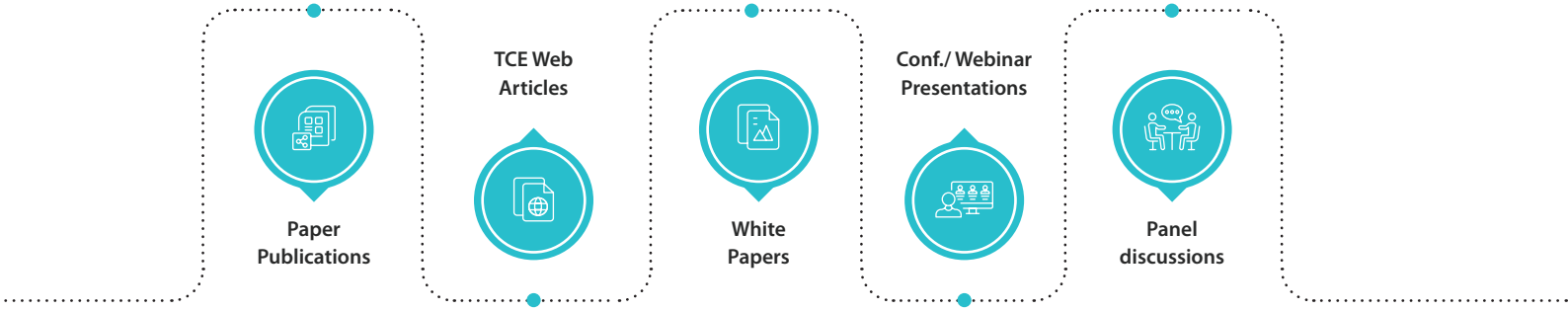
Recognised in ET Edge Sustainability 2025

Technology Team Update

The Technology team at Tata Consulting Engineers plays a critical role in shaping how engineering knowledge is created, applied and shared across the organisation and the wider industry. More than a centre of technical expertise, the team acts as a learning engine that connects emerging technologies, project experience and future-facing thinking. Through structured research, technical publications and active participation at national and international platforms, the team ensures that learning flows continuously from projects to people and from global practice back into delivery.

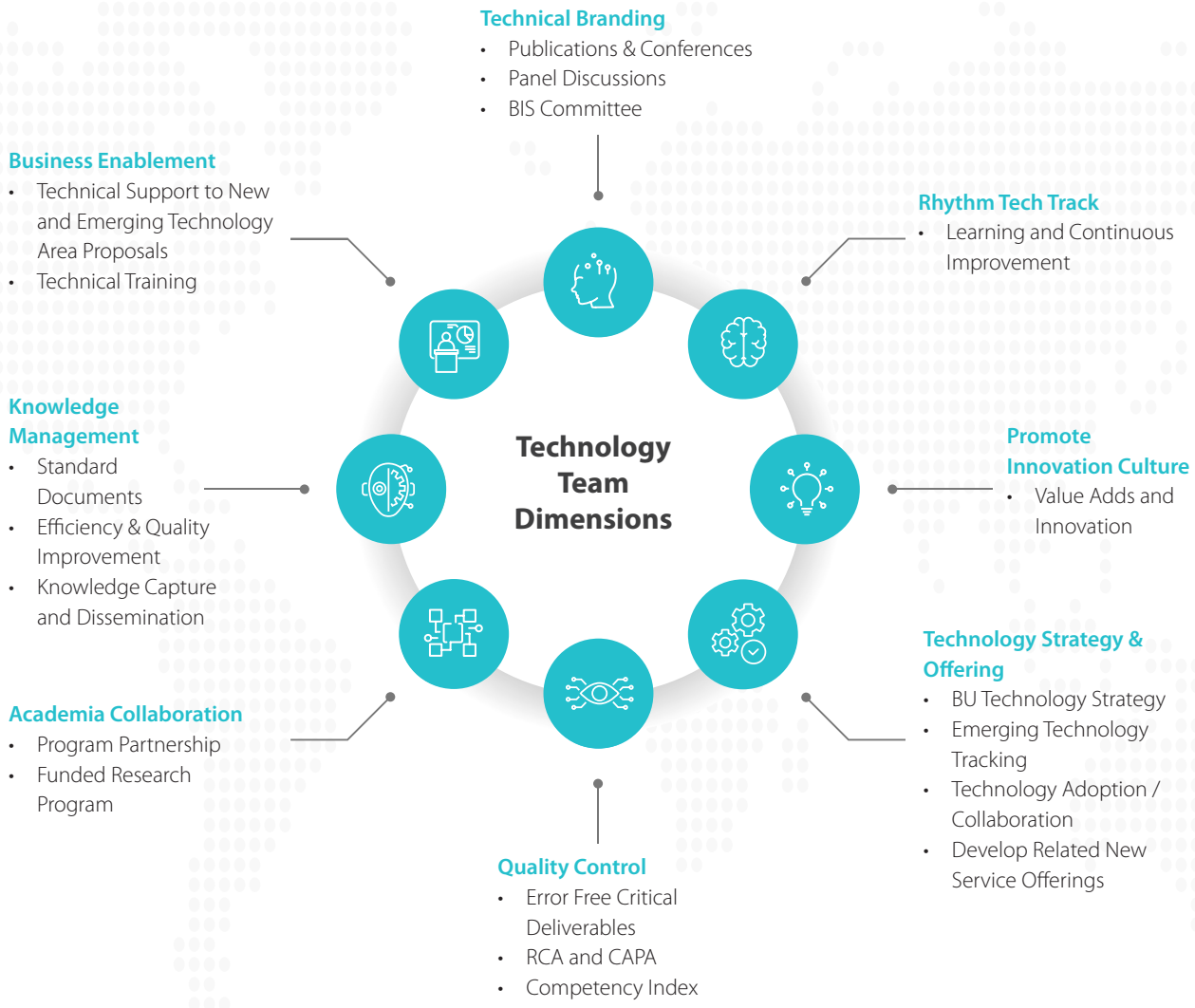
Advocacy

The Technology Group and Subject Matter Experts (SMEs) play a pivotal role in enhancing the organisation's visibility through impactful branding initiatives across national and international platforms. By showcasing innovative designs and achievements on TCE's portal and other industry forums, we solidify our position as leaders in digital engineering for a sustainable future. TCE's branding activities during FY25 reflect our alignment with the overarching theme of AI, circularity, and sustainability.



Technology Team Dimensions

The Technology group and Subject Matter Experts contribute actively to Tata Consulting Engineers' brand by translating complex engineering challenges into structured, accessible insights. This is achieved through white papers, technical articles, conference presentations and expert panels across sectors such as power, infrastructure, industrial automation, sustainability and digital engineering. Each contribution is grounded in practice. Rather than focusing only on emerging trends, the team shares lessons from implementation, design decisions, risk management and performance outcomes. During FY26, this approach strengthened TCE's positioning as a knowledge-led organisation that combines technical depth with delivery certainty.



Knowledge Management at TCE

As the technology team at Tata Consulting Engineers, we focus on strengthening engineering excellence through structured knowledge management. We draw on our project experience to maintain and evolve platforms such as Ask Expert, Problems Worth Solving, Lessons Learnt, Value Addition and Innovation, Tech DMS, Wrench, and specialised design suites. These tools help capture technical insights, standardise best practices, and support fast, high-quality engineering delivery.

We also lead the development and enhancement of TechHub, our unified space for engineering knowledge, innovation, and collaboration. By ensuring strong technical content, seamless integration of tools, and easy access to engineering know-how, we help teams solve problems faster, reuse proven solutions, and drive continuous improvement across projects. Our contribution ensures that engineering knowledge becomes institutional rather than individual, strengthening TCE's capability to deliver complex projects with confidence.

WHITE PAPER FY26

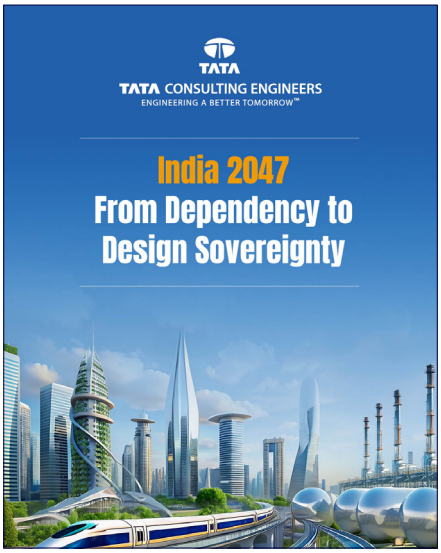
Net Zero and Carbon Capture Technologies

Authored by Amit Sharma and Atul Choudhari

The white paper presents a realistic view of the net zero challenge. While renewable energy, electrification and efficiency are expanding rapidly, heavy industries such as cement, steel, chemicals and hydrogen production continue to emit large volumes of carbon dioxide.

