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Engineering Practice





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PLUS promotes the value of constantly learning with great appreciation for those who are willing to put their best efforts in gaining knowledge. I have obtained my Professional Technologist, my Chartered Professional Civil Engineer, my Professional Engineer and most recently the accreditation as Professional European Engineer from Engineers Europe Engineering Council. The accreditation received would be crucial in promoting the drive for PLUS in being the best in Highway and Transportation Asset Management within a fast-moving Malaysia's transportation infrastructure industry.

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PUBLISHER

Lembaga Jurutera Malaysia

Tingkat 17 Blok F, Ibu Pejabat JKR,

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Tel: 03-2698 0590, 03-2691 2090 Fax: 03-2692 5017

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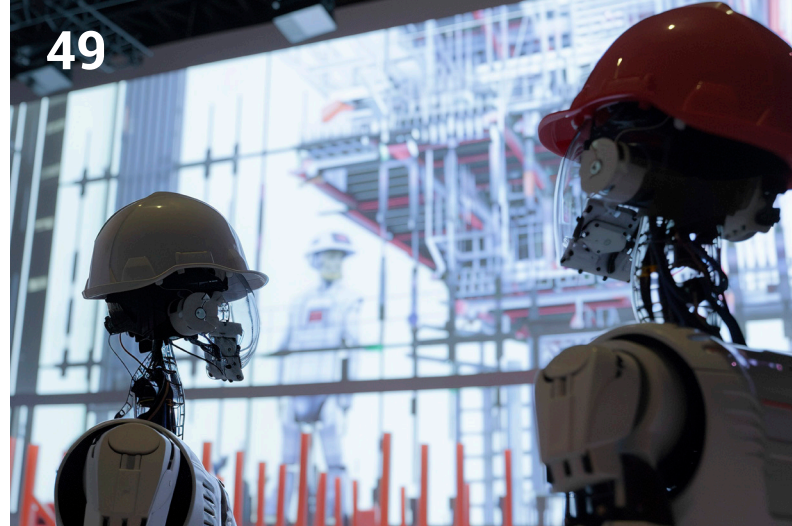
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CALL FOR ARTICLES

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Engineering the Energy Transition

Vol. 107 Jul-Sept 2026

Engineering Physical Connectivity

Vol. 108 Oct-Dec 2026

Building Lifeline

Articles and other contributions relevant to the themes are welcomed, but the decision to publish rests with the Editorial Board.

Advertising inquiries are also welcomed. Please refer to the BEM advertisement on Page 30 for the latest rate card and booking form.

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Engineering Practice



Datuk Wira Ir. Roslan bin Ismail
President
Board of Engineers Malaysia

As we enter 2026, the Board of Engineers Malaysia (BEM) marks an important milestone with the launch of the BEM Strategic Plan 2026-2030. This new plan strengthens our long-term direction and reinforces our commitment to excellence, public trust and national development.

Engineering practice carries a profound responsibility: The protection of public safety. Every structure we design and every system we certify affects communities and the nation's well-being. This duty demands strict compliance with standards, continual upskilling and unwavering professionalism. Through the Strategic Plan, BEM will reinforce competency development, improve regulatory clarity and enhance enforcement to ensure safety remains the profession's foremost priority.

Integrity remains the backbone of engineering. As projects grow in scale and complexity, ethical decision-making becomes even more essential. Engineers often operate under time, cost and commercial pressures, yet must remain guided by honesty, transparency and accountability. The Strategic Plan elevates integrity as a central pillar, supported by stronger ethics education and governance measures.

Sustainability has become inseparable from engineering. Environmental, Social & Governance (ESG) principles now shape how infrastructure is planned, how industries operate and how technologies evolve. Engineers must champion sustainable solutions - from low-carbon designs to climate-resilient systems - to support Malaysia's transition toward a greener future. BEM will continue strengthening partnerships to embed ESG thinking into professional standards.

The rise of Artificial Intelligence (AI) and advanced digital technologies is reshaping engineering practice at extraordinary speed. While AI enhances modelling, design optimisation and safety analysis, its use must remain responsible and transparent. BEM will introduce competency guidance and ethical frameworks to help engineers harness technology confidently and safely.

As we embark on this new strategic cycle, let us reaffirm our collective purpose: To serve society with competence, integrity and a forward-looking mindset. Together, Malaysia's engineering community will continue advancing the profession and contributing to a safe, sustainable and technologically empowered future. 🤖

Engineering with Vision, Wisdom & Impact

From shaping Malaysia's water governance framework to delivering one of the world's most innovative infrastructure projects, Dato' Paduka Ir. (Dr.) Keizrul Abdullah has spent nearly five decades redefining what it means to be an engineer.

Recipient of the Board of Engineers Malaysia (BEM) Anugerah Tokoh Kejuruteraan Negara 2024 (National Engineering Icon Award 2024), his career exemplifies engineering as leadership, stewardship and service to society.



Dato' Paduka Ir. (Dr.) Keizrul Abdullah exemplifies engineering ingenuity, professionalism and leadership.

The Anugerah Tokoh Kejuruteraan Negara (National Engineering Icon Award) recognises engineers of exceptional stature - individuals who embody integrity, visionary leadership, innovation and who have a lasting impact on the nation and the profession.

The recipient, Dato' Paduka Ir. (Dr.) Keizrul Abdullah, stood out not only for the scale of his achievements, but for the depth of his influence. A former Director-General of the Department of Irrigation & Drainage (Jabatan Pengairan & Saliran or JPS), a global authority on water resources management and the engineering mind behind Kuala Lumpur's SMART Tunnel, he is widely regarded as one of Malaysia's most respected and internationally recognised engineers.

Engineering is Not Enough

"We engineers are very proud of our achievements," says Dato' Paduka Keizrul. "We are nation builders."

Indeed, from buildings and roads to water systems and energy networks, engineers shape every aspect of modern life. Yet, for Dato' Paduka Keizrul, engineering excellence must extend beyond technical mastery.

"In my opinion, we must also look beyond engineering and into policymaking, contributions to the profession and service to the country," he says. "We are trained to analyse problems and come up with solutions, but too often we stop at the technical level."

This conviction crystallised into a phrase that has since become synonymous with his professional tagline: "Look beyond the drain". Coined during his years at JPS, it reflects the need for engineers to step back, see the wider system and address root causes rather than symptoms.

Curiosity, the First Teacher

Born on 16 December 1951, Dato' Paduka Keizrul's journey in engineering was guided by not only formal career counselling, but by curiosity. The child from a modest family once made his own kite because his parents could not afford to buy him one.

"I didn't know anything about aerodynamics then," he recalls. "I just observed what worked - and it flew."

That simple act of observation, experimentation and creation planted the seeds of engineering thinking long before he understood the term. It was this fascination with problem-solving and making things work that eventually led him to University of Malaya, where he enrolled in engineering.

During his early years, students were exposed to all four major branches of engineering. Civil engineering appealed to him most. "Civil is about building

things you can see,” he explains. “You can see the difference you’ve made.”

He graduated with a Bachelor of Engineering (Honours) in Civil Engineering in 1975 and later, enhanced his expertise with a Diploma with Distinction in Hydraulic Engineering from IHE Delft, the Netherlands and a Master of Science in Water Resource Systems Engineering from the University of Newcastle upon Tyne, UK. He has been conferred a Doctorate in Engineering (Honoris Causa) from Universiti Sains Malaysia (USM) and a Doctorate in Engineering (Honoris Causa), from Universiti Tenaga Nasional (UNITEN).

Forged in Public Service

After graduation, Dato’ Paduka Keizrul joined JPS at a time when engineers were in high demand. What drew him to JPS was its structured training programme and emphasis on mentorship.

His first posting in Negeri Sembilan proved formative. Under the guidance of an experienced Technical Assistant, he learnt practical engineering from the ground up, a lesson he still credits today at the age of 74, by continuing to impart his knowledge and experience to young engineers.

After two years, he was transferred to JPS headquarters in Kuala Lumpur, where he gained exposure to planning, project appraisal and financial analysis, including programmes funded by the World Bank. These early experiences broadened his perspective, teaching him that engineering decisions were inseparable from economics, governance and accountability.

Director-General & National Water Strategist

In 1997, Dato’ Paduka Keizrul was appointed Director-General of JPS, a position he held for 11 years. He led an organisation of approximately 8,000 staff, managing an annual budget of RM1.8 billion and overseeing the country’s water resources portfolio.

His responsibilities spanned irrigation, drainage, flood mitigation, river and coastal management, hydrology and water resources planning. He served as Technical Advisor to two Ministers (viz. the Minister of Natural Resources & Environment and the Minister of Agriculture & Agro-Based Industries) and sat on the boards of key water and agricultural authorities including MADA, KADA and LUAS.

During this period, he championed a shift from supply-driven, project-centric approaches to Integrated Water Resources Management (IWRM), a holistic framework that considers environmental, social and economic dimensions. Under his leadership,

Integrated River Basin Management (IRBM) plans were developed nationwide, alongside Integrated Shoreline Management Plans (ISMP) for our coastline.

Understanding Floods by Understanding Development

Flooding, Dato’ Paduka Keizrul explains, is often misunderstood as a purely hydraulic problem. Long-term data from Kuala Lumpur reveals a different story.

As urban areas developed, runoff volumes increased dramatically while travel time to rivers decreased. Studies in Subang Jaya showed that post-development, runoff volumes doubled and reached rivers in half the time. Flood data at the Sulaiman Bridge indicated a three-fold increase in flood flows over the past three decades.

The conclusion was clear: Development had altered nature’s balance.

This insight led to one of his most enduring legacies - the Urban Stormwater Management Manual for Malaysia, better known as Manual Saliran Mesra Alam (MaSMA). Approved by the Cabinet in 2000, MaSMA made it mandatory for developments to adopt source-control measures such as detention ponds and rainwater harvesting, mimicking natural hydrological processes.

Long before “nature-based solutions” became a global policy buzzword, MaSMA had already embedded the concept into the Malaysian engineering practice.

The SMART Tunnel: A World First

If MaSMA represents systemic reform, the SMART Tunnel represents bold ingenuity.

Following severe flooding in Kuala Lumpur in 2000, Dato’ Paduka Keizrul proposed to then Prime Minister Tun Dr. Mahathir Mohamad, a flood diversion tunnel. When asked how often the tunnel would be used, Dato’ Paduka Keizrul acknowledged that floods might occur only once or twice every year or two.

Tun Mahathir’s response was pivotal: Could the tunnel serve another purpose?

The result was a dual-purpose tunnel, the only one of its kind in the world, designed primarily for flood mitigation and secondarily to relieve traffic congestion. With an innovative financing structure combining public funding and private-sector participation, the SMART Tunnel delivered maximum economic and social returns.

Dato’ Paduka Keizrul managed the project from conception to commissioning, a rare opportunity for any engineer. The SMART tunnel has since won

numerous national and international awards. It was also featured by National Geography & Discovery Channel. Other than the Petronas Twin Towers, it was the only Malaysian engineering project getting such prominent coverage.

From Nation Builder to Global Influencer

Throughout his career, Dato' Paduka Keizrul has always been active in professional activities. After retiring from public service, he did not slow down. Instead, his influence continued to expand internationally.

He served as President of the International Commission on Irrigation & Drainage (ICID), advocating the philosophy of "More Crop per Drop" to address global water and food security. He chaired and advised in programmes of numerous international bodies, including UNESCO's International Hydrological Programme, the Global Water Partnership, NARBO, ADB, OECD, OIC and UN-ESCAP.

As Chair of Wetlands International Malaysia and Regional Co-ordinator for Building with Nature Asia, he continues to promote climate adaptation through the integration of engineering and ecological solutions across five Asian countries.

Professional Leadership & Mentorship

Locally, Dato' Paduka Keizrul has been a tireless advocate for professional excellence. A two-term Board Member of BEM, he played a key role in the 2015 amendments to the Registration of Engineers Act and currently serves as Chairman of BEM's Disciplinary Committee.

He is a Past President and Honorary Fellow of IEM, a Founding Fellow of the ASEAN Academy of Engineering and Technology and an ASEAN Chartered Professional Engineer.

To him, professionalism goes beyond compliance: Engineers must be competent in technical skills, management, communication, teamwork, ethics and environmental stewardship.

"Many engineers, who are competent technically, lack communication skills," he says frankly. "But no project is done by one discipline alone. So, engineers must communicate well and work effectively in a team. Part of the training for engineers must focus on improving communication and teamwork. This is important, especially when engineers have good project proposals; we must know how to present and defend our proposals well," he says.

He hopes BEM will also focus on communication skill in its training programmes for engineers.



Dato' Paduka Keizrul with Emeritus Prof. Ir. Dr. K.S. Kannan, who sits on BEM's Engineering Accreditation Council, the Application Committee and Examination & Qualification Committee.

Ingenuity, Creativity & Engineer of Tomorrow

The word engineer, he reminds young professionals, comes not from engines, but from ingenuity. Creativity must sit alongside analysis.

"Somewhere between identifying the problem and giving the solution, we may forget to be creative," he observes.

This belief underpins his views on digitalisation and artificial intelligence. AI, he argues, is simply an advanced decision support system - a tool to assist rather than replace human judgment. Engineers must remain critical thinkers, not passive users of technology.

Life Philosophy Rooted in Learning

When asked about the philosophy guiding his life, Dato' Paduka Keizrul resists offering a single doctrine. Instead, he speaks of continuous learning, openness and ethical reciprocity.

"We are influenced by many people," he reflects. "Some lessons we keep forever."

Quoting Confucius, he adds: "Do unto others what you want others to do unto you."

Measure of an Icon

Dato' Paduka Keizrul's career demonstrates that engineering, at its best, is not merely about structures or systems, but is also about vision, responsibility and service to society. By consistently looking "beyond the drain" - beyond projects, beyond disciplines and beyond convention - he has helped move the nation forward.

His conferment as Tokoh Kejuruteraan Negara 2024 is both a recognition of past achievements and a challenge to future generations of engineers to think broader, act wiser and serve with purpose. 🇲🇾

Engineering with Purpose: The Making of a National Young Engineering Icon

Named the Board of Engineers Malaysia (BEM) Tokoh Muda Kejuruteraan Negara 2024 (National Young Engineering Icon 2024), Prof. Ir. Dr. Hassimi Abu Hasan embodies the ideals of a new generation of Malaysian engineers who are technically accomplished, ethically grounded and socially driven. From pioneering sustainable water and wastewater treatment technologies to empowering communities and mentoring future engineers, his journey illustrates how engineering excellence can serve both nation-building and humanity.



Deserving recognition as Tokoh Muda Kejuruteraan Negara 2024.

The Tokoh Muda Kejuruteraan Negara award is one of the highest recognitions conferred by BEM upon young professionals. Reserved for engineers below the age of 40, the award honours individuals who have demonstrated outstanding professional competence, integrity, leadership and meaningful contributions to society.

Following a rigorous selection process, Prof. Ir. Dr. Hassimi Abu Hasan, whose career reflects a rare blend of scholarly excellence, community impact and dedication to engineering education, was

chosen as the recipient. His selection was not just a recognition of achievements but was also an affirmation of values, placing service, sustainability and social responsibility at the heart of engineering practice.

Early Curiosity

Born on 5 November 1984 in Kuala Kedah, Kedah, Prof. Hassimi's inclination towards engineering took root early. As a child, he was naturally curious, enjoyed creating and experimenting with objects and balanced academic interests with extracurricular pursuits such as badminton and athletics. These formative years nurtured both discipline and creativity - traits that would later define his professional life.

His interest in engineering crystallised during his teenage years, when he was first exposed to technical projects involving fermentation processes for bioproduct generation. That experience sparked a deeper fascination with how scientific principles could be translated into practical, scalable solutions.

"At that time, my supervisor asked me to do simulation work on acetone-butanol-ethanol production," he recalls. "From there, my interest in the engineering field, especially in research, grew. For my university education, I chose biochemical engineering. I thought the name of the programme was very interesting. It was my first choice of study as it interacted with my interest. So, without too much thinking, I immediately chose this programme."

That decisive choice led him to Universiti Kebangsaan Malaysia (UKM), where he pursued a Bachelor's degree in Biochemical Engineering and he graduated in 2007. His growing passion for research soon propelled him further along the academic path.

From Student to Scholar: Embracing Research & Academia

Encouraged by early research exposure and mentorship, Prof. Hassimi continued his academic journey at UKM, completing his PhD in Chemical & Process Engineering, with his doctoral studies concluded in 2012.

While many of his peers gravitated towards industry, Prof. Hassimi made a deliberate decision to pursue academia. Advice from senior engineers, who observed limited opportunities in large private-sector firms at the time, reinforced his choice. More importantly, he recognised that academia offered a powerful platform to generate knowledge, train engineers and serve society simultaneously. "I moved on to research and to transfer my knowledge to the community and to teach students," he says.

His academic career progressed steadily at UKM: Post-Doctoral Researcher (2012-2013), Senior Lecturer (2013-2019), Associate Professor (2019-2025) and finally Professor in August 2025. Today, he is Head of the Research Centre for Sustainable Process Technology (CESPRO), where he leads interdisciplinary research addressing environmental and sustainability challenges.

Engineering for Impact: Water, Wastewater & Sustainability

Prof. Hassimi's research expertise lies primarily in water and wastewater treatment engineering, an area of critical importance to public health, environmental protection and sustainable development. With over 10 years' experience, his work spans both fundamental research and applied engineering solutions. His research areas include biofiltration, phytoremediation, phycoremediation, coagulation and flocculation processes, nutrient recovery as well as resource recovery technologies. These approaches are designed to improve treatment efficiency while minimising environmental footprints - particularly relevant for developing and rapidly urbanising regions.

He has led or co-led projects addressing small-scale decentralised systems for rural communities as well as large integrated wastewater treatment



Prof. Hassimi's work spans both fundamental research and applied engineering solutions.

systems, reflecting his belief that engineering solutions must be adaptable, inclusive and context-sensitive.

Defining Community Project

Among the many initiatives he has led, one project stands out as a defining moment in his career, a community-based water purification project in Rembau, Negeri Sembilan.

Leading a multidisciplinary team, Prof. Hassimi designed and implemented a system to supply clean water to a community which lacked reliable access. Crucially, the project went beyond infrastructure development. "We built the system and we taught them how to operate it," he explains. "We taught them how to note the quality of the water before they could clean it."

Implemented over one and a half years, the project focused on knowledge transfer, enabling the local community to operate, maintain and replicate the system independently. This emphasis on sustainability and empowerment exemplifies his philosophy of engineering as a tool for long-term societal benefit.

Research Excellence & Global Recognition

Prof. Hassimi's scholarly output places him among Malaysia's most productive and influential engineering researchers. He has authored more than 240 publications, accumulated over 8,700 citations and achieved a h-index of 50 as recorded in the SCOPUS database. His work appears in

leading international journals such as Bioresource Technology, Journal of Water Process Engineering, Water (Switzerland) and Environmental Science and Pollution Research. His research excellence has earned him international recognition. He was named among the World's Top 2% Scientists by Stanford University for three consecutive years (2022, 2023 and 2024) and received the Top Research Scientist Malaysia Award in 2025.

Beyond publishing, he serves as an editor and editorial board member for several national and international journals, contributes as an external examiner for postgraduate theses worldwide and regularly presents at international conferences as a keynote, plenary and invited speaker.

Funding Innovation: Grants, Patents & Industry Collaboration

Innovation requires resources and Prof. Hassimi has demonstrated exceptional ability in securing research funding. He has served as principal investigator for more than 25 research grants, totalling over RM2 million, alongside dozens more as a co-researcher.

His funded projects focus on nutrient recovery, bioproducts, phytoremediation, domestic wastewater reclamation and biofilm technologies. Notably, he has received significant funding for sustainable wastewater reclamation projects and nutrient recovery from palm oil mill effluent - key priorities for Malaysia's environmental agenda.

His work has also resulted in patents and intellectual property, including a granted patent for treating sago mill effluent and patent filings for bacterial consortia for ammonia removal and biofilm-supporting media. These innovations are designed to improve treatment efficiency while supporting circular economy principles.

Industry collaboration is another hallmark of his work, with partnerships involving Indah Water Research Centre, technology firms and environmental consultancies, ensuring research findings translate into real-world applications.

Educator, Mentor & Advocate for Future Engineers

Despite his demanding research portfolio, teaching remains central to Prof. Hassimi's professional identity. He teaches more than 10 undergraduate and postgraduate courses, supervises more than 40 PhD students and 19 MSc students as well as plays an active role in curriculum development and accreditation.

He consistently emphasises the importance of strong fundamentals, adaptability and teamwork.

"I always tell my students that if they want to be good engineers, they should work hard and try to learn new things," he says. "Today, especially, with automation and digitalisation, they must learn AI, but they must also have a strong foundation in engineering basics."

For him, technical competence must be complemented by communication skills, ethical awareness and collaboration, qualities which he believes are essential for engineers navigating the challenges of the industry.

Beyond Academia: Community Engagement & Service

True to his belief that engineering must serve society, Prof. Hassimi is actively involved in community engagement programmes, popular science writing and public education initiatives. Through programmes such as Program Saintis Air (MyStiA), he has helped raise awareness on water reuse, recycling and environmental sustainability, particularly among local communities and indigenous settlements.

These initiatives reinforce his view that engineers have a responsibility to not only design systems, but also to educate, engage and empower the communities they serve.

Role Model for Malaysia's Engineering Future

Prof. Hassimi's journey shows what is possible when engineering excellence is guided by purpose. His career seamlessly integrates rigorous research, impactful community service, innovative technology development and dedicated mentorship.

His recognition as the Tokoh Muda Kejuruteraan Negara 2024 is both a celebration of past achievements and a statement of confidence in his future contributions. More importantly, it sends a powerful message to young engineers across Malaysia that success in engineering is measured not only by professional accolades, but also by the positive difference one makes to society.

As Malaysia advances towards a more sustainable, digitally enabled and resilient future, leaders like Prof. Hassimi exemplify the role engineers must play - thinking critically, acting ethically and offering engineering solutions that truly matter. 🌱

Remembering Almarhum Datuk Ir. Mohd Adnan bin Mohd Nor (1959 - 2025)

An Enduring Legacy of Professional Excellence, Leadership and Service

Almarhum Datuk Ir. Mohd Adnan bin Mohd Nor was a towering figure in Malaysia's engineering fraternity whose professional life exemplified technical excellence, principled leadership and unwavering service to the profession. A Professional Engineer with Practising Certificate registered with the Board of Engineers Malaysia (BEM) and an ASEAN Chartered Professional Engineer (Civil), he brought more than four decades of distinguished experience in water resources development, management and policy formulation to every role he undertook.

Datuk Adnan served with distinction at both national and regional levels. He was a six-term BEM Board Member from 2017 to 2024, a Past President of the Association of Consulting Engineers Malaysia (ACEM), a Fellow of the Academy of Sciences Malaysia and a Corporate Member of The Institution of Engineers, Malaysia (IEM). He chaired and served on numerous key committees on the BEM, including the Management Committee, Engineers Act Committee, Examination & Qualification Committee, Training & Education Committee and the National Monitoring Committee, in addition to several working groups. His steady leadership contributed significantly to strengthening professional standards, competency development and regulatory governance for engineers, engineering technologists and inspectors of works in Malaysia.

Within BEM, Datuk Adnan played a pivotal role in expanding Malaysia's engineering footprint internationally. He championed initiatives to formalise cooperation with developing countries through memoranda of understanding and facilitating the export of Malaysian engineering consultancy services. He further contributed to the materialisation of ongoing FIDIC training programmes for registered persons, substantially supported by BEM, reinforcing global best practices within the local profession.

His contributions to ACEM were equally profound and enduring. First elected as a Council Member in June 2005, he served ACEM for two decades in various leadership capacities. He chaired the Publications & Public Relations Committee for more than six terms, served as Honorary Treasurer in 2014, Honorary Secretary in 2016 and subsequently as Deputy President for two terms before assuming the office of President from 2019 to 2021. In all these roles, he was widely respected for his integrity, professionalism and tireless commitment to advancing the consulting engineering profession.

His presidency coincided with one of the most challenging periods in recent history, one marked by economic uncertainty and the nationwide Movement Control Order during the Covid-19 pandemic. During this time, Datuk Adnan worked relentlessly to advocate for the needs of Engineering Consulting Practices



YBhg. Datuk Ir. Mohd Adnan bin Mohd Nor represented Malaysia in chairing the 107th ACPECC Meeting held in Siem Reap, Cambodia on 4 June 2024.

(ECPs), engaging closely with the Ministry of Finance, MITI, CIDB, KKR and EPU to address operational and financial challenges faced by the industry. His calm but resolute leadership ensured that the concerns of the profession were heard at the highest levels of government, providing crucial support to consulting engineers during a period of unprecedented disruption.

Regionally and internationally, Datuk Adnan was a passionate advocate for professional mobility and collaboration. As Chairman of the ASEAN Chartered Professional Engineer Coordinating Committee (2023-2024), he championed initiatives to enhance cross-border recognition and mobility, culminating in the establishment of the ASEAN Engineers Excellence Award, first presented on 7 November 2025 in Nha Trang, Vietnam. He also spearheaded the successful ASEAN Chartered Professional Engineer Mobility Forum during National Technical Profession Day (HPTN) 2023 and National Engineering Convention (NEC) 2025.

Through his involvement with the International Federation of Consulting Engineers (FIDIC), FIDIC Asia Pacific (FAP) and the Federation of ASEAN Consulting Engineers (FACE), he elevated Malaysia's standing within the global consulting engineering community and consistently promoted international best practices.

Beyond his institutional roles, Datuk Adnan was Chairman of RPM Engineers Sdn. Bhd., a respected consulting firm established in 1994 with an international footprint across Asia, Africa and beyond. Under his leadership, the firm collaborated with renowned international organisations, including the Food & Agriculture Organisation (FAO), the Japan International Cooperation Agency (JICA) and Cap-Net, contributing to sustainable water management and capacity development worldwide.

Until his passing, Datuk Adnan remained an active and valued member of the National Monitoring Committee, continuing to serve the profession with dedication and wisdom. His legacy is one of courage, commitment and quiet strength, a legacy that has strengthened professional institutions, uplifted industry standards and inspired generations of engineers.

Almarhum Datuk Ir. Mohd Adnan bin Mohd Nor will be remembered with deep respect and gratitude for a lifetime of service and for the lasting impact he had made on Malaysia's engineering profession and beyond. 🇲🇾

Editorial Note:

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Evolving Role of the Practising Engineer in Operations & Maintenance

by
Tania Tan Boon Nor

Recent reports highlight a growing maintenance crisis in Malaysia's building stock. Studies indicate that most buildings experience leakage, seepage, or waterproofing failures, particularly in roofs, walls and wet areas. Minor defects often go unnoticed due to a prevalent "reactive maintenance culture", where inspections are infrequent, causing issues to escalate and affect structural integrity and property values.

High-profile cases, such as the temporary closure of certain iconic towers underline these concerns. Authorities required extensive maintenance and safety upgrades after identifying deteriorating facilities and potential hazards.

These developments reveal systemic under-maintenance across Malaysia's built environment, threatening safety, liveability and long-term asset value. However, growing public scrutiny, government interventions and potential regulatory reforms indicate a shift toward proactive, professional and accountable maintenance, with engineers and property managers playing a key role in ensuring safer, well-maintained buildings for the future.

Across the industrial and built environment sectors, the practising engineer's role is undergoing rapid and profound transformation. Manufacturing plants, hospitals, airports, data centres, shopping

complexes and high-rise developments now operate within a climate of fast-changing technologies, rising regulatory expectations and heightened concerns for safety, energy efficiency and long-term asset reliability. What was once viewed as routine operations and maintenance work has become the backbone of organisational resilience. Modern facilities are densely packed with mechanical, electrical, control and fire protection systems that must function seamlessly every hour of the day. Any operational lapse can disrupt production, compromise occupant safety, trigger financial penalties, or cause severe reputational damage.

In this environment, the practising engineer is no longer a reactive troubleshooter but a strategist and systems steward responsible for integrating technology, managing people, interpreting data and ensuring that physical assets perform at peak reliability. This shift is especially evident in mission-critical facilities where downtime is unacceptable, such as semiconductor plants, pharmaceutical factories, food-processing lines, major commercial buildings and high-dependency complexes like hospitals and data centres. As operational demands increase, so does the need for engineers who can ensure safety, achieve cost-effective performance and maintain compliance while navigating a new digital landscape.



Expanding Responsibilities of Engineers in O&M

The practising engineer's responsibilities have broadened far beyond traditional equipment repair. Modern plants and buildings include extensive systems: HVAC and chilled-water networks, complex electrical distribution, switchgears, UPS units, compressed air systems, steam and hot-water circuits, wastewater treatment plants, vertical transportation systems and increasingly sophisticated building automation systems. Engineers must not only understand each subsystem individually but, more importantly, also the interactions between them. A fault in one part of the system often cascades into others and the engineer is expected to foresee and manage these interdependencies.

In many facilities, the engineer acts as the bridge between the design team, the construction contractors and the end-users. Designs often assume ideal performance

conditions, but real-world operations introduce load variations, environmental influences, human behaviour and ageing equipment. Engineers must interpret design documents, verify installation against specifications, study system behaviours and make informed adjustments to align performance with operational needs. They are increasingly required to provide feedback to designers and consultants, ensuring that lessons learnt during operations are incorporated into future upgrades and capital projects.

This expanded mandate also includes a more strategic role. Instead of responding only when something breaks, engineers must anticipate issues, manage risks and plan long-term maintenance strategies that preserve asset value. Downtime is no longer accepted as an inevitable part of operations. Organisations expect foresight, planning and continuous improvement - responsibilities that fall squarely on the engineer's shoulders.

AI & Digital Tools: Transforming the Engineer's Daily Work

One of the most significant changes in modern O&M practice is the integration of digital technologies. Artificial intelligence, smart monitoring and data-driven analytics have become indispensable tools for ensuring reliability and efficiency. Equipment across manufacturing plants and building complexes is now equipped with sensors that continuously measure vibration, temperature, pressure, flow rates, humidity and power characteristics. These sensors feed real-time information into AI algorithms capable of identifying early signs of deterioration or anomalies. Instead of waiting for equipment to fail, engineers can predict failures months in advance, plan maintenance more effectively, optimise spare parts inventories and reduce costly breakdowns.

Digital twins (virtual replicas of physical equipment or entire facilities) are increasingly used to simulate operations. Engineers can use these systems to model how equipment performs under different load profiles, evaluate the impact of system changes and plan shutdowns more safely. Digital twins are especially useful in large complexes such as airports, data centres and industrial plants, where interactions between cooling systems, electrical networks and mechanical equipment are highly dynamic. By replicating real-world behaviour virtually, engineers can test scenarios and optimise operations without disrupting the actual facility.

Modern O&M work also relies heavily on building management systems (BMS) and supervisory control and data acquisition (SCADA) platforms. These systems provide live dashboards, alarm notifications, diagnostic information and scheduling tools. Engineers must understand the underlying software logic, automation sequences and data analytics in order to troubleshoot effectively. The days when engineers could operate solely with mechanical knowledge are gone; digital literacy has become a core competency.

Remote monitoring has also revolutionised the engineer's workflow. Cloud-based platforms allow engineers to oversee multiple sites simultaneously, receive fault alerts on mobile devices and track maintenance records through QR-coded digital logs. These capabilities reduce response times, improve accountability and enhance coordination across distributed teams.

Preventive & Predictive Maintenance: The Core of Modern Engineering Practice

Preventive maintenance remains one of the pillars of plant and building reliability. However, it has evolved into a far more structured and analytical discipline. Instead of simply following manufacturer recommendations, engineers today must tailor maintenance schedules based on actual operating conditions, failure histories, equipment criticality and environmental factors. Preventive tasks such as lubrication, calibration, cleaning, adjustment and component replacement still form the foundation of routine maintenance, but they are now supported by data, trend analysis and risk evaluation.

Predictive maintenance takes this concept further by detecting potential failures long before they occur. Engineers use techniques such as thermography to identify electrical hotspots, vibration analysis to monitor rotating machinery, ultrasonic testing to detect leaks or hidden cracks and oil analysis to observe contamination or wear. These specialised tools allow problems to be identified at a microscopic level, giving engineers ample time to schedule repairs, plan parts procurement and avoid unexpected stoppages. Predictive maintenance reduces unnecessary component changes, extends equipment life and raises overall system availability.

Many high-reliability industries also apply reliability-centred maintenance (RCM), a methodology that evaluates each piece of equipment based on the consequences of failure. Engineers must study potential failure modes, analyse the impact on safety and operations and determine the most cost-effective

maintenance strategy. RCM demands both technical expertise and strategic judgement, as engineers must consider multiple variables: The severity of failure, its frequency, the cost of downtime and the economic feasibility of various maintenance approaches.

Cost Evaluation & Optimisation a Key Engineering Function

With rising energy prices, labour shortages and tighter budgets, practising engineers now play a substantial role in cost management. In many organisations, they are involved in operational planning, budgeting and resource allocation. Cost evaluation requires an understanding of both the technical and financial aspects of maintenance. Engineers must prepare life-cycle cost analyses, justify replacement or upgrading proposals, evaluate the economic implications of corrective versus preventive actions and assess the cost of downtime in manufacturing operations.

Energy consumption forms a large portion of operational costs in both industrial plants and large building complexes. Engineers must closely study chiller efficiencies, pump operations, fan performance, compressed air losses, lighting systems and peak demand patterns. Improvements in energy performance, sometimes even marginal, can produce significant long-term savings. Engineers must also make informed decisions regarding equipment replacement, weighing whether to repair ageing systems or invest in modern, energy-efficient alternatives. Their recommendations must balance cost, performance, safety, compliance and sustainability.