Their high temperature and process driven operations make rapid decarbonisation difficult in the near term. Carbon capture is therefore positioned as an immediately deployable solution rather than a future option. The paper explains carbon capture as a set of technologies that separate CO_2 from industrial exhausts or directly from the air for safe storage or reuse. It outlines key pathways including post combustion capture using solvents, pre combustion capture suited to hydrogen and syngas processes, and oxy fuel combustion that produces CO_2 rich exhaust streams. Emerging options such as chemical and calcium looping, membranes, adsorption, cryogenic separation and Direct Air Capture are also discussed, with a balanced view of their maturity. Sector specific insights guide technology selection.

Cement applications favour calcium looping and solvent systems, steel benefits from higher CO_2 concentrations that improve capture efficiency, and hydrogen production enables high purity capture before combustion. The paper concludes that carbon capture is not a standalone answer but a critical element of any credible net zero pathway for heavy industry, shaped by innovation, cost reduction and integration with renewable energy and digital optimisation.



India 2047: From Dependency to Design Sovereignty

Authored by Amit Sharma and Atul Choudhari

This paper explores India's long journey from post Independence dependence to the aspiration of becoming a design led, innovation driven nation by 2047.It argues that modern sovereignty is no longer defined only by borders and defence, but by control over ideas, technology, data, standards, and institutional capability.

While India has produced global leaders and world class professionals, the paper highlights a persistent structural paradox where domestic engineering and design institutions continue to rely on foreign advisors in many critical sectors. The paper traces the roots of this dependency through nation building, liberalisation, and the rise of global consulting models, and examines how it manifests across infrastructure, aviation, taxation, digital governance, education, and industrial policy.

It introduces the concept of design sovereignty as the ability to conceive, own, and govern solutions across the full lifecycle rather than merely execute imported designs. A central theme is the need to shift from a narrow CAPEX driven mindset to a lifecycle based OPEX oriented approach that values long term outcomes, resilience, and institutional learning.

The paper outlines policy, institutional, and industry level reforms required to build domestic design champions, leverage CSR and public funding for innovation, integrate AI into engineering, and align academia with national missions. It concludes with a roadmap for achieving a confident, self directed, and globally competitive India by 2047.

TECHNICAL ARTICLES AND PUBLICATIONS FY26

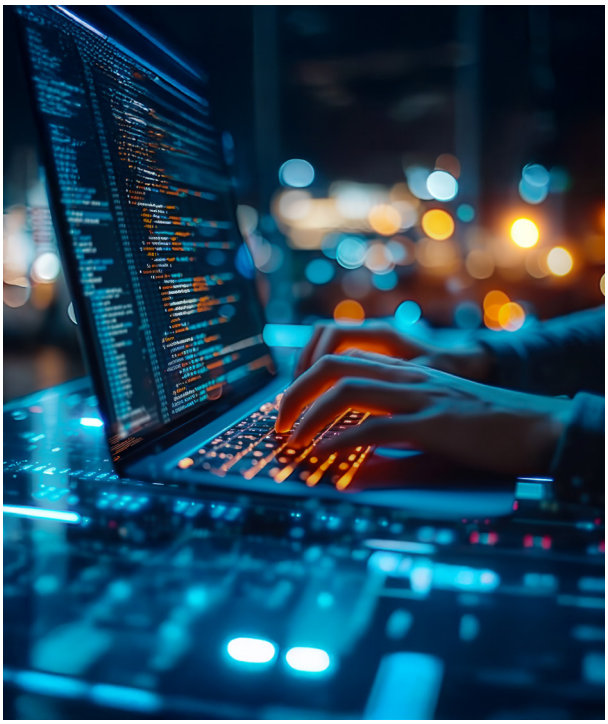
Deepening Engineering Understanding Through Practice

The Technology team's articles published during FY26 are designed to educate as much as they inform. Each piece explains not only what a technology does, but why it matters, how it is applied, and what engineers must consider during implementation.

Automation in the Power Sector

Authored by Sandhya Mukherjee

This article provides a comprehensive view of how automation is transforming the power sector across generation, transmission and distribution. It begins by explaining the fundamental purpose of automation: improving reliability, enhancing safety, and enabling faster, data-driven decision-making. The reader is guided through the core building blocks of automation, including data acquisition via sensors, real-time monitoring, and automated control. These fundamentals extend to advanced applications such as SCADA systems, AI-driven fault prediction, robotics and drones for asset inspection, and Dynamic Line Rating systems that increase transmission capacity based on real-time conditions. The importance of communication networks such as fibre optics, power line communication, LTE and emerging 5G systems is clearly explained. These networks form the digital backbone of smart grids and enable secure, responsive control. The article also addresses practical challenges, including high capital investment, cybersecurity risks and infrastructure constraints in remote regions. By referencing national smart grid initiatives and TCE's experience implementing a 400 kV Dynamic Line Rating project, the article connects engineering theory with real-world implementation.



Front End Engineering Design Projects in Today's Perspective

Authored by Sunil Laxman Choudhari and Shireesh S Swamy

This article explains why Front End Engineering Design is a critical stage in large capital projects. It clarifies how decisions made during FEED shape cost, schedule, and operational performance well before construction begins. The authors discuss common challenges such as incomplete data, evolving scope, coordination gaps and cost estimation uncertainty. These issues are shown to be leading causes of cost overruns and delays.

To address them, the article outlines a disciplined FEED approach that emphasises clear project definition, early risk identification, structured cost planning and early vendor engagement. Digital tools such as BIM, AI-driven analytics, and digital twins are described as enablers of design maturity and informed decision-making. The reader gains a clear understanding that strong FEED is about clarity and alignment, not documentation volume.

Pile Termination Criteria for Establishing Good Quality Piles

Authored by Manos Kumar De, Kailasa Rahul, B V Sushma and Shashank Shekhar Chaubey

This technical paper explains the importance of pile termination in ensuring safe and durable foundations for heavy structures. Pile termination is described as the point at which a pile achieves the required load transfer through soil or rock interaction. The risks of improper termination, including soft toe conditions, reduced load capacity, and excessive settlement, are explained in practical terms.

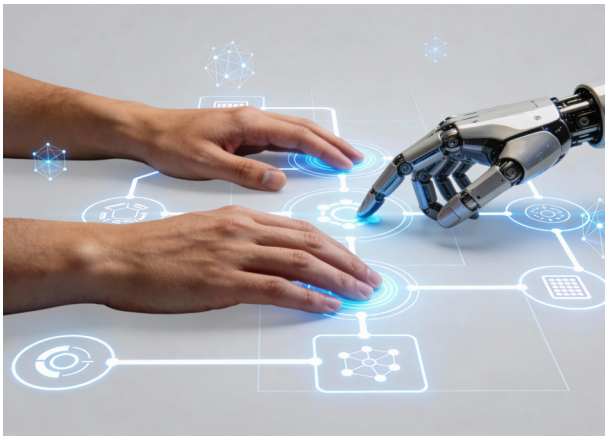
Three termination methods are discussed in detail: the Pile Penetration Ratio, the Chisel Energy Method, and the Reverse SPT Method. Through comparative analysis and case studies, the authors demonstrate that the Pile Penetration Ratio method provides a reliable, real-time assessment when supported by appropriate instrumentation and monitoring. The article reinforces the need for intense geotechnical investigation, skilled execution and quality control.

The Fifth Industrial Revolution

Authored by Sandhya Mukherjee

This article introduces Industry 5.0 as an evolution beyond efficiency-driven automation. While Industry 4.0 focused on digitisation and productivity, Industry 5.0 is presented as a shift towards human-centric, sustainable and resilient industrial systems.

The article explains how advanced technologies such as AI, robotics and IoT can augment human expertise rather than replace it. Ethical considerations, workforce well-being, and environmental responsibility are core elements of industrial competitiveness. Circular economy principles and continuous upskilling are highlighted as essential to this transition.



Artificial Intelligence in Industrial Automation

Authored by D S Latha

This article demystifies Artificial Intelligence by explaining its role in modern industrial automation. It traces the transition from rule-based systems to intelligent, adaptive operations that learn and optimise in real time. Applications such as predictive maintenance, smart manufacturing, digital twins and supply chain optimisation are explained in practical terms. The article also discusses challenges related to data integration, legacy systems and workforce readiness, providing a balanced and realistic view of AI adoption in industry.

Sustainable Power Generation

Authored by Haripriya Sahoo

This article explains the growing importance of integrating conventional power systems with renewable energy sources. It introduces hybrid generation models to balance reliability and sustainability.

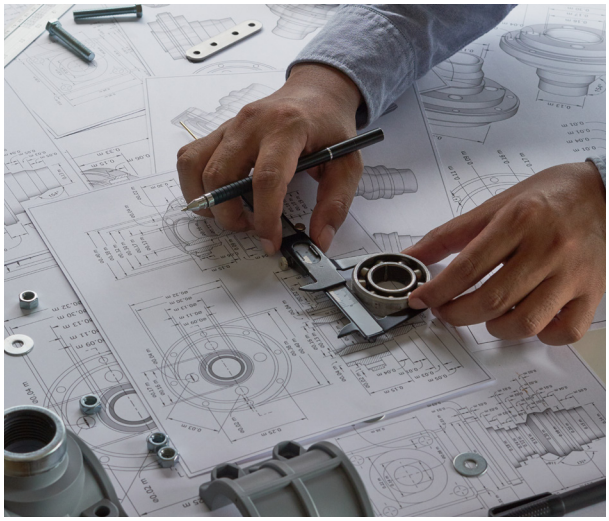
Modernisation strategies, such as improved power quality, efficient system design, and smart grid integration, are essential to meeting rising energy demand while reducing environmental impact.

Integrated Engineering of Projects

Authored by Atul Choudhari

This article addresses the limitations of traditional silo based engineering in complex projects. It explains how fragmented workflows lead to delays, rework and safety risks. Integrated engineering is a collaborative approach in which disciplines work concurrently on shared digital platforms.

Technologies such as 3D modelling, cloud collaboration and everyday data environments are explained alongside governance tools such as RACI matrices and early vendor engagement. The reader gains insight into how integration improves delivery certainty and lifecycle performance.



Design and Engineering Aspects of Cross Country Pipelines

Authored by Shivnarayan Pareek, Lakshmana Rao V and Charan S

This article offers a holistic view of pipeline engineering as a multidisciplinary challenge. Route selection, hydraulic design, material selection, stress analysis, and corrosion protection are presented as interconnected decisions.

Operational practices such as pigging and sectionalising valves are discussed in the context of safety and maintainability. The use of advanced simulation tools and strict adherence to standards are essential for minimising environmental impact and ensuring long-term reliability.

EXTERNAL REPRESENTATION FY25

MR. ATUL CHOUDHARI

Mr. Atul Choudhari, ***Chief Technology Officer*** at Tata Consulting Engineers (TCE), addressed the **"G H_2 India Exhibition & Conference"** on the pivotal role of hydrogen in advancing global decarbonisation.

In his presentation, he explored the complexities of hydrogen storage and transportation, covering high-pressure composite vessels, cryogenic systems and emerging Liquid Organic Hydrogen Carriers (LOHCs). He emphasised how automation technologies, such as cryogenic boil-off control, pipeline leak detection, smart diagnostics for embrittlement, and advanced pressure management, are critical to ensuring safety and resilience.

Mr. Choudhari also highlighted the role of digital innovation, from electrolyser control systems and digital twins for lifecycle monitoring to AI-powered predictive maintenance. Drawing on global case studies and research, he underscored the need to integrate automation and intelligence into hydrogen logistics and infrastructure as the hydrogen economy scales.

DR. SNEHA R IYER

Dr. Sneha R Iyer, ***Senior Manager*** – Technology at Tata Consulting Engineers (TCE), shared her insights on **"Storage and Transportation of Hydrogen and the Use of Automation Technologies"** at the Conference on Sustainable Process Evolution: Automation for a Greener Future, Automation Expo 2025.

Her talk explored how hydrogen can be safely stored and transported at scale, and how automation technologies are enabling innovation across thermal management, leak detection, digital twins, and predictive safety systems.

She also highlighted advancements in solid hydrogen storage, sensor fusion, and AI-driven risk assessment, positioning hydrogen as a vital element in building a sustainable and resilient energy future.

MS. LATHA D. S.

Latha D S, ***Senior General Manager*** – Discipline Head (PBU) at Tata Consulting Engineers (TCE), spoke on **"Industrial AI and TCE's AI Applications"** at the ARC Advisory Group India Forum held in Bengaluru.

She also shared insights into TCE's ongoing AI-led innovations, including:

- AI tools for defect detection in concrete, steel and healthcare
- Automation of P&ID development
- Generative AI for productivity enhancement
- Predictive maintenance for rotary equipment
- Energy optimisation in industrial furnaces
- Intelligent single line diagram generation
- Digital point solutions

MR. DEVDATTA BOSE

Mr Devdatta Bose, *Senior General Manager* at Tata Consulting Engineers (TCE), participated in a session on **"Upcoming Developmental Projects and Challenges organised by India Infrastructure".**

During his session, he shared insights on mega ports and the challenges ahead, including the development of India's first offshore mega port and the lack of skilled manpower for remote locations. He highlighted the complexities of transporting stone and construction materials from inland quarries to offshore locations for breakwater construction, the need for a sustainable source of renewable power in eco-sensitive areas, and the importance of advanced automation to match international terminals and bunkering hubs.

He also emphasised the need for a fast-track approach to execute such large-scale projects between 2025-2029. He further discussed innovative and sustainable solutions, such as using caisson-type vertical breakwaters at depths beyond 14m to reduce the need for rock in offshore and remote breakwater construction.

He also explored the installation of modular LNG infrastructure in remote areas, with caissons and top-side structures prefabricated on the mainland and transported, as well as the deployment of offshore floating solar solutions for regions with high wave activity, such as offshore and isolated islands.

MS. SUSHMA B. V.

Ms. Sushma b v, *Deputy General Manager (Civil)* from Tata Consulting Engineers, actively contributed to the conference. She delivered a presentation on **"Shallow and Deep Foundation Systems: A New Approach Incorporating Construction Practices, Stress Interference Mapping, and Sustainability Features"** under the theme "Foundations – Shallow and Deep." Additionally, she collaborated with the eminent Dr. Chandresh H. Solanki as Co-Chair for Session 1, facilitating enriching discussions and knowledge exchange.

The conference highlighted the importance of sustainable geotechnical practices, and TCE is committed to supporting such meaningful initiatives driving innovation and resilience in infrastructure engineering.

MR. PRANAB DASGUPTA

Mr Pranab Dasgupta, *General Manager* – Infrastructure Business, Tata Consulting Engineers (TCE), presented on **"Innovating for a CircularEconomy: TCE's Global Experiences in Sustainable SludgeManagement"** at a seminar organised by CAMBI India and Team Norway from the Royal Norwegian Consulate General, Mumbai.

As the Knowledge Partner, TCE shared insights on global technologies and best practices for municipal sludge treatment and disposal, drawing from our experiences across Sweden, Germany, and Denmark.

At Tata Consulting Engineers, we continue to contribute to sustainable engineering solutions that enable a circular economy and support responsible infrastructure development.

MR. MANOJ KUMAR CHAUHAN

Manoj Kumar Chauhan, *AGM – Infrastructure Business at Tata Consulting Engineers (TCE)*, participated in the Conference on "Digitalisation in Water Networks held in New Delhi. The event brought together thought leaders to deliberate on how emerging technologies are reshaping water systems globally."

Key insights included:

- Use of AI, digital twins, IoT, and smart meters to reduce Non-Revenue Water (NRW) by up to 30%
- Opportunities for operational efficiency, predictive maintenance, and enhanced water conservation
- Emerging innovations such as blockchain, AR, and cyber-physical systems in water network planning and control
- Challenges in adoption including cybersecurity, infrastructure readiness, and data complexity

MR. AMIT SHARMA

Mr Amit Sharma, *Managing Director & CEO of Tata Consulting Engineers (TCE)* addressed the main stage at the Autodesk Design and Make Summit 2025, sharing insights on "The future of digital transformation in the Architecture Engineering and Construction (AEC) sector."

He spoke about how TCE is leveraging advanced digital tools and data-driven workflows to enhance design efficiency, enable seamless collaboration, and deliver sustainable, future-ready engineering solutions.