Managing Sub-Professionals, Tradesmen & Service Providers

The practising engineer works with a diverse team that includes chargemen, wiremen, HVAC technicians, mechanics, plumbers, welders, instrumentation specialists and

building technicians. Effective management of these sub-professionals requires not only technical authority but also strong leadership and communication skills. Engineers must provide clear instructions, ensure that safety procedures are strictly followed and verify that work is carried out according to standards.

Competency management is an important part of this responsibility. Engineers must ensure that technicians and tradesmen possess the correct certifications, attend necessary trainings and remain competent in handling specialised equipment. They also play a supervisory role during hazardous tasks, such as high-voltage switching, confined space work and hot work operations, ensuring that every step is executed safely.

Many facilities outsource portions of their maintenance work, bringing in external service providers for elevators, chillers, fire systems, boilers, specialist diagnostics, or major overhauls. Engineers must evaluate these contractors, oversee their work and ensure that they meet contractual performance criteria. This aspect of the job requires negotiation skills, contract knowledge and the ability to assess the quality of service objectively.

Inspection Schedules for M&E Equipment: Ensuring Reliability & Compliance

To maintain safe and reliable operations, engineers must implement structured inspection schedules for mechanical and electrical systems. These include electrical equipment, mechanical machinery, lifts and escalators, HVAC components, boilers, pressure vessels, water systems and sewage installations. Inspections not only keep systems running efficiently but also maintain compliance with regulatory bodies, insurance requirements and industry standards.

Fire protection systems demand particularly rigorous attention. Engineers must oversee the testing and maintenance of fire alarm panels, detection devices, sprinkler networks,

hydrant systems, fire pumps, hose reels, gas suppression systems, smoke control systems, fire dampers, extinguishers and emergency lighting. Inspections occur on a monthly, quarterly, annual and five-yearly basis depending on the component. Activities such as monthly pump runs, quarterly alarm panel checks, annual hydrant flow testing and periodic internal pipe inspections must be carried out without fail. These actions are essential to ensuring that fire systems respond effectively during emergencies, as a single malfunctioning component can compromise an entire facility's safety.

Documentation forms a critical part of inspection regimes. Engineers must maintain accurate logs, testing reports, calibration certificates, equipment history records, schematics and compliance documents. Increasingly, these records are migrating to cloud-based platforms, enabling easier retrieval, audit readiness and long-term traceability.

Safety, Regulatory Compliance & Risk Management

Safety remains the foundation of all engineering responsibilities. Engineers must cultivate a strong safety culture within their teams, ensuring that procedures such as lockout-tagout, confined space protocols and hot work safety are consistently followed. They are responsible for conducting hazard identification exercises, preparing risk assessments and implementing mitigation measures.

Regulatory compliance is equally important. Engineers must stay informed of updates in building codes, occupational safety regulations, fire authority requirements, environmental protection laws and energy efficiency standards. Failure to comply can lead to financial penalties, legal consequences, or operational shutdowns. Engineers also play a central role in emergency preparedness, developing response plans for power failures, equipment breakdowns, fires,

floods and other crises. Their knowledge and planning significantly influence how well a facility withstands unexpected events.

Sustainability & Environmental Stewardship

Modern operations place strong emphasis on sustainability. Engineers contribute by improving energy efficiency, reducing water consumption, managing waste responsibly and minimising greenhouse gas emissions. They are involved in retrofitting older systems, integrating renewable energy sources, monitoring refrigerant leaks and optimising equipment to reduce environmental impact. Sustainability is no longer a peripheral concern but a core responsibility aligned with global environmental goals and corporate expectations.

Conclusion

The practising engineer in today's O&M landscape is a far more multifaceted professional than ever before. No longer limited to mechanical troubleshooting, the engineer is now a strategist, analyst, mentor, systems integrator and steward of safety and sustainability. They navigate complex engineering systems, interpret digital data, manage teams and contractors, safeguard compliance and make cost-effective decisions which directly influence an organisation's resilience and performance.

As manufacturing plants and building complexes continue to grow more sophisticated, the engineer's importance will only increase. Their success will depend on their ability to embrace technology, uphold professional integrity and maintain a commitment to continuous learning.

The future of operations and maintenance belongs to engineers who can balance technical mastery with leadership, foresight and adaptability, ensuring that the facilities of tomorrow remain safe, reliable and ready for the challenges of a rapidly evolving world. 🌱

Structural Lightweight Aggregate Concrete: From Research to Practice in Malaysia

by
Payam Shafigh^{1,2},
Muhammad Aslam¹

¹Wenzhou University of
Technology, China

²Centre for Building,
Construction & Tropical
Architecture (BuCTA), UM

This article introduces structural lightweight aggregate concrete (LWAC) and highlights its use in well-known modern projects to resolve several on-site issues and challenges. The main advantage of this type of concrete is its lower density while its engineering properties are comparable to or better than other structural concretes at the same strength.

In some specific projects where the weight of a structure dominates the design, application of this concrete cannot be ignored. However, it can be considered a good alternative to conventional concrete to reduce the overall cost of construction by saving on steel and concrete materials, although this concrete is more costly than conventional concrete. This concrete has been successfully utilised in a bridge and in the extension of an old building in Malaysia.

Concrete is the most common construction material with several advantages over steel in terms of cost, sustainability and environmental benefits. Concrete offers several long-term mechanical and environmental benefits, including high strength, durability and less maintenance. Although the production of cement and aggregates causes carbon emissions, it is possible to produce high-quality concrete materials using industrial wastes and by-products as cement and aggregate replacement to lessen the environmental damage of concrete production.

Concrete is more affordable than steel because its production relies on locally available raw materials, which also reduces transportation costs. As a thermal mass material, it helps improve the efficiency of buildings by maintaining indoor temperatures. Although steel is important for strength and recyclability, concrete is more eco-friendly and cost-effective for structural applications.

Apart from conventional concrete widely used in the construction industry, there are several types of “special concrete” designed to meet specific criteria of a particular project to not only overcome the project challenges but to also achieve more technical, environmental, economic and performance benefits. Some of these include:

- Self-Compacting Concrete (SCC) which is designed for heavily reinforced sections and complex formworks as it flows under its own weight without any vibration.
- High-Performance Concrete (HPC), an engineered concrete providing exceptional strength, durability and workability. It contains supplementary materials and ad-mixtures to achieve higher toughness and lower permeability.
- Ultra-High-Performance Concrete (UHPC), which often has a compressive strength of more than 120 MPa in the absence of coarse aggregates while containing fibres. It provides superior resistance to harsh environments and has excellent ductility.

- Heavyweight Concrete (HWC) which is prepared with denser aggregates such as magnetite or barite to increase the unit weight. Its applications are in nuclear radiation shields, laboratories and medical centres.
- Structural Lightweight Aggregate Concrete (SLWAC). Its main advantage over other structural concretes is its lower density.

Structural Lightweight Aggregate Concrete and Its Applications

Structural LWAC is defined by ACI-213R and ASTM C330 as concrete made with structural lightweight aggregates. It has a dried density in the range of 1,400-2,000 kg/m³. With a wide range of compressive strength which can reach up to 70 MPa, it is suitable for use in almost all structural applications. Its lower unit weight offers several advantages, including reduced steel and concrete usage, savings in handling and transportation costs, savings in foundations, allowing to build long-span members and the construction of taller buildings on low-bearing capacity soil. In addition to structural benefits, this concrete provides better sound and thermal insulation, energy saving in buildings and minimises the temperature and shrinkage cracks in the structural members due to its lower modulus of elasticity compared to conventional concrete.

The initial application of structural LWAC was for the construction of ships made around 1920 and used in World Wars I and II. By reducing the concrete density by about 16 kg per cubic metre, the carrying capacity of ships could be increased by 30,000 kg^[1]. The first application of structural LWAC for buildings in the US was initiated in 1928 for the vertical expansion of the Southwestern Bell office building in Kansas City, Missouri. Originally designed as an 8-storey building, it was extended to 14 stories after the use of conventional concrete was switched to LWAC^[1].

Later in the 1950s, multi-storey buildings such as the 18-storey Statler Hilton Hotel in Dallas,

Texas and the 42-storey Prudential Life Building in Chicago, Illinois, were constructed using expanded clay LWAC, both of which utilised LWAC in the frames and floors^[2]. In Sydney, the Australia Square has a 56-storey tower. From the 7th floor upwards, the entire building was constructed with structural LWAC, using Litecrete or expanded shale aggregates which helped reduce the overall weight of the building by about 38%^[2].

It is estimated that if structural LWAC with a dry density in the range of 1,600-1,700 kg/m³ is used in a superstructure, significant savings of 35-45% in materials (reinforcement and concrete) of the slab-foundation can be achieved^[3].

Different grades of this concrete were extensively used in the construction of buildings and bridges in developed countries. However, it has not been well applied in developing countries including the Asian region. Table 1 shows the information of some specific projects in which structural LWAC has been used.

Lightweight Aggregate

Lightweight aggregate (LWA) is the main composition of structural LWAC. In the early 1900s, Stephen Hayde discovered the manufacturing process of lightweight aggregates (LWA) for the design and construction of lightweight concrete structures^[1]. Currently, there are many types of LWAs, but not all types can be used to produce structural LWAC. The LWAs are mainly categorised into three major sources of natural, artificial and industrial wastes/by-products.

Natural LWAs which can be used to produce structural grades of LWAC are pumice, diatomite, volcanic cinders, tuff and scoria. Artificial LWAs are produced in factories. These aggregates are usually the result of firing clay, shale, slate, or shells at high temperatures (typically over 1,000°C) in the kiln. Some LWAs used in construction of structural members are LECA (lightweight expanded clay aggregate), Lytag, sintered slate and expanded shale/perlite/vermiculite.

Country	Project Name	Year of Construction	Specifications	
			Density (kg/m ³)	Compressive Strength (MPa)
USA	50-storey One Shell Plaza, Houston, Texas	1967	1840	42.0
Germany	The BMW administrative building, Munich	1972	1500	30.0
Australia	Australia Square, Sydney	1967	1870	30.0
Spain	The Picasso Tower, Madrid	1988	1650	45.0
UK	NLA Tower, Croydon	1970	-	29.0
UK	Bridge at Redesdale	1970	1890	49.0
UK	The Friarton Bridge, Scotland	1988	1700	30.0
USA	Woodrow Wilson Bridge, Washington DC	1961	1840	35.0
USA	Bridge Project in Coweta County, Georgia	2008	1920	70.0

Table 1: Specific projects in which structural LWAC was used [1, 4, 5, 6, 7]

Project Name	Project Name								Slump (mm)	Compressive Strength (MPa)	Density (kg/m³)
	Binder			LWA	Sand	w/binder ratio	WRA	HRWRA			
	OPC	FA	SF								
Bank of America Project, Charlotte, N.C	550	140	-	900	1370	0.428	27.6	53.2	63-130	43.0	1890
	650	140	-	900	1287	0.384	31.6	81.4	51-191	47.0	1890
	750	140	-	900	1203	0.348	35.6	80.1	57-171	51.0	1890
Stovset Free Cantilever Bridge (Bodo, Norway)	425	-	30	520	685	0.350	1.0	4.5	200	65.0	1920
Nordhordland Cable Staged Bridge (Bergen, Norway)	430	-	35	570	630	0.350	-	10-12	200	50.0	1880
Sandhornoya Bridge (Bodo, Norway)	400	-	25	650	575	0.350	-	-	200	60.0	1850

Note: OPC - Ordinary Portland cement, FA - Fly ash, SF - Silica fume, WRA - Water reducing agent, HRWRA - High-range water reducing agent.

Table 2: Mix Proportions of Structural LWAC for Specific Projects [7, 11, 12, 13]

A lot of energy is required to produce artificial LWAs, resulting in the higher price of structural LWACs as compared to conventional concrete of the same grade.

There are many types of LWAs sourced from wastes or industrial by-products such as oil-palm-shell (OPS), coconut shell (CS), expanded polystyrene (EPS), pelletised furnace slag, etc. Although research shows that these LWAs can be used for manufacturing structural LWACs, they are not commonly used in the construction industry and have remained at research or prototype-product stage. Practically, manufactured LWAs are most successfully used in building and bridge constructions.

Mix Proportions for Structural LWAC

There are many methods to design the structural grades of LWACs. However, due to the diversity and different properties of LWAs, the main method is the “Trial and Error Basis” to achieve the targeted density and strength. Although a whole LWAC (all aggregates are lightweight) of structural grade can be made, there are some concerns over the durability and long-term properties such as shrinkage and creep, so it is recommended to use LWA as coarse and normal sand fine aggregates.

The cement content for structural LWAC may be used from 200-500kg per cubic m^[8]. Generally, the cement content in LWAC varies from the same as NWC to about 70% more to achieve the same grade of the concrete^[9]. The water for mixing must be adjusted, depending on the water absorption of LWAs. The LWA used for structural purposes has a 24-hour water absorption in the range of 5-25% by mass of dry aggregate^[10], which is significantly higher than the conventional coarse aggregates. This water absorption rate is one of the challenges during the construction stage. To eliminate the issue, the LWAs must be pre-wetted before mixing. Table 2 shows mix proportions of structural LWACs previously used in different projects.

Application of Structural LWAC in Malaysia

1. **Terengganu Drawbridge.** The Terengganu Drawbridge design was inspired by London's Tower Bridge. Completed in 2019, it was built for carrying motor vehicles and pedestrians and was the first drawbridge in Malaysia and South-East Asia. It features four towers measuring 90m in height and two skybridges connecting the towers. The length of the bridge is 638m and it has 76m bascules which can be raised for passing ships.

As a strict design requirement, the concrete on the bascules must be grade 35 with a density of about 1850 kg/m³. It was also not allowed to cover the concrete surface with any other paving material such as bituminous asphalt due to concern over the weight of the structure. The structural LWAC was also used in both skybridges (Figure 1).

The LWA used in this project was expanded clay and was imported. There were three types of locally available LWAs but these could not be used. The local aggregates - OPS^[14], oil-palm boiler clinker^[15, 16] and coconut shell^[17] - are sourced from agricultural wastes and are still under research. Figures 1-3 show the Terengganu Drawbridge. The design, development and site supervision of the LWCs in this project were under Universiti Malaya.

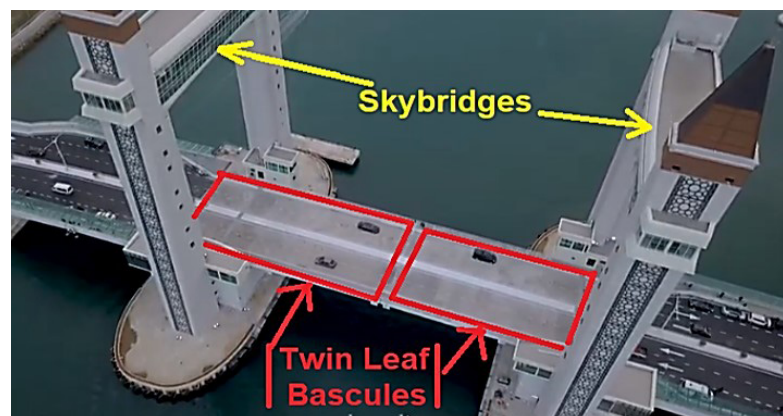


Figure 1: Application of lightweight aggregate concrete on the Twin-Leaf Bascules and skybridges of the Terengganu Drawbridge.



Figure 2: Terengganu Drawbridge during construction in 2018



Figure 3: Workable lightweight aggregate concrete on the bascule (top) and pedestrian (bottom) of Terengganu Drawbridge

2. Application in Extension of Old Building.

For extensions to old buildings, engineers are usually concerned over issues such as cracks developing in the joint section between the new and old structures as well as cracks in the surrounding buildings due to vibrations caused by drilling of the pile foundation. One effective solution is to reduce the weight of the new structure using structural LWAC instead of using pile foundations. In a project in Kuala Lumpur (Figures 4 & 5), a structural LWAC with a 28-day compressive strength of 30 MPa and the equivalent dry density of about $1,750 \text{ kg/m}^3$ was used.

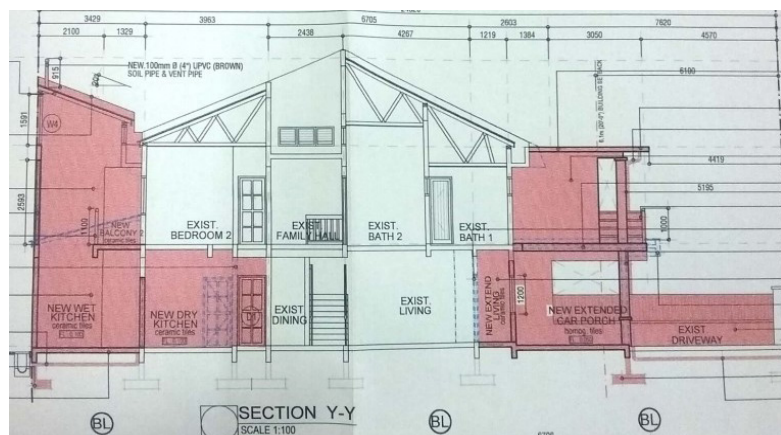


Figure 4: Red highlights indicate the extended part of an old building.