The session highlighted TCE's commitment to harnessing technology to create value for clients, shape resilient infrastructure, and accelerate the industry's digital journey.

MR. ATUL CHOUDHARI

Mr. Atul Choudhari, *Chief Technology Officer, at Tata Consulting Engineers (TCE)* emphasised the need to move from pilots to scale with modular design, robust MRV, and bankable project structures supported by green procurement, credit frameworks and certification. His message was direct: treat carbon as a feedstock, not a liability, and accelerate a circular economy that is commercially competitive and technologically credible.

The 4th Edition of the Net Zero & CCUS Technology Summit 2025 brought together leaders from industry, academia and policy to explore how demand creation for CO_2 utilisation can unlock a credible circular economy.

TCE looks forward to being part of this dialogue and advancing carbon-to-value solutions with partners across sectors.

MR. ATUL CHOUDHARI

Atul Choudhari, ***Chief Technology Officer at Tata Consulting Engineers (TCE)***, recently shared his insights on **"Consultant's Role for a Circular Economy"** at the seminar on Sludge Management for a Circular Economy, hosted in collaboration with CAMBI Group and the Royal Norwegian Consul General, Mumbai.

The discussion focused on how consultants can enable sustainable sludge treatment, resource recovery, and innovative technologies that turn waste into value. By integrating circular principles into water and wastewater management, industries can reduce environmental impact while creating economic opportunities.

This seminar brought together global experts and industry leaders to exchange ideas and strengthen partnerships for a greener future. TCE remains committed to advancing engineering solutions that support sustainability, resilience, and circularity in infrastructure and industrial processes.

MR. SACHIN MISHRA

Mr. Sachin Mishra, ***General Counsel and Company Secretary, TCE, recently represented Tata Consulting Engineers (TCE)*** as a speaker at the 22nd Indo-US Economic Summit, organised by the Indo-American Chamber of Commerce, India (IACC) at The Leela Palace, New Delhi.

The summit, inaugurated by Hon'ble Minister for Commerce & Industry, Shri Piyush Goyal, served as a dynamic platform to strengthen India–U.S. economic ties.

Sachin shared practical perspectives on how businesses can navigate regulatory challenges and ensure compliance while fostering innovation in IT and ITeS. He also highlighted the importance of clear legal frameworks to build trust and enable seamless collaboration between global partners.

The event witnessed participation from leading industrialists, CEOs, and business leaders, making it one of India's most significant economic forums.

MR. BISWAJIT BHATTACHARYYA

Mr. Biswajit Bhattacharyya, ***Head of Mining and Metals Business at Tata Consulting Engineers (TCE)***, participated as a Plenary Speaker at the International Conference on Vibration Engineering, Science, and Technology (INVEST 2025) organised by the Council of Vibration Specialists (CVS) at IIT Delhi.

He shared perspectives on emerging trends and innovations in vibration engineering, contributing to an important dialogue on advancing this specialised field.

PANEL DISCUSSION FY25

MR. AMIT SHARMA

Mr Amit Sharma, *MD & CEO of Tata Consulting Engineers (TCE),* was a panellist at India Energy Week, speaking on **"Make in India: Developing India's Global Role as a Green Manufacturing Powerhouse."**

He emphasised how engineeringexpertise, technologycollaboration, and supplychainresilience are key to driving India's clean energytransition. He highlighted the importance of investing in R&D, strengthening industry-academia partnerships, and enhancing local manufacturing of critical clean energy components. By developing dedicated green industrial zones, securing raw material supply, and advancing digital manufacturing, India can position itself as a global leader in sustainable energy solutions.

At Tata Consulting Engineers, we are committed to supporting this journey with our engineering consulting expertise, strategic advisory, and sustainable solutions. Together, we can accelerate India's clean energy future and strengthen its leadership in green manufacturing.

MR . SRIDHAR RADHAKRISHNAN

Mr. Sridhar Radhakrishnan, *The Chief Financial Officer of Tata Consulting Engineers (TCE),* he took part in a CFO roundtable series hosted by BW Businessworld in Mumbai. The theme of the event was **"CFO: Maintaining the Equilibrium".**

The discussions focused on how the role of the CFO is changing. Today's CFOs are not just financial experts. They are key business leaders who help shape growth, manage risk and support innovation. Sridhar Radhakrishnan shared his views on how CFOs need to balance careful financial planning with bold business goals and other changing priorities of CFO. He also spoke about the need to build investor trust and guide companies through uncertain times with clear thinking and flexibility.

The conversation also revolved around use of technology in finance and in particular managing spends. These technologies are no longer just support systems. They are essential to the way finance works today. The roundtable also highlighted how CFOs can encourage innovation while still keeping strong governance in place. This is important for staying competitive without losing focus on quality and compliance. Gujarat's maritime sector and its role as a regional hub.

MR. PAWAN RALLABANDI

Mr Pawan Rallabandi, *Head – Digital & Advanced Technologies,* joined a high-impact panel discussion on scaling sustainability, navigating workforce shifts, and accelerating digital transformation in engineering.

His insights highlighted how TCE is leveraging open, interoperable technologies to empower Indian infrastructure with future-ready digital solutions that are aligned with national priorities like Gati Shakti and Smart Cities.

MR. SACHIN MISHRA

Mr Sachin Mishra, ***General Counsel and Secretary, Tata Consulting Engineers (TCE),*** joined industry leaders as a panel member at the Confederation of Indian Industry National Conference on Legal Services in New Delhi.

During the session on **"Enhanced Compliance & Liability in a Changing Regulatory Landscape",** Sachin shared practical insights on how technology can simplify compliance and strengthen governance. He also spoke about the evolving role of General Counsels as strategic advisors, helping organisations balance risk and growth in a dynamic regulatory environment. Thank you to Confederation of Indian Industry for bringing together diverse perspectives that drive actionable solutions. TCE looks forward to engaging in more such forums that influence the future of legal and compliance practices.

MR. ATUL CHOUDHARI

Mr Atul Choudhari, ***CTO of Tata Consulting Engineers (TCE),*** joined an insightful panel discussion on **"Grid-Scale Storage – How Battery Technologies Can Turbocharge the Energy Transition"**

During the discussion, Mr Choudhari highlighted the need for an integrated approach to grid-scale storage, emphasising the importance of battery innovation, regulatory support, and hybrid energy solutions to enable a resilient and scalable energy transition. He also highlighted how advanced analytics and digital twins can optimise storage performance and grid stability.

As we move towards a net-zero future, collaborations and technology-driven solutions will be key in shaping a sustainable energy landscape.

MR. RAMESH KRISHNAMURTHY

Mr. Ramesh Krishnamurthy, ***President,*** Representing Tata Consulting Engineers (TCE) on the Governing Council of CEAI, moderated an engaging discussion on **"Forging Strategic Partnerships: Consultants and Vendors"** at the Consulting Engineers Association of India (CEAI) Annual Conference & Awards 2025 in New Delhi. The session explored how collaboration can drive innovation, improve project delivery, and create long-term value for India's infrastructure sector.

Ramesh also joined the Valedictory Panel on "Propelling a $5 Trillion Economy – What Needs to Be Done from an Engineering Perspective", sharing actionable insights on technology adoption, sustainability, and engineering excellence as key enablers of growth. TCE continues to play a pivotal role in shaping industry dialogue and advancing solutions for a stronger, future-ready India.

Closing Perspective

Through sustained focus on learning, structured knowledge sharing and active industry engagement, the Technology team continues to strengthen Tata Consulting Engineers' ability to respond to complexity with clarity. By ensuring that technology is not only adopted but deeply understood and responsibly applied, the team supports better project outcomes, long-term value creation and a stronger engineering ecosystem.

Ethics ReEnvisioned: Engineering Trust, Delivering Certainty

In today's world, engineering no longer operates in a predictable or linear environment. Projects are larger, stakeholder ecosystems are more complex, regulatory expectations are sharper, and societal scrutiny is constant. In such an environment, technical excellence alone is not enough. What distinguishes organisations that endure from those that merely deliver is trust. And trust, in turn, is built on ethics.