Figure 5: Part of the enlarged section and casting of LWAC.

Conclusion

LWAC is a type of concrete designed to reduce the overall weight of concrete structures while maintaining strength and integrity. Typically, its density ranges between 1,400 and 2,000 kg per cubic metre, with a compressive strength of 20-70 MPa. The best way to produce structural LWAC is the use of Lightweight aggregate (LWA). However, not all types of LWAs are suitable for the manufacturing of this type of concrete.

After the fall of the Roman Empire, the use of lightweight concrete was limited until the 20th century when newly manufactured materials such as expanded shales became available for commercial use as LWAs. This special concrete was well developed and applied in many developed countries.

There are several challenges during the development and application of this concrete such as the development of mix proportions using locally available materials, lack of knowledge and familiarity of the consultant engineers on the specifications and design parameters regarding its structural behaviour, cost, quality of LWAs and the lack of confidence of engineers/contractors in the manufacturing and delivering stages. As it is a relatively new material, it is also considered a higher risk material compared to traditional concrete for the major construction projects despite its many advantages. However, recent applications of structural grades of LWAC in small and mega projects in Malaysia have revealed the practicality of this special concrete material in the region. 🏡

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Future-Proofing Engineers:

CPD to Stay Current, Competent and Ready

by
Dato' Ir. Dr. Eric Goh KH
Dato' Ir. Fong Tian Yong

In today's rapidly evolving global landscape, engineering is no longer confined to technical competence within traditional boundaries. Digital transformation, accelerated technological cycles, shifting economic dynamics and the rise of Environmental, Social & Governance (ESG) imperatives have reshaped expectations for engineers.

As the world confronts climate change, resource constraints, global competition and increasingly complex urban challenges, engineers are at the forefront of delivering solutions which are sustainable, safe and socially responsible. In this environment, Continuing Professional Development (CPD) is no longer merely an obligation but is also a strategic necessity.

Under a fast-changing technological and economic landscape, CPD has become vital for engineers, not only professionally, but also economically, ethically and globally. ESG considerations have transformed the profession into one that demands lifelong learning, multidisciplinary adaptability and a global mindset.

Shorter Technology Cycles - Competence Must Update Faster

A generation ago, engineering tools, methodologies and standards evolved steadily over decades. Today, innovation cycles are

exponentially faster. Artificial intelligence (AI), digital twins, robotics, cloud-based engineering platforms, drones, additive manufacturing, IoT sensors and advanced materials are reshaping engineering design, construction and operations. What was cutting-edge five years ago may already be outdated.

Engineers must remain fluent in emerging technologies. Modern engineering practice increasingly relies on:

- AI-assisted design and decision-making.
- BIM and integrated digital delivery.
- Real-time monitoring through IoT and analytics.
- Predictive maintenance powered by machine learning.
- Virtual prototyping via digital twins.
- Automation in project management and quality assurance.

Without CPD, engineers risk misalignment with contemporary tools, reducing effectiveness and introducing technical risks. Rapid technological shifts mean that competence today does not guarantee competence tomorrow.

Digital transformation reshapes regulatory and client expectations. Regulatory bodies in many countries now incorporate digital competencies into professional standards. Clients increasingly demand faster, more transparent and data-driven solutions. Engineers who engage in structured CPD



remain resilient, adaptable and relevant across technological eras. CPD is no longer optional but is also a critical mechanism for maintaining professional credibility.

Economic Forces & Global Competition Require Stronger Professional Currency

Engineering services are no longer constrained by national borders. ASEAN integration, global infrastructure financing, free-trade arrangements and international procurement platforms have opened opportunities worldwide - but they also intensify competition.

CPD enhances competitiveness. Countries importing engineering expertise expect engineers to demonstrate:

- Verified professional competence.
- Updated knowledge of global standards such as ISO, IEC, Eurocodes, AASHTO.
- Familiarity with emerging technologies and methodologies.
- Ethical and responsible conduct aligned with ESG principles.

CPD acts as a professional currency, signalling that an engineer maintains high standards, keeps up with knowledge and aligns with international practice norms. For engineers aiming to work overseas or with multinational clients, CPD is a market requirement.

Economic disruptions demand versatility. Global economic volatility, from supply chain disruptions to fluctuating raw material costs, requires engineers to possess broader competencies:

- Risk management.
- Project financial evaluation.
- Contract management and dispute avoidance.
- Supply chain resilience planning.

CPD programmes allow engineers to diversify skills, adapt to unexpected shifts and remain employable in various roles. In a dynamic economy, lifelong learning is a safeguard against obsolescence.

ESG an Industry Requirement - CPD Ensures Engineers Meet Modern Sustainability Standards

One of the most significant changes reshaping engineering practice is the rise of Environmental, Social & Governance (ESG) standards. Governments, investors and international clients increasingly demand engineering solutions that are responsible, low-carbon, socially inclusive and ethically governed.

Environmental responsibilities. Engineers are expected to understand:

- Climate-resilient design.
- Carbon accounting and reduction.
- Environmental impact mitigation.
- Energy efficiency and renewable integration.
- Circular economy principles.

CPD ensures engineers remain current with evolving sustainability frameworks such as:

- UN Sustainable Development Goals (SDGs).
- Malaysian Climate Change Action Policies.
- Global reporting standards such as GRI, SASB and TCFD.
- International low-carbon design guides.

Social expectations. Communities now demand:

- Safe infrastructure.
- Socially inclusive planning.
- Stakeholder consultation.
- Respect for heritage, culture and accessibility.

CPD equips engineers to integrate social impact assessments and community-sensitive project planning, promoting public trust and positive societal outcomes.

Governance expectations. Global procurement increasingly requires:

- Transparency in project delivery.
- Ethical compliance and anti-corruption measures.
- Data governance and cybersecurity knowledge.

For engineering firms exporting services, alignment with ESG-linked procurement frameworks is essential. CPD helps engineers meet these expectations, reducing risk and enhancing credibility.

International clients, especially those in Europe, Australia, Singapore and multilateral agencies, now require:

- Evidence of sustainability competencies.
- Demonstration of ESG integration in engineering design.
- Assurance that practitioners meet ethical and governance standards.

Countries receiving engineering services often assess whether the exporting professionals' national CPD system aligns with recognised global CPD frameworks. Strong CPD engagement enhances a firm's export-readiness.

Regulatory & Public Safety Expectations Are Rising

High-profile failures in infrastructure, construction and industrial operations have sharpened regulatory scrutiny worldwide. Investigations frequently highlight human factors or outdated knowledge among contributors to failures. Consequently, regulators and professional boards emphasise that competence must be continuously updated. Engineering failures can result in:

- Loss of life.
- Economic disruption.
- Environmental damage.
- Legal and professional liability.
- Reputational harm to the profession.

CPD ensures engineers:

- Stay updated with evolving safety standards.
- Understand changes in codes of practice.
- Learn from case studies and forensic engineering.
- Improve design verification and risk mitigation.

Maintaining public trust is fundamental and CPD provides the framework to uphold it.

AI & Automation Reshaping Engineering Roles

AI and automation are not replacing engineers, but engineers who understand AI will outperform those who do not. The integration of AI into design, analysis and construction management requires engineers to:

- Use AI tools responsibly.
- Validate AI-generated outputs.
- Manage cybersecurity risks.
- Uphold ethical standards in automated decision-making.

AI literacy has become a core CPD domain. Without continuous learning in digital ethics and AI governance, engineers may lack the skills needed to supervise automated processes safely.

BEM's 2022 survey revealed that digital adoption among local Engineering Consultancy Practices (ECPs) is only 38%, highlighting an urgent need for acceleration. CPD provides a structured path to enhance digital competence, integrate ESG principles and adopt data-driven workflows, ensuring engineers remain competitive globally.

CPD Strengthens Professional Ethics & Accountability

Engineering is not only a technical profession but also an ethical one. CPD reinforces the values of:

- Integrity.
- Transparency.
- Accountability.
- Public interest.
- Environmental stewardship.

Ethical failures, whether due to negligence or misconduct, can severely damage public confidence in the profession. Structured CPD ensures engineers are regularly reminded of evolving ethical frameworks, anti-corruption measures and professional conduct standards.

Engineering Problems Have Become Multidisciplinary

Today's challenges, including climate change adaptation, smart cities, resilient transportation systems, water security and clean energy, require engineers to work across disciplinary boundaries. CPD offers exposure to fields such as:

- Economics.
- Ecology.
- Digital technologies.
- Law and regulations.
- Social sciences.
- Public policy.

Engineers who pursue multidisciplinary CPD develop into leaders, collaborators and innovators who are better equipped to tackle complex, integrated problems.

CPD Supports Career Progression & Professional Mobility

Many engineers pursue roles such as:

- Senior consultant.
- Project director.
- Accredited checker or reviewer.
- Asset manager.
- Policy advisor.
- Engineering researcher.
- International expert.

These positions often require documented evidence of continuous learning. A strong CPD record demonstrates initiative, commitment and leadership potential, enhancing career advancement and global mobility.

CPD Enhances Reputation of Engineering Profession

A profession is only as strong as its collective competence. Engineers who continuously upgrade skills:

- Build public trust.
- Strengthen employer confidence.
- Enhance the profession's voice in national decision-making.
- Increase global credibility.

— “ —

Countries with robust CPD cultures, such as the UK, Australia, Singapore and Canada, are trusted exporters of engineering services.

— ” —



Countries with robust CPD cultures, such as the UK, Australia, Singapore and Canada, are trusted exporters of engineering services. Strengthening CPD practices positions Malaysian engineers competitively in international markets and raises the profession's global profile.

Conclusion: CPD the Engine of Future-Ready Engineering

Engineering is transforming faster than ever. Technology, climate transition, global competition and governance expectations are rewriting the rules of practice. CPD is no longer just a compliance exercise but is also the engine of professional survival and excellence.

CPD empowers engineers to:

- Stay technologically relevant.
- Remain competitive in a globalised marketplace.

- Meet ESG expectations central to international procurement.
- Protect public safety.
- Uphold ethical and governance standards.
- Contribute meaningfully to national and global development.

The Board of Engineers Malaysia (BEM), through its Strategic Plan 2021-2025, is driving a vision to place Malaysian engineers at the forefront of the global engineering value chain. CPD ensures engineers acquire new skills, adopt emerging technologies and align with international best practices, preparing them for cross-border projects and complex infrastructure challenges.

The world is changing and engineers must evolve with it. Continuing Professional Development ensures they do so with confidence, competence and integrity. 🏗️

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To-date there are more than 16,000 Professional Engineers, 140,000 Graduate Engineers and 9,000 Engineering Technologists registered with BEM.

Published quarterly by BEM, *The Ingenieur*, reaches out to the engineering community via a **16,800 printed** version as well an **e-format** for other readers in general.

Readership exceeds 100,000.



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Cryptography:

Unsung Mathematical Empowerment of Information Security

by
Muhammad Rezal
Kamel Ariffin

Malaysia Cryptology
Technology and
Management Centre



Cryptography plays a vital role in engineering, especially in the digital era where data exchange occurs extensively online. In digital engineering, cryptography is essential for securing information and communication between

devices, systems and users. For instance, engineers developing industrial automation systems, Internet of Things (IoT) platforms, or digital control software must integrate cryptographic algorithms such as AES, RSA, or SHA to ensure the transmitted data remains confidential and protected from tampering or interception. Without cryptographic safeguards, sensitive engineering data such as design parameters, control signals and performance reports, may be exposed to cyber threats.

Beyond data confidentiality, cryptography also ensures the integrity and authenticity of digital engineering systems. In the development of technologies like smart grid networks, autonomous vehicle safety systems and blockchain-based logistics, the use of digital signatures and cryptographic authentication is crucial to prevent forgery and to validate legitimate communication between system components. As a result, knowledge of cryptography is increasingly becoming a critical skill for digital engineers, in line with the demands of the 4th Industrial Revolution and advancements in artificial intelligence, automation and cyber-physical systems.

But how many of us are truly aware of the mathematical influence of cryptography? Any mention of algebra, calculus, statistics, geometry and the many other branches of mathematics, often invokes a sense of fear. For most people, mathematics seems complex and is often viewed as merely numbers, theories, formulas and equations. Basic arithmetic may



not be too challenging, as it forms the foundation of mathematics - addition, subtraction, multiplication and division. However, in line with current developments, the field of mathematics has expanded with the emergence of new technologies.

One such field is cryptology, a mathematical science aimed at encrypting or concealing information and analysing encrypted data. Generally, cryptology is divided into two branches: Cryptography, the mathematical science of encrypting information and Cryptanalysis, the science of analysing encrypted data. Encrypting information is different from the common perception of simply coding data. Encryption involves transforming plain-text into cipher-text so that the original information can only be understood by authorised parties. The encrypted data will then be decrypted by trusted parties which are permitted to do so.

Coding is the process of converting information into another format that is publicly known and is intended to ease transmission. An example of a coding method is Morse Code. A key difference between encryption and coding lies in the use of a key in encryption, whereas coding does not involve any key.

Cryptology has a long and rich history. Historical records show that cryptographic tools were used as early as ancient Greek times. A device known as the scytale, which used a transposition technique, was widely used during the Spartan War (404 BC). Another widely used cryptographic technique was the Caesar Cipher, a substitution method employed by Julius Caesar (100-44 BC) during his military campaigns to expand the Roman Empire.

The earliest well-documented cryptanalysis was performed by al-Kindi (800 AD). He successfully broke ciphers using a technique called frequency analysis (studying the frequency of letters in a given language). For example, in the Malay language, the letters N, K, R, G and A are the most frequently used. If an encryption method is weak, analysing the letter frequencies in a ciphertext may reveal information about the original message.

By the 16th century, an encryption method known as the Vigenère Cipher emerged and was hailed as the “perfect cipher”. It could represent more than one plain-text message at a time, introducing confusion for cryptanalysts. This method endured until 1854, when it was broken by Charles Babbage.

Many encryption techniques were developed afterward, but none lasted long. In the 19th and early 20th centuries, scientists began researching and publishing new ideas to develop stronger encryption methods. Notable contributors include Kerckhoff (1883) and Shannon (1948). Between these periods, World War I and II saw the extensive use of encryption, especially in military communications. During World War I, the wide use of telegraphs made it possible for enemies to intercept messages. If the messages weren't encrypted, enemy forces could easily uncover secrets. However, during World War II, encryption science made a paradigm shift in human history. The Germans used a machine called Enigma, which created unreadable messages. The British Allies, especially, faced a flood of encrypted information that they couldn't decipher.

As a result, a plan was executed where British mathematicians were gathered at a place called Bletchley Park in the United Kingdom. There, they worked hard to break the encrypted German messages. This was no easy task as the Enigma machine was highly effective. It became clear that the encrypted messages couldn't be cracked with just "pen and paper". Eventually, a team at Bletchley Park, led by Alan Turing, created the first electrical computer to break the German encryptions. The electrical machine succeeded in defeating the mechanical one. The effort of the Bletchley Park team was said to shortened World War II by two years.

After the war, electrical machines and eventually electronic devices were widely used. Used initially by governments, encryption was later widely adopted by the commercial sector, especially banks. In the 1960s, numerous algorithms were created for encryption. By the 1970s, the US government introduced a symmetric encryption standard called DES (Data Encryption Standard) with a 56-bit secret key as a public standard. The widespread use of computers introduced a new problem never seen before - key management. If the parties involved were easily reachable, sharing a secret key was simple. However, if one needed

to communicate securely with thousands of clients, it was impossible to meet each one to share the secret key.

In 1976, researchers Whitfield Diffie and Martin Hellman introduced a groundbreaking concept: Unlocking something with one type of key (called key "e") and lock it with a different type of key (called key "d"). Key "e" was the public key and key "d" was the private key. In 1977, three researchers - Rivest, Shamir and Adleman - discovered the mathematical model for this system, now known as RSA. Because it used different keys for encryption and decryption, RSA was classified as asymmetric encryption.

After the RSA, other public key algorithms followed. However, none gained as much popularity among cryptographers until the 1980s, when new, smaller devices required more efficient algorithms. In 1985, Neil Koblitz introduced a public key method based on Elliptic Curves. Known as ECC (Elliptic Curve Cryptography), it steadily gained acceptance among cryptographic practitioners.

On the other hand, symmetric encryption methods such as DES became weaker and were eventually broken. The US National Institute of Standards & Technology (NIST) organised an international competition to find a new encryption algorithm, which would be named the Advanced Encryption Standard (AES).

The competition began in January 1997 and the winner was announced in October 2000. The selection criteria included a complete mathematical foundation, implementation efficiency in software and hardware and more. This meant the algorithm required a combination of mathematics, software programming and hardware engineering. Fifteen entries were received for the first round and only five made it to the final. The winner was a Belgian team - Joan Daemen and Vincent Rijmen.

Moving forward towards the quantum computer era, current asymmetric encryption were now rendered insecure. Differing from the classical computer that



operated on bits (either 0 or 1), the quantum computer operated on qubits (0 or 1 or 0 and 1). As such, the computational capabilities increased exponentially. Together with Shor's algorithm, classical hard mathematical problems such as the integer factorisation problem and discrete logarithm problem were no longer intractable. To this end, there a new breed of asymmetric cryptosystems was needed. Dubbed as post quantum cryptography (PQC), these algorithms were based upon hard mathematical problems believed to be intractable by a quantum computer.

Again, NIST was instrumental in galvanising the international community to find new standards. Beginning in 2016 and ending around 2022, NIST eventually listed 4 algorithms: CRYSTALS-Kyber, CRYSTALS-Dilithium, Falcon and SpHincs. However, challenges abound. These algorithms have large keys, large CPU cycles, not seamless replacement into existing systems and probably will interrupt current user experience. These challenges will certainly be met by mathematicians in

order to provide the best possible solution for future proof security as we enter the quantum computer era.

Malaysia is no exception in preparing for the challenges in the future. The National Cyber Security Agency (NACSA) and Universiti Putra Malaysia (UPM) are instrumental in setting up the Malaysia Cryptology Technology & Management Centre (PTPKM). At the point of inception in March 2025, the centre had around 20 experts from 6 agencies. It has various verticals mandated to ensure cryptographic security for the country. Moving towards the quantum computer era, it facilitated national PQC algorithm candidates to be evaluated and hopefully standardised.

The National PQC Migration Plan (2025-2030) is also entrusted upon the centre in order to facilitate the smooth national transition towards PQC solutions. This feat, which engages the academia, government and industries, will certainly test the resilience of Malaysia in preparations to ensure its people will be safe digitally. 🏠

Empowering Engineering Leadership for Malaysia's Digital Edge

by
Dr. Megat Zuhairy
Megat Tajuddin



I was recently invited to attend a technology conference abroad. Before the event, I had the opportunity to visit several global technology companies and what I saw left a lasting impression.

Their headquarters are not just impressive buildings but are also dynamic environments where research, development and innovation converge, with engineers at the centre of it all.

In every organisation I visited, one pattern emerged: Innovation was driven by challenges. Some came from within, others from a

fast-changing world outside. At times, these challenges were forward-looking, addressing problems that had yet to fully emerge but required pre-emptive thinking and bold solutions.

The real insight was this: None of these companies shied away from tough problems. Instead, they gave their engineers the space, resources and trust to tackle the problems head-on.

Their leadership structures often reflect this culture. Many are led by engineers who understand that great ideas do not emerge from



rigid hierarchies, but from a mindset rooted in problem-solving, analytical thinking and attention to detail. They aim for perfection and value the power of fresh thinking.

Engineering has always been about taking the difficult path - not for the sake of difficulty, but because that is where the real work lies. Challenges, after all, are just unsolved problems. Not everyone chooses this route but those who do, gain something deeper: Experience, resilience and a clarity of thought which will serve them for life.

We sometimes forget what engineering education really gives us. Yes, we study complex mathematics and physics, subjects that many give up on halfway. While most engineers do not use every formula in their daily work, the real outcome is not the equations. It is the way they shape our thinking: Structured, logical and grounded in evidence. That mindset becomes second nature and, over time, informs how we solve problems, how we lead and how we live.

Malaysia is on a journey of aggressive transformation, especially in the digital realm. If we are serious about accelerating our progress,

we need more engineers making decisions - not just technical decisions but strategic, national-level decisions which will shape our future.

Many of tomorrow's challenges are still taking form and addressing them will require foresight, clarity and technical depth. Engineers are trained to face such challenges directly. Yet often, they become so focused on solving problems behind the scenes that they overlook their own career pathways or remain absent from policy discussions. At times, this is a matter of temperament - engineers may prefer to build quietly rather than to lead visibly but this inadvertently limits how their leadership potential is recognised or supported. To shape the future with confidence, we must empower engineers to lead it.

To get there, we need to build better pathways for engineers - not only in industry but also in government, academia and leadership. Engineering is more than a profession. It is a way of thinking and a way of contributing.

If we want to shape the future, we must start engineering it - together. 

13th Malaysia Plan: New Growth Era for Engineering & Industry

by
Lee Soo Leng



When the 13th Malaysia Plan (13MP) was unveiled in 2025, the government laid out a five-year vision (2026-2030) to reshape the nation's development through inclusive growth, value-creation and strategic industrial transformation. Under that vision, engineering industries, from construction, infrastructure and manufacturing to industrial services and even emerging high-tech sectors, are set to play a pivotal role.

Key to that ambition is a combined development and private-investment thrust: 13MP projects with a total development expenditure of RM430 billion over the five years, with large expected contributions from Public-Private Partnerships (PPP), government-linked companies and private sector investments.

Construction & Infrastructure - Surge of Projects

Accelerated Public Infrastructure Build-out.

Engineering firms, especially civil, structural and infrastructure contractors, are likely to see a surge in demand. Under 13MP, authorities have earmarked:

- RM20 billion for flood mitigation projects nationwide: 103 projects to manage flood risks.
- Large-scale rural infrastructure expansion: Around 2,800km of rural roads, particularly prioritising less developed states.
- Continued investment in transport infrastructure, cross-border upgrades and public-facility development.

With the RM430 billion allocation over five years, many of these will likely be rolled out through 2026 and beyond, offering stable project pipelines for civil and construction engineering firms.

Positive Outlook for Construction Sector Growth. Analysts expect the construction industry to grow by 5.0% per year under 13MP, supported by the expected wave of public infrastructure, energy, transport and industrial-park projects. Some forecasts even suggest a modest 4% annual average for 2026-2029, buoyed by new industrial, transport and energy-related construction activity.

More Efficient Project Delivery & New Procurement Models. To support this expansion, 13MP introduces a revamped project-management mechanism, including tighter cost controls, more use of turnkey or design-and-build procurement and better coordinated land-use and land-acquisition processes. For engineering firms which can deliver design-build services, integrated project delivery and end-to-end solutions, this offers opportunities to be engaged from early design stages to final delivery.

Manufacturing & High-Value Industry From Volume to Value

Higher Growth Target for Manufacturing. Under 13MP, the manufacturing sector is targeted to grow around 5.8% per year (2026-2030), up from ~5.1% in the previous period

This shows the government's intention to reverse de-industrialisation trends and push for a stronger manufacturing backbone.

Shift to High-Value, High-Growth (HGHV) Industries. One core thrust of 13MP is to pivot towards HGHV industries - meaning sectors that emphasise technology, value-addition, innovation and competitiveness rather than just low-cost mass manufacturing. For engineers, this means growing demand in areas such as:

- Advanced manufacturing (automation, robotics, Industry 4.0).
- High-tech industrial parks (e.g. green industrial estates, high-tech zones).
- Green industry - eco-friendly manufacturing practices, sustainable industrial design, demand for ESG-compliant engineering solutions.

Talent & Skills Demand - Good News for Skilled Engineers & Technical Staff

13MP sets a target of 700,000 new jobs by 2030 in manufacturing and manufacturing-related services.

To meet this, the government will support skills training, especially via expanded technical and vocational education (TVET), as well as industry-based training programmes for automation, design, project management and green/sustainable engineering. This suggests a strong demand surge and potential for career growth.



Strategic & Emerging Opportunities Beyond Traditional Engineering

Integration of AI, Digitalisation and Smart Industry: 3MP places emphasis on digital transformation: Encouraging AI-based digitalisation of domestic supply chains, automation and smart manufacturing processes. For engineering firms, this means opportunities in designing smart factories, robotics integration, automation systems and data-driven infrastructure.

Regional & Balanced Development - Infrastructure Outside Urban Centres

With about RM93.9 billion allocated for development in less-developed states, including rural infrastructure, road/building works, basic



amenities (water, electricity, internet), there will be increased demand for civil and infrastructure engineering outside major metropolitan areas.

This decentralisation opens up opportunities for local engineering firms and contractors based outside Klang Valley or major cities - offering more equitable distribution of projects across the country.

Green & ESG-oriented Industrial & Infrastructure Projects

Under the 13MP industrial transformation agenda, the incorporation of environmental, social and governance (ESG) standards is emphasised. Therefore, there is likely to be demand for engineering expertise in sustainable building, green manufacturing facilities, renewable energy infrastructure and efficient waste/water management - especially as more projects integrate ESG from the planning stage.

Challenges & Considerations

While the 13MP provides a wealth of opportunity, successful realisation will depend on several factors:

- **Effective governance and project execution.** The government has introduced new guidelines to streamline 13MP project proposals and implementation for better cost control and timely delivery.
- **Need for skilled workforce.** The shift to high-value, high-tech and digital manufacturing demands engineers with advanced skills, not just traditional civil

or mechanical capabilities. Upskilling and training (through TVET or industry-based programmes) will be essential.

- **Private sector participation & PPPs.** Many projects will rely on PPP and private investment. Engineering firms must be capable of working in PPP models and meet higher compliance, financing and coordination standards.
- **Sustainability and ESG compliance.** As ESG becomes more embedded in industrial and infrastructure planning, firms will need to adopt sustainable design and construction practices. This may require retooling, new certifications, or expertise in green engineering.

Conclusion: Engineering as Cornerstone of Growth (2026-2030)

The 13MP lays down a bold blueprint which sees engineering - across construction, infrastructure, manufacturing and high-tech industry - as central to the country's transformation into a value-driven, competitive economy.

From massive public infrastructure work, rural development, flood mitigation and transport upgrades to advanced manufacturing, smart factories, green industry and high-value sector growth, there is significant scope for engineering professionals, firms, contractors and industry stakeholders to contribute meaningfully.

For those ready to adapt by embracing digitalisation, automation, sustainability and advanced skills, the next five years under 13MP offer substantial opportunity for growth, innovation and long-term impact on the nation's industrial trajectory. 🏗️

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ASEAN Plan of Action for Energy Cooperation 2026-2030

Powering a Low-Carbon Future

by
Amanda Lee Siek Hsia

“The next phase of ASEAN’s energy journey isn’t just about megawatts - it’s about markets, mobility and mindsets.”

South-East Asia stands on the brink of a new energy era. As economies grow and urban skylines multiply, the demand for power continues to surge. Home to over 680 million people, the region is expected to see electricity demand soar by nearly 60% by 2035 - one of the fastest growth rates in the world. Yet, this expansion unfolds amid a global call for climate responsibility. Energy choices made today will shape economic security, environmental health and social wellbeing for generations.

In this dynamic context, the ASEAN Plan of Action for Energy Cooperation (APAEC) 2026-2030 serves as the cornerstone of regional strategy. It represents the third phase of ASEAN’s long-term energy framework, following the earlier 2016-2025 plan, which focused on integration and sustainability. The 2026-2030 phase expands on these themes,

bringing renewed urgency and sharper targets to reflect the energy transition’s accelerating pace.

Energy is no longer just a national matter; it is a regional connector that shapes economies, communities and climate resilience.

ASEAN’s Long-Term Energy Vision

At the heart of APAEC lies ASEAN’s aspiration to achieve a secure, sustainable and inclusive energy future. It recognises that regional cooperation, rather than isolated national policies, is essential for success.

The plan operates under the principle of One ASEAN Community for Sustainable Energy and aligns closely with broader ASEAN blueprints on connectivity, digitalisation and climate resilience. It envisions a regional energy system that is:

- **Resilient.** Able to withstand market shocks and natural disruptions.
- **Integrated.** Allowing electricity trade and resource sharing.
- **Sustainable.** Powered increasingly by renewables.
- **People-centred.** Ensuring equitable access and affordability.

These pillars reflect ASEAN’s determination to reconcile growth with responsibility and prosperity with sustainability.

Headline Targets: Ambition Grounded in Reality

APAEC 2026-2030 sets clear, quantifiable goals to measure progress:

- 40% reduction in energy intensity from 2005 levels by 2030.
- 30% renewable share in the region's total primary energy supply.
- 45% renewable share in installed power generation capacity.

These numbers are not arbitrary. They have been crafted through rigorous analysis of energy trends, technological readiness and national capacities. The targets represent a shared but differentiated responsibility, encouraging flexibility while maintaining collective direction.

The emphasis is on balance - pushing boundaries without ignoring local realities. Countries at different stages of development can contribute through varied pathways: Solar in Vietnam, geothermal in Indonesia, bioenergy in Thailand and hydropower in Laos.

ASEAN's energy future is diverse by design, a mosaic of national strengths forming a regional powerhouse.

From Vision to Execution: Seven Strategic Programme Areas

APAEC's strength lies in its operational depth. It translates vision into tangible programmes organised around seven priority areas:

- 1. ASEAN Power Grid (APG)** - Expanding cross-border interconnections to enable multilateral electricity trading and improve system reliability.
- 2. Trans-ASEAN Gas Pipeline (TAGP)** - Enhancing natural gas and LNG networks to ensure transitional energy security.
- 3. Coal and Clean Coal Technology (CCT)** - Encouraging cleaner combustion and gradual phase-down of high-emission systems.

4. Energy Efficiency and Conservation (EE&C) - Promoting standards, labelling and digital energy management systems.

5. Renewable Energy (RE) - Accelerating deployment through feed-in tariffs, auctions and blended finance.

6. Regional Energy Policy and Planning (REPP) - Strengthening data, modelling and policy alignment across member states.

7. Civilian Nuclear Energy (CNE) - Building capacity for safe and peaceful nuclear technology development where applicable.

Collectively, these programmes create a comprehensive policy ecosystem that bridges infrastructure, technology, markets and capacity building.

Linking the Region's Future

The ASEAN Power Grid (APG) remains the flagship initiative - a long-term vision to integrate national electricity grids through cross-border interconnections.

So far, eight bilateral interconnections have been completed, with several more in advanced planning. The grid enables multilateral electricity trade, allowing surplus renewable power in one country to support deficits in another.

It also mitigates variability in renewable generation: Solar in Vietnam can complement hydropower in Laos or geothermal in Indonesia. This regional balancing mechanism will be vital as renewables expand.

The APG isn't just an engineering project; it's a symbol of ASEAN integration, transforming borders from barriers into bridges of shared progress.

Energy as an Engine for Growth

Transitioning to clean energy is often perceived as costly, but APAEC reframes it as an economic opportunity. According to the ASEAN Centre for

Energy (ACE) projections, full implementation of APAEC can mobilise over US\$180 billion in renewable and grid investments by 2030, creating millions of new jobs in construction, technology and services.

New industries, from solar module manufacturing to green hydrogen, will stimulate domestic value chains. Moreover, improved efficiency will reduce import dependency and strengthen fiscal stability.

For ASEAN, clean energy isn't just an environmental choice - it's an industrial strategy for competitiveness and innovation.

Challenges Ahead

Despite the optimism, several challenges persist.

- **Financing and Investment:** Many renewable projects struggle with bankability due to unclear pricing mechanisms, limited credit guarantees and high upfront costs.
- **Grid Infrastructure:** Ageing transmission systems are ill-equipped for variable renewable inputs.
- **Policy Fragmentation:** Divergent national regulations slow down regional harmonisation.
- **Energy Subsidies:** Fossil fuel subsidies distort market signals and hinder clean energy competitiveness.
- **Human Capital:** Skilled workforce shortages threaten timely implementation.

These barriers highlight the need for consistent policy, transparent regulation and institutional coordination. The technology is ready; the question is whether our institutions and markets are.

Financing the Transition: Blended Pathways to Scale

APAEC emphasises innovative financing models to attract both public and private capital. Blended finance, where concessional funds

de-risk private investment, has already proven effective in pilot renewable projects in Vietnam and the Philippines.

ASEAN is also exploring green bond frameworks, transition finance instruments and carbon pricing mechanisms. These tools provide long-term visibility for investors while encouraging decarbonisation.

Multilateral institutions such as the Asian Development Bank (ADB) and the World Bank continue to play key roles in providing technical assistance and low-cost capital.

Furthermore, ASEAN's collaboration with dialogue partners like Japan, the EU and South Korea provides access to advanced technologies in hydrogen, grid digitalisation and battery storage.

Financing the transition is about turning capital flows into climate flows.

Energy Security & Geopolitical Realities

Amid global uncertainties, energy security remains a core ASEAN priority.

Diversifying energy sources and supply routes through APAEC reduces vulnerability to external shocks such as fuel price volatility or supply chain disruptions.

Natural gas, while still part of the mix, is being repositioned as a transition fuel - bridging today's reliance on fossil energy with tomorrow's renewable-based systems.

Regional collaboration also strengthens collective bargaining power in energy trade negotiations and fosters technological self-reliance.

Social Dimension: Towards a Just & Inclusive Transition

A just transition ensures that no one is left behind in the energy transformation. Many ASEAN economies still depend on fossil-based

industries for employment. APAEC calls for policies that reskill workers, support affected communities and ensure equitable benefits from new industries.