At Tata Consulting Engineers, ethics is not treated as a rulebook that sits alongside business. It is the foundation on which business is built. It influences how decisions are made when information is incomplete, how risks are disclosed when pressure is high, and how responsibility is upheld when outcomes carry long-term social and environmental consequences. Ethics is not an intervention at TCE. It is an instinct. Engineering, by its very nature, shapes the physical and social world. Every design choice, procurement decision, and execution strategy carries implications beyond cost and schedule. It affects safety, livelihoods, public confidence, and future resilience. Recognising this responsibility has shaped TCE's ethical approach over the decades.

Ethics is embedded in how the organisation thinks, not applied after decisions are taken. This embedded approach becomes especially critical in an era defined by complexity. As projects span geographies, regulations, technologies, and cultures, the number of variables increases exponentially. In such conditions, ambiguity is inevitable. Ethics provides the compass. It ensures that even when paths are unclear, direction remains certain. At TCE, ethics is not viewed as a constraint on performance. It is understood as the enabler of consistent performance. Excellence without integrity is fragile. Compliance without conviction is unsustainable. True engineering certainty emerges only when competence and character operate together.

This belief is reflected in the organisation's approach to compliance. The Tata Code of Conduct and the supporting framework of policies are not treated as external obligations. They are integrated into the way work is planned, executed, and reviewed. Policies covering anti-bribery and anti-corruption, anti-money laundering, conflict of interest, gifts and hospitality, supplier conduct, software usage, and safety, health and environment form a coherent system rather than isolated requirements. Together, they ensure that ethical intent is translated into operational discipline. Importantly, this discipline is not limited to leadership or corporate functions. It is expected to be visible in everyday decisions. Ethics at TCE lives in the ordinary moments that define project culture. It is present when a design team chooses transparency over convenience. When a site team prioritises safety despite schedule pressure. When a commercial decision is evaluated not only for immediate gain but also for long-term consequences.

These moments rarely make headlines, yet they shape reputation far more powerfully than any formal declaration. Recognising that ethical dilemmas often arise in grey areas rather than clear violations, TCE has focused on strengthening everyday judgement. The introduction of the Code of Ethics Handbook reflects this intent. Designed as a practical guide rather than a theoretical document, it helps employees navigate real-world situations with confidence. By making ethical guidance accessible and usable, the organisation reinforces that ethics is meant to guide action, not merely describe ideals. This clarity of judgement becomes a strategic advantage in a competitive engineering environment. Clients today are not only seeking technical expertise. They are seeking partners they can trust with complex, high-risk, multi-year responsibilities. Transparency, honesty in risk disclosure, fairness in procurement, and uncompromised safety practices build credibility over time. At TCE, ethical consistency has translated into long-standing client relationships, repeat engagements, and partnerships built on mutual confidence. Ethics also safeguards project outcomes. Engineering decisions have irreversible consequences. A compromise in quality or safety may not be apparent immediately, but its impact can be profound.

At Tata Consulting Engineers, ethics provides that consistency. It transforms complexity into clarity and responsibility into reliability. Ethical engineering builds trusted partnerships. Trusted partnerships deliver successful projects. Successful projects strengthen institutions and the societies they serve.

Ethical discipline ensures that standards are upheld even when external pressures tempt shortcuts. This protects not only client investments but also public trust in engineering institutions. From a risk perspective, the value of ethics is equally tangible. Ethical shortcuts often lead to hidden costs, including rework, disputes, regulatory action, and reputational damage.

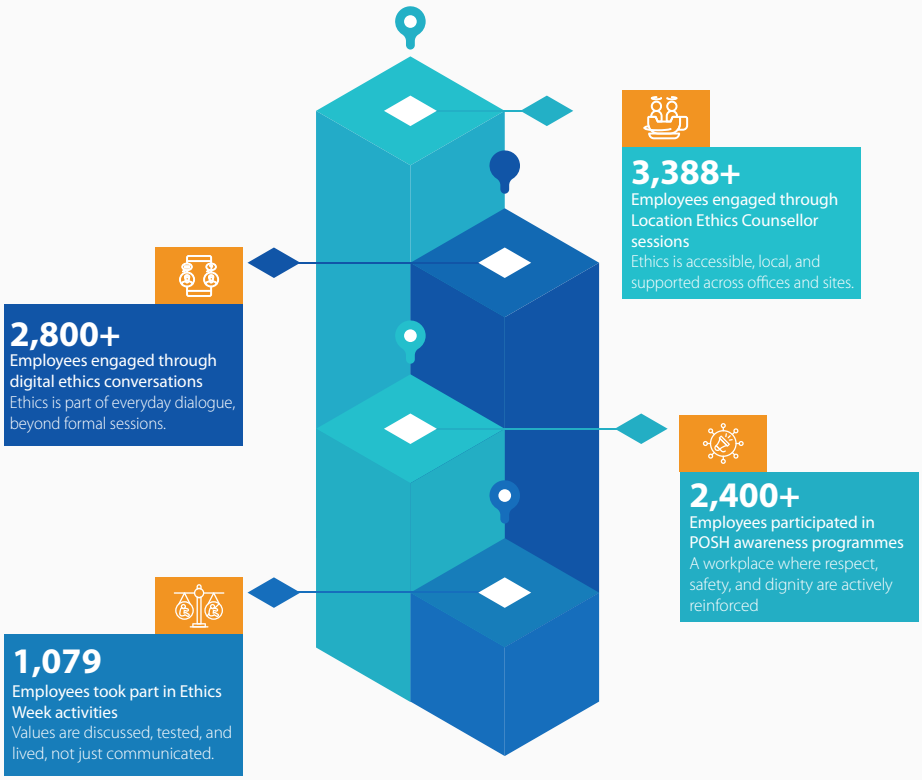
By embedding strong governance and clear accountability, TCE reduces exposure to operational, legal, financial, and reputational risks. Doing the right thing the first time is not only principled. It is efficient. Ethical clarity also accelerates decision-making. In complex environments, delays often arise not from lack of information but from uncertainty about what is acceptable. When ethical boundaries are clear, teams act faster and with greater confidence. Awareness programmes, scenario-based learning, and structured engagement during Ethics Week help employees internalise this clarity. As a result, ethical behaviour becomes intuitive rather than deliberative. Culture plays a decisive role in sustaining this approach. An ethical organisation is not one where violations never occur, but one where concerns are raised early and addressed constructively. At TCE, employees are encouraged to speak up without fear.

Multiple grievance redressal mechanisms ensure accessibility, confidentiality, and fairness. This confidence to raise concerns strengthens workplace safety, project integrity, and mutual respect. The role of leadership is central in reinforcing this culture. Ethical behaviour is not delegated. It is demonstrated. Governance structures at TCE ensure oversight, independence, and accountability. Ethics officers, compliance leads, POSH committees, location ethics counsellors, investigators, and audit mechanisms work together to ensure ethical standards are consistently upheld across offices and sites. Digital platforms further ensure that guidance and reporting mechanisms are easily accessible. Yet governance alone is not sufficient. Ethics must be lived collectively. This is where engagement initiatives play a vital role. Ethics Week and year-round awareness programmes create spaces for dialogue, reflection, and learning. Participation across the organisation demonstrates that ethics is not the responsibility of any function or department. It is shared by everyone.

The themes explored during these engagements reinforce this belief. Professional ethics emphasises fairness, integrity, and transparency in every interaction. Ethics ReEnvisioned recognises that while values remain constant, contexts evolve. New technologies, digital tools, and delivery models introduce new ethical questions. Addressing them requires vigilance, adaptability, and continuous learning. Interactive formats such as scenario challenges, quizzes, and digital campaigns are deliberately chosen. They mirror real-world complexity and demonstrate how ethical clarity reduces confusion rather than adding to it.

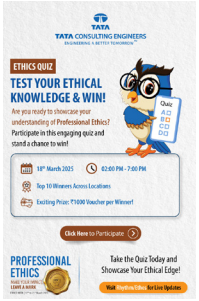
Employees experience how values guide action when rules alone are insufficient. Ethics also finds expression across the entire engineering lifecycle at TCE. From early conceptualisation to final handover, decisions are evaluated through the lens of safety, sustainability, quality, and societal impact. Design choices consider not only performance but long-term use and environmental responsibility. Procurement processes emphasise fairness and transparency. Execution prioritises safety and accountability. Closure processes ensure statutory compliance and transparent reporting. This continuity ensures that ethics is not episodic. It is end-to-end. Continuous capability building supports this ecosystem. Structured learning modules, expert sessions, regular communication, and practical tools ensure that employees remain equipped to handle emerging ethical challenges.