Rural electrification remains another critical priority. Despite progress, around 45 million people in South-East Asia still lack reliable access to electricity. Expanding mini-grids and off-grid solar can provide clean, affordable energy to these communities.

Energy transition is not only about replacing fuels - it's about empowering people.

Technology, Innovation & Digitalisation

The 2026-2030 plan emphasises digital transformation as a catalyst for efficiency and reliability. Smart grids, advanced metering and data analytics can optimise energy flows, prevent outages and integrate distributed renewables seamlessly.

Innovation clusters and technology incubators, such as those emerging in Singapore and Thailand, are fostering regional startups in energy storage, carbon capture and green hydrogen.

Digitalisation will also enhance transparency in carbon accounting and renewable certification, improving investor confidence and consumer participation.

Monitoring Progress: Metrics & Accountability

To ensure accountability, ASEAN will track progress through key performance indicators (KPIs), including:

- Annual reduction in energy intensity.
- Renewable share in TPES and installed capacity.
- Number of cross-border grid projects completed.
- Amount of private investment mobilised.

- Greenhouse gas reduction relative to baseline.
- Socioeconomic indicators such as jobs created and rural electrification rates.

Regular peer reviews and scorecards will allow benchmarking and course correction - ensuring that policy ambition translates into measurable results.

Lessons from Previous APAEC Phases

Earlier APAEC phases (2016-2025) demonstrated both progress and limitations. ASEAN successfully increased renewable capacity and launched several interconnection projects, but the pace of integration remained uneven. The 2026-2030 phase builds upon these lessons with greater focus on:

- Policy harmonisation instead of isolated initiatives.
- Private-sector engagement rather than state-dominated models.
- Cross-sectoral collaboration linking energy, industry and transport.

This evolution signifies ASEAN's maturity as a regional energy community.

Role of International Cooperation

APAEC is not pursued in isolation. It aligns with global frameworks such as the UN Sustainable Development Goals (SDG7), the Paris Agreement and the Global Stocktake process under the UNFCCC.

Collaboration with partners like the International Renewable Energy Agency (IRENA), IEA and the Clean Energy Ministerial (CEM) ensures that ASEAN stays connected to global knowledge networks.

Such partnerships also bring access to innovation, training and investment - vital ingredients for sustained progress.

Malaysia's Perspective: National Transformation Aligned with Regional Goals

While APAEC takes a regional view, each country contributes uniquely. Malaysia, for instance, is implementing its National Energy Transition Roadmap (NETR), which aligns closely with the APAEC principles.

The NETR outlines six energy transition levers: Renewable energy, hydrogen, bioenergy, energy efficiency, carbon capture and green mobility. It aims to attract RM1.85 trillion in cumulative investment by 2050.

Malaysia's Corporate Green Power Programme, Third-Party Access (TPA) system and Large-Scale Solar (LSS) schemes demonstrate how domestic reforms can reinforce regional objectives.

Additionally, Malaysia's geographic position - connected to Singapore, Thailand and Indonesia - makes it a strategic node in the ASEAN Power Grid. Its experiences in grid modernisation and energy governance offer valuable insights for regional coordination.

Human capital development is another area of contribution. Through institutions such as the Sustainable Energy Development Authority (SEDA) and Energy Commission (Suruhanjaya Tenaga), Malaysia has developed training modules, standards and certification systems that can be shared across ASEAN.

Malaysia's progress in policy design and renewable integration serves not as leadership, but as partnership - strengthening the collective ASEAN capacity to move forward.

Looking Ahead: The Road to 2030 & Beyond

APAEC 2026-2030 is not an endpoint, but a launchpad for deeper integration. By 2030, ASEAN aspires to have a partially unified energy market supported by cross-border power trading, diversified renewables and digital-smart grids.

Beyond 2030, the region will begin shaping its post-carbon strategy, focusing on hydrogen corridors, carbon capture utilisation and storage (CCUS) and electrified transport systems.

The ultimate goal is to establish ASEAN as a global model for cooperative energy transition - one that balances growth, inclusion and sustainability.

Conclusion: Turning Vision into Reality

APAEC 2026-2030 stands as a powerful statement of collective ambition and shared responsibility. It captures ASEAN's determination to move beyond incremental progress toward a truly transformative regional energy future. The plan acknowledges the diversity of its member states - from resource-rich economies to small island nations - yet binds them through common aspirations: energy security, affordability, sustainability and resilience.

Turning this vision into reality will require unwavering commitment, coordination and creativity. Governments must establish stable policies and regulatory certainty, private investors must bring in capital, technology and innovation and societies must adapt through education, awareness and inclusive participation. Regional mechanisms such as the ASEAN Power Grid, cross-border trade frameworks and technology partnerships will be instrumental in ensuring that progress is both tangible and equitable.

If pursued with consistency and courage, APAEC 2026-2030 will redefine South-East Asia's economic and environmental landscape, shifting from dependence on fossil energy imports to a dynamic system powered by renewable innovation and regional cooperation. It represents not just an energy plan, but a collective leap toward shared prosperity and climate resilience.

Energy is the bloodstream of ASEAN's development. With APAEC 2026-2030, that bloodstream will run cleaner, stronger and more connected than ever before. 🌱

Engineering for Climate Change Mitigation & Sustainability: Integrating ESG in Modern Engineering Practice

by
Cheo Hong Keyong



Climate change is one of the defining global challenges of the 21st century. Engineering professionals stand at the forefront of developing solutions to reduce greenhouse gas (GHG) emissions and to support sustainable development. As Environmental, Social & Governance (ESG) reporting becomes mandatory across regions, engineers must understand how their work influences all three emission categories: Scope 1, Scope 2 and the increasingly critical Scope 3.

Scope 3 emissions, which arise indirectly across the entire value chain, often make up the largest share of an organisation's carbon footprint. This broadens the responsibility of engineers to design systems, materials, processes and supply chains that minimise environmental impact from cradle to grave.

In this article, we will explore how engineering can drive climate change mitigation and sustainability while aligning with ESG expectations across all emission scopes.

Understanding ESG and Emission Scopes

1. ESG as a Framework for Sustainable Engineering

ESG reporting strengthens accountability in how companies manage energy, waste, emissions, workers' welfare and governance. For engineers, the "E" (Environmental) pillar is particularly relevant as it encompasses carbon footprint, resource use, pollution control and climate resilience.

2. Scope 1. Direct Emissions

These are emissions from sources owned or controlled by an organisation and include:

- On-site fuel combustion (boilers, furnaces, diesel generators).
- Company fleet and machinery.
- Fugitive emissions (e.g., refrigerants).

Engineers influence these through efficient design, clean technologies and equipment optimisation.

3. Scope 2. Indirect Energy Emissions

These arise from purchased electricity, steam, heating, or cooling. Engineers can reduce Scope 2 through:

- Energy-efficient building services.
- Renewable energy adoption.
- Smart automation and demand management.

4. Scope 3. Value Chain Emissions

Scope 3 covers all indirect upstream and downstream emissions, including:

- Purchased materials and construction activities.
- Transportation and logistics.
- Waste generation during operations.
- Use-phase of engineered products.
- End-of-life disposal.
- Business travel and employee commuting.

Scope 3 is the most complex and largest category, requiring whole-life-cycle thinking and cross-industry collaboration.

Engineering Strategies for Climate Change Mitigation

1. Life-Cycle and Scope 3 - Focused Design

Engineers must shift towards whole-life carbon assessments, considering emissions from:

- Material extraction.
- Manufacturing and fabrication.
- Construction and installation.
- Operation and maintenance.
- Decommissioning and recycling.

Decisions on material selection such as choosing low-carbon steel, recycled concrete and timber structures, can significantly reduce Scope 3 emissions.

2. Energy Efficiency and Low-Carbon Systems

Efficiency remains the most effective mitigation measure. Key engineering approaches include:

- High-efficiency motors, pumps and compressors.
- Variable speed drives and automation.
- Thermal insulation and passive design.
- Heat recovery and cogeneration.

These reduce Scopes 1 and 2 emissions substantially.

3. Renewable Energy Integration

Engineering makes renewable energy adoption feasible through:

- Solar PV and solar farms.
- Wind and hydropower systems.
- Bioenergy and waste-to-energy plants.
- Grid modernisation to stabilise intermittent renewables.

This reduces Scope 2 and can influence Scope 3 (e.g., cleaner supply chains).

4. Electrification and Clean Mobility

Replacing fossil-fuel-based systems decreases Scope 1 emissions. Engineering roles include:

- EV charging infrastructure.
- Electrified industrial processes.
- Battery energy storage design.
- Hydrogen supply chains for steel, cement and heavy transport.

5. Circular Economy Engineering

Circularity reduces Scope 3 emissions significantly by limiting material extraction and waste. Engineers contribute by:

- Designing modular, repairable and recyclable products.
- Implementing waste-to-resource systems.
- Using reclaimed materials.
- Incorporating industrial symbiosis (e.g., using waste heat from one plant as energy for another).

6. Climate-Resilient Infrastructure

Designing for climate resilience aligns with long-term sustainability:

- Flood mitigation systems.
- Erosion and slope stability engineering.
- Water resource management.
- Heat-resilient urban planning.

Integrating ESG into Engineering Practice

1. Carbon Accounting in Engineering Decisions

Engineers now require skills in:

- Quantifying Scopes 1, 2 and 3 emissions.
- Conducting carbon footprint and life-cycle assessments.
- Comparing carbon performance of design alternatives.
- Advising clients on decarbonisation pathways.

2. Meeting International Standards and Frameworks

Sustainable engineering aligns with standards such as:

- Greenhouse Gas Protocol (Scope 1, 2, 3).
- ISO 14064 (GHG management).
- ISO 50001 (energy management).
- Science-Based Targets initiative (SBTi).
- Global Reporting Initiative (GRI).
- Green building certifications (GBI, LEED, BREEAM).

3. Digital Engineering for Sustainability

Digital tools strengthen sustainability outcomes through:

- Digital twins for performance optimisation.
- AI-based predictive models for energy and emissions.
- IoT sensors for real-time monitoring.
- Big data analytics for ESG reporting.

Sector-Based Examples

Industrial Sites

- Fuel switching, heat recovery and clean boilers reduce Scope 1.
- Energy-efficient equipment lowers Scope 2.
- Sustainable procurement and waste minimisation reduce Scope 3.

Construction and Infrastructure

- Material optimisation and low-carbon cement significantly reduce Scope 3.
- Smart building systems cut Scope 2 electricity use.
- Electrified equipment and machinery help reduce Scope 1.

Transportation

- Mass transit engineering reduces Scope 3 related to passenger mobility.
- EV infrastructure reduces Scope 1 from fleets.

Water and Waste Management

- Biogas from wastewater mitigates Scope 1 methane emissions.
- Renewable energy integration lowers Scope 2.
- Circular waste systems reduce Scope 3 impacts.

Conclusion

Engineering is pivotal in addressing climate change through technology, innovation and sustainable design. As ESG reporting expands to include the full spectrum of emission scopes, engineers must adopt holistic approaches that integrate efficiency, renewable energy, material selection, life-cycle assessments and digital technologies.

Scopes 1 and 2 measures remain essential, but the inclusion of Scope 3 elevates engineering responsibility across the entire value chain. Through proactive leadership and sustainable project delivery, engineers can drive meaningful climate mitigation, support global decarbonisation goals and build a resilient future for society. 🌱

Reference

1. International Organization for Standardization (ISO)
2. Global Reporting Initiative (GRI)
3. Science-Based Targets initiative (SBTi)
4. World Green Building Council (WGBC)
5. Intergovernmental Panel on Climate Change (IPCC)
6. United Nations Environment Programme (UNEP)

Transforming Engineering Practice with AI Predictive Tools

by
Samniang Saenram

Artificial Intelligence (AI) is one of the most transformative forces in engineering and construction. Around the world, engineering firms, governments and construction companies are adopting AI-powered predictive tools to improve accuracy in planning, reduce cost overruns, prevent delays and enhance risk management.

As infrastructure grows increasingly complex and sustainability expectations continue to rise, engineers are now expected to integrate AI into decision-making, design processes and project delivery. In 2022, the Board of Engineers Malaysia (BEM) conducted a survey among Engineering Consultancy Practices (ECPs) to assess the adoption of emerging technologies. The findings showed that digitalisation adoption stood at only 38.91%, indicating significant room for improvement and further advancement within the industry.

Why AI Matters in Modern Engineering Practice

Engineering projects frequently face challenges such as schedule delays, resource shortages, unforeseen design conflicts and safety risks. Traditional planning tools rely heavily on human judgement, which may overlook hidden patterns. AI predictive tools help engineers by:

- Analysing vast amounts of project data to detect early warnings.
- Forecasting schedule risks before they occur.

- Optimising resource allocation (labour, machinery, materials).
- Predicting equipment failure using real-time data.
- Improving site safety by identifying high-risk patterns.
- Enhancing decision-making with data-driven insights.

All these enable engineers to deliver projects on time, within budget and with improved safety performance.

Key AI Technologies in Construction & Engineering

1. Machine Learning for Schedule Prediction

AI compares historical project performance with ongoing progress to forecast which activities will likely be delayed, how delays can cascade and which mitigation strategies are most effective.

2. Predictive Analytics for Resource Optimisation

AI can simulate different resource allocation scenarios and recommend the most efficient combination of workforce distribution, equipment usage and material supply chains.

3. Digital Twin Technology

A digital twin integrates real-time data from sensors, equipment and BIM models to predict structural behaviour, monitor equipment health and identify deviations from design.



4. Natural Language Processing (NLP)

Used to scan reports, drawings and contracts to identify safety issues, inconsistencies in specifications and early contractual risks.

5. AI-Powered Risk Assessment Tools

These tools combine geotechnical, structural and environmental data to predict slope failures, estimate structural service life and evaluate construction risks before approval.

Global Trends: How the World is Adopting AI Predictive Tools

AI adoption in engineering is growing rapidly worldwide. Major trends include:

1. Government-Led Digital Construction Initiatives

- Singapore integrates AI with BIM through its CORENET X platform.
- UK mandates digital project delivery for most public-sector infrastructure.
- Japan invests heavily in AI-driven automation to address labour shortages.

2. AI in Infrastructure Megaprojects

Large-scale projects increasingly rely on AI simulation and predictive systems:

- High-speed rail corridors.
- Smart cities.
- Underground metro expansion.
- Renewable energy infrastructure.

3. AI for Sustainable and Green Construction

AI helps reduce carbon footprint by predicting:

- Material usage.
- Energy consumption.
- Optimal building orientation and façade performance.

4. AI for Safety and Compliance

Tools monitor worker movement, weather patterns and equipment to prevent accidents.

Real-World Examples from Around the Globe

United States. Predictive Scheduling with ALICE Technologies. ALICE uses AI-generated simulations to optimise construction schedules.

Used in: Bridges and tunnels, commercial buildings, high-rise construction and identifies millions of sequencing options and recommends the optimal path.

United Kingdom. HS2 High-Speed Rail Digital Twin.

The HS2 megaproject uses digital twins and AI to predict maintenance during construction, prevent clashes and monitor geotechnical risks.

Japan. AI for Equipment Failure Prediction. Construction companies deploy IoT sensors and AI to predict crane component failure, excavator hydraulic issues and concrete pump maintenance needs. This reduces downtime and improves safety.

Singapore. Smart Construction Sites. AI-powered systems are used to predict worker congestion, monitor unsafe behaviour via cameras and optimise resource deployment in real time. This is integrated within BCA's digital built environment frameworks.

China. AI for Mega Housing and Prefab Construction. AI predicts factory production rates and delivery patterns for large-scale prefabricated housing, ensuring timelines are maintained.

Middle East. AI for Mega Infrastructure and Smart Cities. AI predictive tools are widely used in projects such as NEOM (Saudi Arabia) to simulate construction sequencing, logistics, worker allocation and climate-related risks.

How AI Improves Key Areas of Engineering Practice

Timeline Optimisation. AI identifies schedule risks early and provides alternative sequences.

Benefits:

- Realistic scheduling.
- Early warning when activities drift.
- Ability to plan recovery measures.

Resource Management. AI predicts the most efficient resource mix based on project stage.

Benefits:

- Reduced wastage.
- Optimised labour and machinery use.
- Better material lead-time planning.

Risk Management. AI highlights high-risk areas during design, planning and construction.

Benefits:

- Improved safety.
- Reduced insurance claims.
- Better contract management.

Improved Communication and Reporting. AI systems automatically summarise:

- Progress delays
- Cost variances
- Safety alerts
- On-site conditions

Enhancing Competencies and Professional Practice. Engineers increasingly must:

- Interpret AI-generated data.
- Validate AI predictions.
- Integrate AI with BIM, GIS, sensors.
- Use AI insights to support professional judgement.