An empowered workforce is better prepared to identify risks early, act responsibly, and uphold standards even when unobserved. In a world where engineering complexity continues to intensify, certainty does not come from control alone. It comes from trust. Trust is earned through consistency, transparency, and integrity over time. At Tata Consulting Engineers, ethics provides that consistency. It transforms complexity into clarity and responsibility into reliability. Ethical engineering builds trusted partnerships. Trusted partnerships deliver successful projects. Successful projects strengthen institutions and the societies they serve. This is how ethics moves from principle to practice. And this is how trust is engineered, and certainty is delivered.



Ethics week celebration

March 2025



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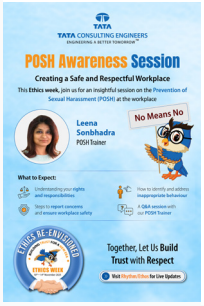


2025: A Year of Resilience, Growth, and Purpose

As we reflect on 2025, what stands out is not only what Tata Consulting Engineers achieved, but how those achievements came together to define a year of purpose driven progress. This was a year shaped by resilience in the face of complexity, growth rooted in capability and learning, and an unwavering commitment to values that guide who we are as an organisation.

Across geographies, businesses, and teams, 2025 was not about isolated milestones. It was about building momentum. It was about investing in people, strengthening leadership, listening more deeply, and creating an environment where innovation, inclusion, and integrity could thrive together. In many ways, the year reaffirmed a simple truth that has always defined TCE. When people are empowered, organisations move forward with confidence. It was also a year that tested our adaptability. Markets shifted, technologies evolved, and expectations rose across sectors. Yet, in every challenge, TCE responded with clarity and purpose. Teams collaborated across boundaries, leaders stepped forward with empathy and conviction, and learning became a daily discipline rather than an occasional event.

What emerged was a stronger organisation, one that did not merely respond to change but shaped it with intent. At the heart of this journey were three enduring pillars that continue to guide every decision and every action at TCE. People. Responsibility. Integrity. Together, these pillars created a shared compass for the year. They influenced how we designed programmes, how we engaged with one another, and how we showed up for our clients and communities. They reminded us that engineering excellence is not only about technical brilliance but also about the human choices that sit behind every solution. In 2025, TCE's story became one of collective intent, where every initiative, conversation, and achievement reflected a deeper commitment to building an organisation that is capable, compassionate, and future ready.

People at the Centre

At Tata Consulting Engineers, people are not viewed as resources but as the foundation on which engineering excellence is built. In 2025, this belief translated into deliberate and sustained investments in learning, leadership, and well-being, ensuring that every individual had the opportunity to grow with the organisation. Capability building emerged as a central theme. As industries evolve and engineering challenges grow more complex, the need for deep technical expertise combined with leadership agility has never been greater.

Recognising this, TCE focused on creating learning experiences that were both future-focused and grounded in real-world application. One of the defining highlights of the year was the successful completion of the Semiconductor Manufacturing and Controlled Environments Program, developed in collaboration with Arizona State University's Ira Fulton School of Engineering.

This first-of-its-kind initiative marked a significant step in building advanced capabilities for designing contamination-free environments critical to semiconductor manufacturing. The fourteen-week programme blended live learning, asynchronous modules, and expert-led sessions, culminating in a rigorous capstone project evaluated jointly by TCE and ASU faculty.

The graduation ceremony at the Mumbai Corporate Office was more than a milestone. It symbolised TCE's readiness to contribute meaningfully to emerging high-technology sectors. Equally important was the continued strengthening of project management capability through the Project Management Professional Training programme. Now in its third edition, ProMPT reached participants across multiple delivery centres, reinforcing structured thinking, execution discipline, and leadership in delivery. Conducted in partnership with the Project Management Institute Mumbai Chapter, the programme reflected TCE's belief that strong project management is the backbone of client trust and successful outcomes.

Building Leaders for a Complex Future

Leadership development in 2025 was approached not as a one-time intervention but as a continuous journey. TCE deepened its leadership pipeline through programmes designed to address different stages of professional growth, from early career potential to senior leadership readiness. Participation in the Tata Group Strategic Leadership Seminar marked a significant milestone for six TCE leaders. Hosted by TMTC Pune in partnership with Harvard Business School, the seminar offered exposure to global perspectives on strategy, markets, and people leadership through the Harvard Case Method.

The experience equipped participants to navigate ambiguity, make informed decisions, and lead with confidence in a dynamic business environment. The launch of Shikhar during FY25 further strengthened TCE's leadership architecture. Designed as a twenty-four-month programme for high-potential mid-senior leaders, Shikhar combines academic rigour with real business exposure. The rigorous selection process ensured that only the most promising candidates progressed, with participants pursuing advanced programmes at institutions such as SPJIMR and SDA Bocconi.

A defining element of Shikhar is mentorship by Apex leaders through strategic capstone projects, ensuring that learning translates directly into organisational impact. Shikhar represents a long-term investment in leaders who will guide TCE through future complexity. Complementing this was the STAR programme, a fast-track initiative for early-career high performers. STAR continued to identify and nurture individuals ready for larger responsibilities, ensuring continuity in leadership capability.

At the same time, programmes such as CRAFT for PMC leaders and LEAP 2.0 for team leads reinforced leadership capability at the operational and delivery levels, with a focus on customer centricity, a digital mindset, and executive presence. Women leadership development remained a priority through the Breakthrough Series, delivered in partnership with TMTC and academic collaborators such as the Fisher School of Business at Ohio State University. These programmes focused not only on skill-building but also on addressing self-limiting beliefs, enabling participants to navigate career growth with clarity and confidence.

Nurturing the Next Generation

TCE's commitment to young talent continued to be a defining strength. The Young Engineers Development Program for the 2025 batch welcomed 382 trainees from TCE and EcoFirst, selected from premier institutions nationwide. Their journey was carefully designed to blend cultural orientation, technical learning, behavioural capability, and real-world exposure. From pre-onboarding sessions to structured induction, site training, and on-the-job learning, the YEDP experience ensured that young engineers were not only technically equipped but also aligned with TCE's values and way of working.

Power skills training in communication, collaboration, presentation, and prioritisation helped build confidence early in their careers, while the Project Management Foundation Workshop provided a firm grounding in delivery fundamentals. Functional capability was strengthened through advanced tools training and programmes such as ADePT, which continued to build a strong talent pipeline from diploma institutions.

As 2025 draws to a close, it leaves behind more than achievements. It leaves behind strengthened capabilities, deeper trust, and a shared sense of purpose. The year demonstrated that resilience is built through people, growth is sustained through learning, and purpose is realised through values in action. At Tata Consulting Engineers, the journey continues.

These initiatives reflected TCE's belief that sustained growth depends on developing talent at every level, not only hiring it. Innovation among students and young professionals was further encouraged through platforms such as the TCE ACE Hackathon. Season two of the hackathon, themed AI-based engineering solutions, brought together bright minds from across the country to develop ideas that address real engineering challenges. The grand finale at the Mumbai Corporate Office showcased the power of collaboration, creativity, and technical excellence.

Inclusion as a Way of Working

In 2025, diversity, equity, and inclusion moved from intent to action. The formation of the DEI Council provided structured governance and accountability, ensuring that inclusion became embedded in everyday practices rather than remaining a standalone initiative. Listening circles played a vital role in understanding lived experiences across the organisation. Facilitated by an external agency, these sessions created safe spaces for open dialogue, allowing insights to be shared directly with leadership and translated into meaningful action.

Importantly, the organisation also engaged with male colleagues to understand perspectives on inclusion and workplace dynamics, reinforcing the belief that inclusive cultures are built collectively. The Industry Leaders' Round Table Meet, hosted by TCE under the INCLUDE initiative, brought together voices from across industries to discuss disability confidence, inclusive leadership, and the integration of DEI and CSR. These conversations moved beyond compliance to focus on empathy, confidence, and practical action.

DEI Fest brought inclusion to life across delivery centres through shared experiences in culture, food, music, and dialogue. With strong participation and engagement, the week reinforced the message that inclusion begins with individual intent and collective action.

The Open Doors Internship Program for Persons with Disabilities marked another critical step in building accessible career pathways. Through partnerships and thoughtful onboarding, TCE demonstrated that diverse abilities strengthen teams and fuel innovation.

Listening, Engaging, and Recognising

Employee engagement remained strong through consistent listening and dialogue. Initiatives such as Chai Pe Charcha continued to provide platforms for open dialogue between employees and senior leaders, fostering shared learning and mutual trust. The Employee Engagement Survey reflected this commitment, with an engagement score of 81 per cent, surpassing industry benchmarks and signalling positive progress across key dimensions.

Recognition played a vital role in reinforcing values. Value Awards honoured employees who lived TCE's principles through their actions, while platforms such as TechPride, Tata InnFuze, Tata eHack, and Tata Innovista celebrated innovation, collaboration, and engineering excellence. These platforms not only recognised achievement but also encouraged intrapreneurship and cross-company learning within the Tata Group.

Instant recognition through Kudos, along with initiatives such as iTHINK Shark Tank and Super Star Team Awards, ensured that contributions were acknowledged promptly and meaningfully.

Well-being, Culture, and Community

Beyond work, 2025 was marked by a strong focus on well-being, culture, and connection. Happiness Week, wellness initiatives such as yoga and mindfulness sessions, and creative engagements for employees and their families reinforced the belief that a healthy workplace is a productive one. Sports and cultural activities brought employees together across delivery centres and sites, fostering camaraderie, teamwork, and pride. From competitive sports to cultural celebrations, these moments strengthened the sense of belonging that defines the TCE community.

Looking Ahead

As 2025 draws to a close, it leaves behind more than achievements. It leaves behind strengthened capabilities, deeper trust, and a shared sense of purpose. The year demonstrated that resilience is built through people, growth is sustained through learning, and purpose is realised through values in action. At Tata Consulting Engineers, the journey continues. With people at the centre, responsibility as a guiding principle, and integrity as a constant, TCE moves forward with confidence, ready to shape the future of engineering and create lasting impact.










50,000/-

TATA







Embracing
Diversity

UTSAV - 2

2025 at TCE: People Powering Progress

01 Capability and Leadership

14 Week Semiconductor Manufacturing programme with ASU

6 Leaders at Tata Group Strategic Leadership Seminar

85 Team leads in LEAP 2.0

128 Participants in ProMPT across 3 delivery centres

8 Shikhar finalists in a 24-month programme

60 PMC leaders through CRAFT

STAR Season 3 completed and Season 4 with 8 HiPos

02 Young Talent and Future Pipeline

382 YEDP trainees across TCE and EcoFirst

52 ADePT trainees

4 Power skills modules

10 finalist teams in TCE ACE Hackathon Season 2

03 Inclusion, Listening, and Engagement

2200+ Employee pool engagement during DEI Fest

520+ Fireside Chat attendees

11 PwD interns in Open Doors Internship Season 2

1570+ Active DEI participants

81% Employee Engagement Score

DEI Council governance established

Listening Circles across delivery centres and sites

04 Recognition, Innovation, and Well-being

97 Value Awards recipients

333 Tech Pride teams and 1,000+ participants

24 Tata InnFuze teams and 43 participants

14 Tata eHack teams and 1 Gold Ideas award

45 Tata Innovista teams and 210 participants

830 Kudos recognitions

23 iTHINK Shark Tank teams, 13 finalists

9 Super Star Teams

5100 Happiness drops

4627 Thank You Buddy tokens

1700 sports participants

1250+ cultural activity participants

Congratulations

to all the Winners

TCE Day

Mumbai









Enabling Growth

Enabling Growth




Noida



TCE DAY - 2025

ROUND 8
Engineering Excellence
Enabling Growth
TCE DAY - 2025

TCE Day 2025 - Eros Hotel
WhatsApp group







Engineering Excellence
Enabling Growth
TCE DAY - 2025







Vadodara




Pune


Excellence
Enabling
Growth


TCE DAY - 2025
Engineering
Excellence

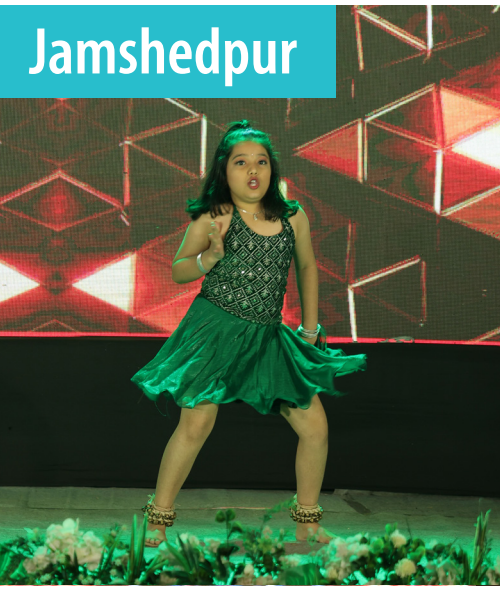
Kolkata


ring Excellence
ELECTRIC WORKS


TATA HITACHI ELECTRIC WORKS


TATA
TATA CONSULTING ENGINEERS
Engineering Excellence
Enabling Growth
TCE DAY - 2025

Jamshedpur

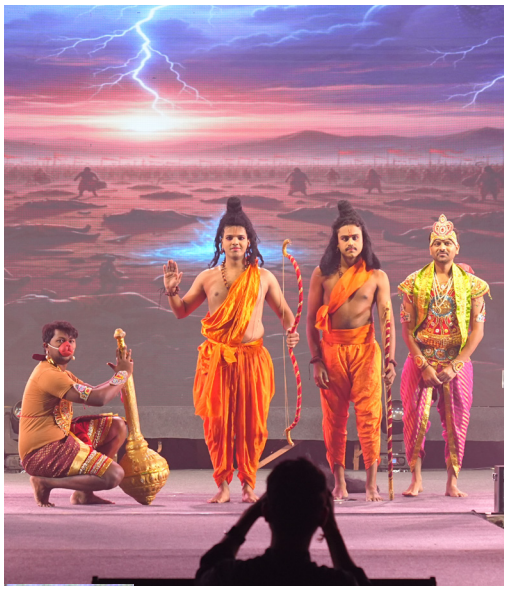








Bengaluru





Engineering Life Through Purpose Driven Impact

At Tata Consulting Engineers, Corporate Social Responsibility is not viewed as a parallel activity but as a natural extension of how engineering excellence is applied to society. It reflects the belief that engineering capability must translate into real and lasting value for people, institutions and communities. While projects deliver infrastructure and assets, CSR enables the organisation to strengthen social systems, reduce vulnerability and contribute to long term national development. Guided by the Tata Group philosophy of Leadership with Trust, CSR at TCE is anchored in responsibility, rigour and continuity of impact.

TCEndeavour brings together all CSR initiatives and employee volunteering at TCE under a single, cohesive framework. This integration ensures that social impact is purposeful, well governed and aligned with the organisation's engineering ethos. Rather than fragmented interventions, CSR programmes are designed as structured initiatives with clear objectives, defined outcomes and measurable impact. During the year, CSR interventions spanned education, employability, disaster response, heritage conservation, advanced research and employee volunteering.

Together, these efforts reflect a holistic approach to responsible growth, where engineering is not only about building assets but also about strengthening institutions, creating opportunity and supporting long term resilience. Under TCEndeavour, CSR and volunteering initiatives are anchored around five interconnected focus areas: STEM education, employability, skilling and inclusion, employee volunteering and leadership engagement, disaster response and community resilience, and environmental sustainability and advanced research.

Across these areas, engineering thinking is consistently applied to complex societal challenges, ensuring that solutions are practical, scalable and rooted in long term value creation. Employees play an active role in this journey, contributing time, expertise and leadership beyond their professional responsibilities.

Nurturing scientific curiosity through Project Vigyaan

Project Vigyaan is designed to strengthen foundational scientific thinking and make STEM education accessible and inclusive for students from Standards 7 to 9 studying in government schools, particularly those under the Navi Mumbai Municipal Corporation. The initiative recognises that early exposure to experiential learning is critical in shaping curiosity, confidence and problem solving abilities among young learners. By moving beyond rote learning and textbooks, Project Vigyaan enables students to experience science as an engaging and relevant discipline connected to everyday life. During the reporting period, Project Vigyaan was scaled in phases, expanding its reach by adding 6 new NMMC schools to those covered in previous years. In total, 635 students participated in structured STEM workshops conducted at the Nehru Planetarium and the Nehru Science Centre in Mumbai. These immersive sessions focused on strengthening core science concepts through hands on demonstrations and interactive learning, helping students understand how theoretical principles translate into real world phenomena.

The programme further deepened learning through Project Based Learning (PBL) in 4 NMMC schools, where 32 students from Standards 7 and 8 worked in teams on guided, real life science projects. Mentored by 14 TCE employee volunteers, students were encouraged to ask questions, test ideas and work collaboratively.