Conclusion

AI-powered predictive tools are reshaping engineering practice worldwide. From optimising timelines and resources to improving safety and risk assessment, AI provides engineers with insights which were previously impossible using conventional methods. Countries like the USA, UK, Japan, Singapore and China are leading the adoption of AI in construction, setting global benchmarks for efficiency and innovation.

For engineers in Malaysia and the region, the integration of AI into project delivery presents an opportunity to enhance competitiveness, build higher-quality infrastructure and shift toward data-driven, sustainable engineering. The future engineer will not replace AI but engineers who use AI will outperform those who do not. 🤖

Engineering the Human Factor:

Elevating Safety Management and Occupational Health from Compliance to Core Ethos

by
Tho Yoke Lai

In the grand narrative of engineering, triumphs of innovation dominate the headlines: The world's longest suspension bridge, the most efficient renewable energy grid, the revolutionary biodegradable polymer etc.

These achievements, celebrated for their technical brilliance and societal impact, form the legacy of the profession. Yet, beneath every equation, every CAD model and every stress analysis lies a silent, non-negotiable priority that underpins all truly ethical and successful practice: The unequivocal safety and health of the people who build, operate, maintain and live alongside these creations.

For the 21st century engineer, a sophisticated and unwavering focus on Safety Management & Occupational Health is no longer a peripheral concern relegated to the site safety officer or a regulatory checklist. It has evolved into a fundamental pillar of design philosophy, a profound moral imperative and a critical determinant of long-term project viability and legacy. This article argues that for engineering to fully meet its potential in serving humanity, safety must be re-engineered moving from a reactive constraint to a proactive, creative and central component of the engineering process itself.

Paradigm Shift from Reactive Compliance to Proactive Culture

Historically, the relationship between engineering and safety was often sequential and reactive. Safety protocols were frequently codified in response to tragedy lessons written in blood, from the industrial accidents of the 19th century to structural collapses of the 20th. Safety was perceived as a cost centre, a set of rules imposed after the design was complete, managed primarily during the construction phase.

This model is catastrophically outdated. Modern safety management demands a foundational paradigm shift, requiring engineers to become proactive architects of safety culture. This culture must be seeded at the very earliest conceptual stage through the principle of Prevention through Design (PtD). PtD posits that the most effective, reliable and economical method to mitigate risk is to eliminate or minimise it at the drawing board, before it ever reaches the worksite or the user.

For the engineer, this transforms the core questions of a project. It is no longer sufficient to ask, "Can it be built?" or "Will it function?". The essential queries become: "Can it be built safely by the workers using foreseeable methods?", "Can it be operated and maintained without

exposing personnel to undue risk across its entire life-cycle?” and “How does it fail and can it fail safely?”

These require foresight that extends beyond material strengths and load capacities to encompass human behaviour, logistical sequences and long-term degradation.

Expanding Engineering Toolkit: A Holistic Approach to Risk

Embracing this proactive stance equips the engineer with a diverse and dynamic toolkit that extends far beyond mandating hard hats and guardrails. It represents a new dimension of technical and social competency.

- 1. Advanced Risk Assessment & Mitigation:** Moving beyond instinct, engineers must master structured, systemic methodologies. Job Safety Analysis (JSA) breaks down tasks step-by-step to identify hazards. HAZOP (Hazard and Operability Study) uses guided brainstorming to probe how a process or system might deviate from its design intent. Quantitative Risk Assessment (QRA) employs probabilistic models to estimate the likelihood and consequence of major accident hazards. These are not mere paperwork exercises but are, instead, rigorous analytical tools which force a deep interrogation of design assumptions and operational realities.
- 2. Human Factors and Ergonomics Engineering:** This discipline recognises that the human element is integral to every system. Engineering must actively account for human capabilities, limitations and predictable errors. This translates to designing control panels that reduce cognitive overload and prevent mode confusion (a factor in everything, from industrial plant accidents to aviation disasters). It involves planning workspaces and tools to minimise

repetitive strain and musculoskeletal disorders. It means considering how a maintenance technician, often working under pressure and in confined spaces, will safely access a valve or replace a component. A well-designed human-machine interface is not a luxury; it is a critical safety system.

3. Management of Psychosocial Hazards:

The frontier of occupational health now clearly includes the psychological environment. Engineers, particularly those in project management and systems design roles, must consider the safety implications of excessive workload, unrealistic deadlines, poor communication channels and toxic workplace culture. Chronic stress and fatigue are insidious hazards which degrade decision-making, attention and reaction time, directly contributing to incidents. Designing manageable workloads and fostering a culture where workers feel psychologically safe to report concerns or near-misses is an engineering responsibility that impacts system safety.

- 4. Data-Driven and Predictive Safety:** The 4th Industrial Revolution offers powerful new allies. The Internet of Things (IoT), wearable sensors and machine learning algorithms enable a shift from periodic inspections to continuous, intelligent monitoring. Engineers can design systems where vibration sensors predict equipment failure before it occurs, environmental sensors provide real-time data on air quality or toxic gas levels and computer vision algorithms identify unsafe behaviours such as entering exclusion zones. This data transforms safety management into a predictive and preventive feedback loop, allowing for interventions before an incident happens.
- 5. Lifecycle Responsibility and Sustainable Safety:** An engineer's duty of care extends from cradle to grave.

True safety management includes planning for safe decommissioning, demolition and disposal or recycling. This is where the principles of the circular economy powerfully intersect with safety. Designing for disassembly, specifying materials that are less hazardous at end-of-life and eliminating toxic components not only benefits the environment but also protects the workers who will handle the structure or product at its conclusion. Sustainable engineering is, by its nature, safer engineering.

Multidisciplinary Imperative: Shattering the Silo

No engineer is an island, especially when it comes to safety. Effective safety management demands the dissolution of professional silos and fosters deep, integrated collaboration. The modern engineer must be a convener and a translator who can work seamlessly with:

1. **Occupational Health Physicians and Hygienists:** To understand the toxicology of materials, establish safe exposure limits for dusts, fumes and noise and design effective ventilation and containment systems.
2. **Social Scientists and Organisational Psychologists:** To help shape a positive safety culture, understand group dynamics and design interventions that encourage safe behaviours rather than merely enforcing compliance.
3. **Legal and Regulatory Compliance Experts:** To navigate an increasingly complex global landscape of standards (like ISO 45001) and regulations, ensuring that designs are not only technically sound but also legally defensible.
4. **Most Crucially, Frontline Workers and End-Users:** Their tacit knowledge, the know-how gained from daily hands-on experience, is an invaluable, often untapped resource for identifying unforeseen hazards and developing practical, workable safety solutions. A safety plan created without their input is a plan built on incomplete data.

The Unassailable Case: Why This Focus is Non-Negotiable

The argument for centering safety management is compelling across all dimensions of engineering value.

1. **The Ethical Imperative:** At its heart, engineering is a profession granted a social licence to improve the human condition. The foundational tenet of this licence is “to hold paramount the safety, health and welfare of the public”. This is not a slogan but a covenant. Protecting lives and well-being is the highest duty, outweighing considerations of cost, schedule, or even aesthetic ambition.
2. **The Business and Financial Case:** Robust safety management is a strategic advantage, not a drain. It directly reduces hard costs associated with worker compensation, insurance premiums, regulatory fines and litigation. More significantly, it mitigates immense indirect costs: Project delays from incident investigations, damage to equipment and materials, loss of productivity due to absenteeism and low morale and the devastating cost of retraining replacement personnel. A safe worksite is an efficient, focused and productive worksite. Furthermore, a strong safety record enhances corporate reputation, making a firm more attractive to clients, investors and top-tier talent.
3. **The Legal and Social Licence to Operate:** In an era of heightened corporate accountability and social media scrutiny, failures in safety can be existential. Regulatory bodies worldwide are strengthening enforcement. Communities are less tolerant of organisations perceived to prioritise



profit over people. Systematic safety management, certified to international standards, provides a demonstrable framework for due diligence and is essential for maintaining the trust and permission to operate from society.

Call to Action: Integrating Safety into the DNA of Engineering

For this paradigm shift to be complete, a dual transformation is required in both education and professional practice.

1. **For Education:** Safety must be liberated from being a single, isolated module in an engineering curriculum. It must become a golden thread woven through every core subject. In a structures class, discuss scaffold design and collapse prevention. In a fluid mechanics class, examine overpressure hazards and relief system design. In a project management

class, integrate safety-based scheduling and the cost of safety vs. the cost of failure. Universities must produce graduates for whom safety-conscious design is as instinctive as calculating a moment force.

2. **For Professional Practice and Leadership:** Senior engineers and project leaders must champion this culture. It requires the courage to pause a project over safety concerns, to allocate budget for PtD workshops and to reward teams for identifying risks early. Professional institutions must mandate continuing education in advanced safety management and human factors. Career advancement should be linked not only to technical achievement but also to demonstrated leadership in safety outcomes.

Conclusion: The Safest Design is the Truest Design

The ultimate measure of the success of an engineering project is not merely that it stands or functions as intended, but that it leaves no trail of harm in its wake, from the quarry where its materials originated, through the bustling construction site, over the decades of operation, to its final decommissioning.

By placing Safety Management and Occupational Health at the very core of their practice, engineers do more than prevent accidents and illnesses. They build trust with the public. They foster resilient organisations and systems. They attract and retain the best talent. They uphold the integrity and honour of their profession.

In this light, the safest design is not a compromised one but is, instead, the most elegant, robust, humane and ultimately, the most enduring engineering solution of all. It is a testament to the fact that the field's greatest triumph is not in conquering the forces of nature, but in safeguarding the human spirit that endeavours to do so. 🏡

Engineering Pathways in APEC Leaders' Declaration 2025: Integrating Innovation, Sustainability and Inclusivity

by
Mary Foo Mee Sim

The APEC Leaders' Declaration 2025 presents a renewed framework for advancing sustainable, inclusive and innovation-driven growth across the Asia-Pacific region. For the engineering profession, the Declaration provides both direction and opportunity - emphasising the pivotal role of technology, digitalisation, green transition and human capital development. It presents implications for the engineering sector, exploring how its policy priorities intersect with the challenges and responsibilities of engineers in achieving resilient infrastructure, low-carbon transformation and cross-border professional mobility.

Drawing from the APEC Putrajaya Vision 2040, the Aotearoa Plan of Action and the APEC Engineer framework, the 2025 agenda guides policy alignment, professional practice and educational reforms in the engineering domain across member economies, including Malaysia.

Since its establishment in 1989, the Asia-Pacific Economic Cooperation (APEC) forum, comprising 21 member economies, has evolved into one of the world's most influential platforms for regional economic and technical cooperation. The APEC Leaders' Declaration 2025, issued under the theme, *Building a Resilient & Sustainable Future Together*, articulates a collective



commitment to advancing sustainability, inclusion and innovation. While APEC operates on voluntary and consensus-based principles, its declarations have shaped national policies and professional standards, particularly in fields where international collaboration is indispensable, such as engineering.

Engineering sits at the heart of APEC's development vision. The profession underpins infrastructure, energy systems, water security and digital transformation, all central to the aspirations of the Declaration. As member economies accelerate transitions toward low-carbon growth, engineers are expected to not only deliver technological solutions but also to uphold ethical and environmental stewardship. This paper analyses the 2025 Declaration from the perspective of engineering policy, practice and education, connecting APEC's regional goals to the evolving global discourse on sustainable development and professional mobility.

Policy Context: APEC 2025 & Putrajaya Vision 2040

The APEC Leaders' Declaration 2025 builds upon the Putrajaya Vision 2040, adopted during Malaysia's 2020 host year, which envisions "an open, dynamic, resilient and peaceful Asia-Pacific community by 2040". The Vision's three drivers - trade and investment, innovation and digitalisation and strong, balanced, secure, sustainable and inclusive growth - frame the 2025 commitments.

The 2025 Declaration reaffirms these ambitions but introduces sharper priorities, notably:

- Accelerating the net-zero transition through renewable energy, circular economy and sustainable infrastructure.
- Enhancing digital connectivity and capacity building to bridge technological divides.
- Fostering women and youth participation in STEM and professional domains.
- Strengthening human capital mobility, particularly through recognition frameworks such as the APEC Engineer Register.

For the engineering sector, these priorities are more than aspirational statements - they represent operational imperatives. Each goal

links directly to engineering competencies

- design for sustainability, digital systems integration and inclusive workforce development
- reinforcing APEC's reliance on engineering excellence to realise its vision.

Engineering & Sustainable Infrastructure Development

Sustainable infrastructure is a recurring motif across APEC policy instruments. Both the APEC Connectivity Blueprint (2015-2025) and the 2025 Declaration recognise infrastructure as a "key enabler of economic integration and social resilience". Engineering, therefore, becomes the executor of APEC's sustainability agenda.

1. Decarbonisation and Green Design

Engineers are increasingly expected to deliver infrastructure compatible with net-zero emissions pathways. The 2025 Declaration explicitly supports the development of low-carbon cities, renewable energy (RE) corridors and smart mobility systems. These commitments align with international frameworks such as the Paris Agreement and the UN Sustainable Development Goals (SDGs 7, 9, 11 and 13).

Civil, mechanical and electrical engineers play a crucial role in operationalising these targets. The integration of life-cycle assessment, energy-efficient materials and adaptive design methods demonstrates how engineering principles directly translate sustainability policy into measurable impact. Moreover, APEC's Green Infrastructure Investment Network (GIIN) promotes cross-border investment in climate-resilient projects, offering new frontiers for engineering consultancies and contractors in member economies.

2. Resilience and Disaster Risk Reduction

Given that the Asia-Pacific region experiences over 70% of global natural disasters annually, resilience engineering is vital. The 2025 Declaration calls for strengthening risk-informed infrastructure

planning and regional knowledge sharing. Engineers must now embed climate and seismic resilience into project life cycles - from site selection to maintenance - supported by digital twin technologies and remote sensing.

Collaborative projects under APEC's Disaster Risk Reduction (DRR) Working Group illustrate how shared engineering expertise enhances community resilience and recovery planning.

Digital Transformation & Future of Engineering

Digitalisation forms the backbone of the APEC 2025 agenda. As economies move toward the digital economy, engineers are both drivers and beneficiaries of this transformation. The Declaration emphasises data interoperability, cybersecurity and innovation ecosystems, all of which rely on engineering disciplines such as systems design, automation and artificial intelligence (AI).

1. Engineering 4.0 and Smart Technologies

Digital engineering - encompassing Building Information Modelling (BIM), Internet of Things (IoT) and AI-assisted design - represents the convergence of traditional engineering with data science. APEC's focus on digital infrastructure enhances productivity, safety and sustainability. For instance, smart grids, precision agriculture and intelligent transport systems illustrate how engineering innovation contributes directly to economic competitiveness and environmental goals.

2. Digital Skills and Professional Readiness

However, digital transformation requires human readiness. The Declaration's commitment to capacity building and skills mobility signals a policy shift toward cross-disciplinary education. Engineering faculties across APEC economies are now encouraged to incorporate digital

literacy, ethics and systems thinking into curricula. Initiatives such as APEC's STEM Education Network and Malaysia's National 4th Industrial Revolution (4IR) policy demonstrate alignment between regional declarations and domestic education reform.

Women's Participation & Inclusive Engineering

A defining feature of the 2025 Declaration is its emphasis on gender equality and inclusion. APEC leaders reaffirmed their support for the La Serena Roadmap for Women and Inclusive Growth (2019-2030), urging all sectors, particularly STEM and engineering, to increase female participation and leadership.

1. Global and Regional Perspectives

Globally, women remain under-represented in engineering, accounting for less than 20% of the professional workforce in most APEC economies. Structural barriers include stereotypes, limited mentorship opportunities and unequal access to technical education. The Declaration promotes gender-responsive policy design, including targeted scholarships, workplace flexibility and professional accreditation support.

2. Malaysia's Commitment

Malaysia has progressively aligned with APEC's gender goals through the National Policy on Women (2021-2030) to promote women in professional registration and leadership. Universities and industry networks have introduced mentorship programmes echoing APEC's inclusivity vision.

Empirical studies indicate that gender diversity enhances creativity and decision quality in engineering teams. Thus, the Declaration's call for inclusive participation is both a moral and economic imperative, ensuring that the engineering workforce reflects the societies it serves.

Professional Mobility & APEC Engineer Framework

Engineering is inherently transnational and the APEC 2025 Declaration recognises human capital mobility as central to innovation diffusion. The APEC Engineer Register, established in 2000, remains a cornerstone mechanism for facilitating cross-border professional recognition among member economies.

1. Role of Mutual Recognition

The Register provides a benchmark for recognising engineers with substantial professional competence and experience (minimum seven years), enabling them to be recognised across participating economies without redundant assessments. This mutual recognition fosters mobility, encourages knowledge exchange and strengthens professional accountability. The 2025 Declaration reaffirms commitment to such frameworks, advocating for expanded participation and harmonisation with digital credentialing systems.

2. Challenges and Opportunities

Despite progress, differences in regulatory environments, liability laws and engineering codes still hinder full portability. To address this, the Declaration calls for regulatory coherence and capacity alignment. The APEC Human Resources Development Working Group (HRDWG) continues to promote competency frameworks that bridge gaps between education, industry and policy.