The resulting 8 working models reflected both creativity and relevance, with themes such as foldable housing under Creativity in Engineering and The Smarter Paan wala, which focused on building local knowledge banks. These projects demonstrated how scientific thinking can be applied to practical challenges within familiar community contexts.

The learning journey culminated in a Science Exhibition at the Nehru Science Centre, Mumbai, held alongside the Western Region Science Exhibition. The exhibition provided students with a public platform to articulate their ideas, engage with peers and experts, and gain confidence in presenting scientific concepts. Beyond individual learning outcomes, Project Vigyaan contributes to strengthening the public education ecosystem by reinforcing experiential learning approaches and encouraging teacher and student engagement with STEM beyond the classroom.

Impact at a glance

1. **635 STUDENTS** engaged through STEM workshops
2. **8 PROJECT-BASED LEARNING** models developed
3. **6 NEW NMMC SCHOOLS** added during the year
4. **120 STUDENTS** from 14 schools showcased projects
5. **32 STUDENTS** participated in project based learning
6. **23 STUDENTS** built models showcased in Science Exhibition, Nehru Science Centre, Mumbai
7. **94 EMPLOYEE** volunteers mentored PBL students

Strengthening employability and inclusion through Project Utkarsh

Project Utkarsh is a multi pronged skilling and employability initiative aimed at bridging the gap between diploma level technical education and industry requirements. With a particular focus on students from marginalised and rural backgrounds, the programme addresses a critical transition phase where technical education often does not fully align with workplace expectations. By enabling industry aligned skilling, career readiness and inclusive employment pathways, Project Utkarsh supports both individual aspirations and broader workforce readiness. During the reporting period from April to December 2025, 239 diploma engineering students from Jamshedpur and Vadodara completed intensive one month design engineering training across Civil, Mechanical and Electrical streams. The training emphasised practical application, use of industry relevant tools and job readiness, helping students gain confidence in applying their academic knowledge to real world engineering contexts.

To support career transitions, career fairs were organised in collaboration with State Technical Education Boards and government aided diploma colleges. These fairs provided industry exposure, guidance and interaction opportunities to 191 students from a total of 458 registrations. Through these engagements, students gained a clearer understanding of career pathways, employer expectations and emerging opportunities within the engineering sector.

In line with inclusion objectives, structured Open Door Internships were offered to 11 persons with disabilities. These internships enabled hands on experience, mentoring and exposure across engineering and business functions, reinforcing the organisation's commitment to inclusive talent development. Collectively, Project Utkarsh contributes to economic resilience, dignity of work and stronger industry academia linkages.

Impact at a glance

1. **239 DIPLOMA STUDENTS** trained in design engineering
2. **458 TOTAL REGISTRATIONS** across career fairs
3. **2 LOCATIONS COVERED:** Jamshedpur and Vadodara
4. **11 PERSONS WITH DISABILITIES** benefited through structured Open Door Internships
5. **191 STUDENTS** supported through career fairs
6. **441 STUDENTS** impacted through the programme

Engineering resilience through disaster response

As part of the One Tata for Disaster Response initiative, TCE supports long term rehabilitation and healthcare resilience in disaster affected regions through engineering led intervention. These efforts demonstrate how structured engineering expertise can bring stability and continuity during periods of disruption and recovery. Following the July 2024 landslide in Wayanad, Kerala, TCE committed to supporting the design and project management of a Trauma Care Centre in collaboration with the Tata Sustainability Group and other Tata Group companies.

The design phase has been completed and the project has progressed to the construction stage, reflecting steady progress from concept to execution. A dedicated team of 22 employees is engaged in architectural and structural design as well as site supervision.

Once operational, the Trauma Care Centre is expected to serve approximately 40,000 people annually. The facility will improve access to specialised emergency healthcare while strengthening regional disaster preparedness and long term healthcare resilience.

Impact at a glance

1 **1 TRAUMA CARE CENTRE**
under development

2 **40,000 PEOPLE**
expected to benefit annually

3 **22 EMPLOYEES**
contributing technical expertise







Reviving environmental sustainability and ecology through Mathura Kund rejuvenation

The Mathura Kund Rejuvenation Project aims to restore the cultural, ecological and spiritual significance of historic kunds or water bodies in Mathura through sustainable engineering solutions. These kunds represent both ecological assets and living cultural heritage, requiring sensitive and integrated interventions of the 2,053 kunds identified through satellite imagery, 213 have been physically verified, with 8 kunds currently being revitalised under the project.

The initiative addresses sewage inflow, improves water quality and strengthens structural elements such as ghats and retaining walls, while preserving historic architecture. Equal emphasis is placed on sustainability, community engagement and long term maintenance planning.

During the year, Tata Consulting Engineers submitted the final Detailed Project Report for all 8 identified kunds to the Government of Uttar Pradesh. The DPR includes integrated Public Health Engineering systems, detailed estimates, construction schedules, risk management frameworks and implementation

Impact at a glance

1. **2,053 KUNDS** identified through satellite mapping
2. **213 KUNDS** physically verified
3. **8 KUNDS** under active revitalisation
4. **1 INTEGRATED DPR** for 8 identified kunds submitted to the State Govt

Advancing national priorities through CSR supported research and development

CSR supported Research and Development initiatives aim to advance applied engineering solutions and early stage innovation aligned with national priorities. By supporting research institutions, these initiatives strengthen India's scientific and technological ecosystem and help address complex challenges related to sustainability, clean energy and resilient infrastructure.

CSR supported collaborations continued with leading institutions including IIT Bombay, IISc FSID Bengaluru, CSIR NCL and NIAS. Research themes during the year focused on clean energy transition, industrial decarbonisation, resilient infrastructure and indigenous engineering technologies. Operating at Technology Readiness Levels 3 and 4, these initiatives enable translation from laboratory research to scalable, real world applications.

Beyond technical outcomes, CSR backed research plays a critical role in building future engineering capability, supporting knowledge creation and enabling innovation pathways aligned with national goals. Collectively, these efforts represent long term investments in science, sustainability and national capacity building.

Impact at a glance

1. 4 leading research institutions
2. Focus on clean energy and decarbonisation
3. Research aligned to TRL 3 and 4
4. Long term national capability building enabled

Strengthening impact through employee volunteering

Employee volunteering is a core component of TCEndeavour, enabling employees to apply their time, skills and leadership to social initiatives. Through structured volunteering platforms, employees contribute meaningfully to education, environment, disaster response and professional capacity building, reinforcing a culture of responsibility and purpose driven engagement.

During the year, volunteering activities were conducted under Tata Sustainability Month, Tata Volunteering Week, ProEngage and disaster response initiatives. These efforts reflect both the scale and depth of employee participation and the integration of volunteering into organisational culture.

Impact at a glance

1. **3,023 EMPLOYEES** participated in volunteering activities
2. **12,812 VOLUNTEERING** hours contributed
3. **9,142 BENEFICIARIES**

Looking ahead

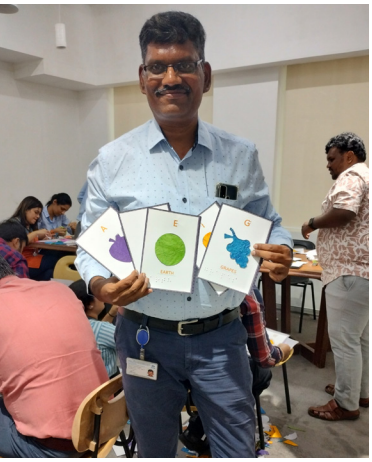
Through TCEndeavour, Tata Consulting Engineers will continue to strengthen the integration of CSR projects and employee volunteering, applying engineering expertise to create sustained social value. By deepening partnerships, strengthening institutions and enabling employees to contribute meaningfully, the organisation remains committed to expanding its positive impact.

Anchored in the philosophy of Engineering Life, these initiatives reaffirm a shared belief that engineering must serve communities, support national priorities and act as a force for positive change, helping build a more resilient and equitable tomorrow for society at large.

TATA VOLUNTEERING WEEK 23

3rd March - 31st March 2025

TVW23 GO THE EXTRA SMILE











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TATA CONSULTING ENGINEERS
Employee Dignity
and Self-respect

TATA VOLUNTEERING WEEK 24

5th September - 7th October 2025

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ENGINEERING A BETTER TOMORROW™

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