For Malaysia, participation in the APEC Engineer Register enhances the international recognition of local engineers, positioning them competitively in global markets, particularly within ASEAN and East Asia. It also supports Malaysia's ambition under the 12th Malaysia Plan (2021–2025) to expand the export of professional services.

Engineering Ethics, Governance & Policy Integration

The APEC Leaders' Declaration 2025 extends beyond economic policy; it implicitly demands ethical governance and accountability in technological deployment. Engineering ethics, therefore, must evolve alongside policy expectations.

1. Ethical Engineering for Sustainable Development

Ethical engineering involves more than compliance with safety codes; it also encompasses environmental justice, equity and intergenerational responsibility. As economies pursue carbon neutrality, engineers must navigate dilemmas surrounding cost, innovation and public interest. APEC's Policy Partnership on Science, Technology & Innovation (PPSTI) encourages embedding ethical impact assessments in technology projects, aligning engineering decisions with community values.

2. Governance and Cross-Sector Collaboration

Effective implementation of the Declaration requires multi-stakeholder collaboration. Engineers must work alongside policymakers, financiers and social scientists to operationalise sustainability indicators. Governance frameworks such as Malaysia's National Sustainable Infrastructure Policy (2023) reflect this integrated approach, ensuring that engineering designs support national commitments under APEC and the UN SDGs.

Building the Next Generation of Engineers

The Declaration's focus on innovation and human capital emphasises the need for educational transformation. Engineering education must respond to evolving technological and environmental challenges through interdisciplinary and experiential learning.



1. Curriculum Modernisation

Universities across APEC are aligning curricula with emerging areas such as renewable energy systems, data-driven design and sustainable manufacturing. Accreditation frameworks, including the Washington Accord, ensure that engineering programmes meet international quality benchmarks. The Declaration reinforces these initiatives by promoting mutual recognition of qualifications and industry-academia collaboration.

2. Lifelong Learning and Upskilling

In a rapidly evolving digital economy, lifelong learning becomes a professional necessity. The Declaration calls for continuous reskilling initiatives supported by governments and industries. Malaysia's Human Resources Development Corporation (HRD Corp.) provides an example through funded technical programmes which align with APEC's upskilling agenda, preparing engineers to adapt to AI, robotics and green technologies.

energy interconnectivity and logistics networks all depend on coordinated engineering planning.

1. Cross-Border Infrastructure Corridors

Projects such as the ASEAN Power Grid and the Trans-Asian Railway illustrate how regional engineering cooperation supports sustainable growth. The Declaration's call for quality infrastructure investment invites engineers to lead feasibility studies, standardisation and monitoring processes.

2. Knowledge Sharing and Technical Cooperation

APEC's cooperative model facilitates the exchange of technical expertise among member economies. Engineers contribute to policy dialogues through APEC's working groups and public-private partnerships, translating policy frameworks into actionable projects. The emphasis on open data and digital standards further enhances transparency and replicability of engineering solutions across borders.

Engineering Contributions to Regional Integration

Engineering underpins the physical and digital integration that APEC envisions. Trans-border infrastructure, renewable

Challenges in Implementing the Declaration's Engineering Agenda

Though the 2025 Declaration provides a visionary roadmap, implementation challenges persist.

1. **Regulatory diversity.** Varying licensing requirements and professional standards complicate mutual recognition.
2. **Resource disparities.** Developing economies face constraints in financing and technological capacity for sustainable infrastructure.
3. **Climate vulnerability.** Increased disaster risks strain engineering resources and demand stronger adaptive design practices.
4. **Ethical governance.** Rapid adoption of AI and automation requires ethical oversight to prevent misuse or inequitable impacts.
5. **Public perception.** Engineers must communicate more effectively with policymakers and communities to ensure trust and transparency.

Addressing these challenges necessitates joint efforts between governments, professional institutions and academic bodies - consistent with the Declaration's spirit of partnership.

Malaysian Perspective within APEC Framework

Malaysia's engineering sector is deeply embedded within APEC's collaborative ecosystem. As host of the Putrajaya Vision 2040, Malaysia continues to integrate APEC priorities into its domestic agenda.

1. Policy Alignment

The 12th Malaysia Plan (2021-2025) emphasises technology adoption, green transition and professional services export - all coherent with APEC's objectives. Agencies can collaborate to enhance global recognition of Malaysian engineers through mechanisms such as the APEC Engineer Register and ASEAN Chartered Professional Engineer (ACPE) schemes.

2. National Innovation and Green Growth

Malaysia's Low Carbon Nation Aspiration 2040 and Green Technology Master Plan (2017-2030) resonate strongly with APEC's sustainability goals. Engineers contribute through renewable energy projects, smart city development and industrial decarbonisation. The Declaration reinforces Malaysia's strategic focus on engineering innovation as a driver of economic resilience.

Conclusion

The APEC Leaders' Declaration 2025 serves as a policy compass guiding Asia-Pacific toward a sustainable, inclusive and digitally empowered future. For the engineering profession, it signifies both responsibility and opportunity. Engineers are essential actors in achieving the Declaration's aspirations - designing climate-resilient infrastructure, advancing digital ecosystems and ensuring equitable participation.

Through initiatives such as the APEC Engineer Register, the La Serena Roadmap and the Putrajaya Vision 2040, APEC establishes an integrated framework linking professional excellence with policy coherence. Yet, realising this vision demands continued collaboration, ethical commitment and adaptive learning among engineers.

In essence, the 2025 Declaration challenges the engineering community to transcend technical mastery and embrace a leadership role in shaping sustainable development across the region. As APEC economies navigate the complexities of energy transition, digital transformation and social inclusion, engineering remains the bridge between aspiration and achievement, a profession not only of precision but also of purpose. 🌱

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Shanghai Declaration 2025: Engineers Unite for Global Sustainable Development

by
Lim Tau Wee



In a historic and unprecedented gathering, the World Federation of Engineering Organisations (WFEO) adopted the Shanghai Declaration at its 2025 General Assembly & Global Engineering Congress (GA & GEC) in Shanghai. The Declaration represents a renewed global commitment by the engineering community to take a leading role in addressing the planet's most pressing challenges such as climate change, social inequality, sustainable development and technological advancement.

At Forefront of Global Challenges

The Shanghai Declaration emphasises that engineers must assume leadership in shaping solutions to global problems. With the pace of technological advancement accelerating and the world facing unprecedented environmental, social and economic pressures, engineers are being called upon to integrate sustainability, innovation and ethics into their professional practices. The Declaration highlights that engineering is no longer merely about infrastructure or industrial projects but is “a strategic driver for societal resilience and sustainable development”.



Four Pillars of Shanghai Declaration

The Declaration outlines four major collective action directions to guide engineering globally:

1. Green Transformation of Engineering.

At the core of the Declaration is the call for a green transformation of engineering practices. Engineers are urged to embed environmental sustainability and ecosystem constraints into the design, construction and operation of infrastructure, industrial systems and urban developments. This includes the adoption of green building materials, renewable energy solutions, low-carbon construction techniques and circular economy principles.

For instance, civil engineers are encouraged to design climate-resilient infrastructure which can withstand extreme weather events, while industrial engineers are asked to implement energy-efficient manufacturing processes. The integration of these sustainable practices aligns engineering projects with international climate goals, including the Paris Agreement and the United Nations Sustainable Development Goals (SDGs).

2. Innovative Solutions through Technology.

The Shanghai Declaration stresses on the responsible use of emerging technologies such as artificial intelligence (AI), digital twins, advanced materials and automation. Engineers are tasked with leveraging these innovations

to not only improve efficiency and productivity but also to generate positive societal impacts, including enhanced public services, improved accessibility and safer infrastructure.

For example, AI-enabled predictive maintenance can reduce failures in critical infrastructure, while digital twins can allow urban planners to simulate environmental impacts before construction begins. The Declaration also emphasises the ethical deployment of technology, ensuring that advancements benefit society equitably and do not exacerbate inequality.

3. Engineering Capacity Building.

A key pillar of the Declaration is the strengthening of engineering education, professional training and workforce mobility worldwide. By investing in skills development and knowledge transfer, the global engineering community seeks to prepare the next generation of engineers to meet complex technical, social and environmental challenges.

Programmes such as global scholarships, exchange initiatives and professional certification recognition are encouraged. These efforts not only enhance technical expertise but also foster cross-cultural understanding and collaboration among engineers, creating a globally competent and interconnected workforce.

4. Global Partnership and Cooperation.

Recognising the interconnected nature of today's world, the Shanghai Declaration calls for cross-border collaboration, mutual recognition of qualifications, standardisation and the sharing of best practices. Engineers are encouraged to work across national and regional boundaries to accelerate sustainable infrastructure projects, transfer technology and harmonise engineering standards globally.

The Declaration underscores that international cooperation is essential to address challenges that no single nation can tackle alone, such as climate change, pandemic preparedness and large-scale urbanisation.

Call for Urgent Action

The Declaration explicitly calls for unprecedented speed, scale and in-depth cooperation to achieve the 2030 Agenda for Sustainable Development. Engineers are seen as pivotal actors in advancing global goals, including climate action, infrastructure development, social equity and digital transformation.

By emphasising urgency, the Declaration signals that engineering solutions must move beyond incremental improvements. Instead, large-scale, collaborative and innovative approaches are required to ensure resilient, sustainable and inclusive growth.

Global Implications of Shanghai Declaration

The adoption of the Shanghai Declaration has profound implications for engineers, policymakers and industry leaders worldwide, such as:

1. **Standardisation and Mutual Recognition.** The call for harmonisation of engineering qualifications and standards promotes mobility of engineers across borders, facilitating international collaboration in complex projects.
2. **Sustainable Development Integration.** Engineers are now expected to systematically incorporate sustainability principles into every stage of design and construction, from planning to operation.
3. **Innovation Leadership.** The Declaration encourages engineers to adopt and shape emerging technologies responsibly, ensuring that innovation serves societal needs rather than solely economic gain.
4. **Capacity Development.** Investments in education, professional training and skills transfer are now a global priority, helping to bridge technical gaps in developing regions.

Examples of Global Engineering Cooperation

Several initiatives already illustrate the spirit of the Shanghai Declaration:

- **WFEO-UNESCO Cooperation.** The renewed WFEO-UNESCO framework (2024-2032) focuses on sustainable

development, engineering education and knowledge transfer, reflecting a shared commitment to global capacity building.

- **Belt and Road Engineering Consensus 2025.** 34 institutions from 17 countries has agreed to harmonise engineering education, accreditation and professional standards, enabling cross-border infrastructure collaboration.
- **International Engineering Education Accreditation (ICEEA 2025).** This global conference helped align engineering curricula and quality assurance frameworks to promote mutual recognition of engineering degrees worldwide.

Engineering as a Global Public Good

The Shanghai Declaration positions engineering as a global public good, emphasising that engineers' responsibilities go beyond economic development to include environmental stewardship, social equity and technological ethics. By adopting this Declaration, engineers collectively affirm that their work can and must contribute to a better, more sustainable and more equitable world.

Conclusion

The Shanghai Declaration 2025 represents a historic commitment by engineers worldwide to lead the way in tackling global challenges. By focusing on green transformation, innovation, capacity building and global cooperation, it provides a roadmap for the engineering community to actively support the 2030 Agenda for Sustainable Development.

As engineers embrace this vision, they are called on to not only design and build but also to shape a future that is technologically advanced, environmentally responsible and socially inclusive. The Shanghai Declaration underscores that the collective action of engineers has the power to drive real and lasting change, setting the stage for a global engineering movement that prioritises sustainability, innovation and human well-being. 🌱

Green Investment Framework

by
Lai Poh Leng

As the world shifts toward low carbon and sustainable economies, Malaysia has stepped up to reshape its industrial and economic trajectory. The Green Investment Framework (GIF) is the nation's blueprint to accelerate green investments, promote sustainable industrial growth and support the transition to a carbon-resilient future. Through GIF, the government aims to attract large scale green investments, drive the expansion of clean energy, support green technology adoption and embed environmental sustainability in the heart of Malaysia's industrial ambitions.

Under the GIF, the government, through the Malaysian Investment Development Authority (MIDA) and its collaborating agencies, has set a bold goal to attract up to RM300 billion in green investments by 2030. This constitutes a dramatic increase over previous periods and reflects the country's commitment to transforming its industrial base, energy systems and manufacturing sectors to align with a low-carbon future.

What the GIF Covers: Strategic Levers for Transformation

The GIF (and associated Green Investment Strategy) identifies 7 core "low carbon levers" - key sectors and action areas through which Malaysia plans to channel investment and development. These levers include renewable energy (solar, hydro, etc.), energy efficiency, hydrogen, bioenergy, green mobility, carbon capture, utilisation and storage (CCUS) and circular economy practices.

These levers reflect both global trends toward decarbonisation and Malaysia's domestic priorities to reduce emissions, improve resource efficiency and modernise industry under sustainable principles. The GIF also seeks to dovetail with other national strategies such as the New Industrial Master Plan 2030 (NIMP 2030) and the National Energy Transition Roadmap (NETR), ensuring coherence across industrial development, energy transformation and environmental goals.

Moreover, the framework is not just about large fossil fuel free energy projects or renewable power but it also extends to promoting sustainable manufacturing, green technology adoption (including clean industrial processes), green financing mechanisms (e.g. incentives, grants, tax allowance/benefits) and supporting green jobs and skills development.

The results of early implementation are already visible. In 2024, Malaysia recorded green investments amounting to RM7.88 billion, contributing to more than 2,000 new "green jobs" - a tangible sign that green policies are translating into economic activity.

Why GIF Matters

GIF represents a strategic inflection point for Malaysia's economy for several reasons:

- **Global competitiveness and sustainability compliance.** As global supply chains, investors and buyers increasingly demand Environmental, Social and Governance (ESG) compliance, GIF helps local industries

modernise and stay competitive on the global stage. Green credentials may open access to premium markets and investors valuing sustainability.

- **Economic diversification and long term resilience.** Moving toward green energy, clean technology and sustainable manufacturing reduces reliance on traditional high carbon industries, helping to future proof our industrial base against shifts in global demand and climate regulation.
- **Job creation and high skilled green sector growth.** The shift will stimulate new sectors such as renewable energy, clean-tech manufacturing, green infrastructure and energy-efficiency retrofits, creating demand for specialised, high-skilled labour and engineering talent.
- **Environmental and social benefits.** Reduced emissions, improved resource efficiency, responsible industrial practices and green mobility contribute to climate change mitigation, better public health and more sustainable urban and rural development.
- **Attracting foreign and domestic investment.** By signalling a clear, government-backed commitment to green industrialisation, GIF provides confidence to investors - both local and foreign - that Malaysia is a stable, forward-looking investment destination aligned with global sustainability trends.

Engineering & Technical Implications: Where GIF Meets Engineering Practice

The GIF is more than policy as it has deep technical and engineering implications. For engineers across disciplines such as civil, mechanical, electrical, environmental, energy, process and industrial, GIF opens a broad field of opportunity and responsibility. Here are some key intersections:

Design and Construction of Green Infrastructure and Renewable Facilities. As Malaysia increases investments in renewable

energy (solar parks, bioenergy plants, hydrogen infrastructure, energy-efficiency retrofits, CCUS facilities), engineers will be needed in planning, designing and constructing these complex systems. Civil and structural engineers will design foundations, grid infrastructure and plant layouts. Mechanical and electrical engineers will handle energy systems, storage, turbines, piping, control systems. Environmental engineers will ensure compliance with sustainability and emission standards.

Green Manufacturing & Sustainable Industrial Upgrades. Industries will need to upgrade factories and industrial plants to meet green standards. This may involve retrofitting for energy efficiency, implementing emission controls, waste management systems, recycling/circular economy processes and cleaner production technologies. Industrial, process and environmental engineers will have central roles in redesigning workflows, optimising resource use (water, energy, materials) and ensuring compliance with emerging green regulations and standards.

Energy Efficiency, Smart Systems and Industrial Automation. Adoption of smart systems such as energy efficient HVAC, smart metering, IoT enabled monitoring, automation and predictive maintenance, will require systems, electrical and automation engineers to design, implement and integrate these technologies. Through these innovations, factories and facilities can operate more efficiently, reduce waste, lower emissions and improve cost effectiveness, aligning with the GIF green goals.

Circular Economy, Waste Management & Environmental Engineering. Green investments under the circular economy lever will involve waste reduction, recycling, resource recovery and sustainable materials handling. Environmental, chemical and civil engineers will be needed to design systems for wastewater treatment, material recycling, waste to energy, emissions control, environmental monitoring and compliance mechanisms.

Infrastructure for Green Mobility, Hydrogen, Bioenergy, CCUS - Technical Challenges & Opportunity

Emerging segments such as green mobility (EV charging infrastructure, battery recycling), hydrogen production and distribution, bioenergy plants and carbon capture facilities will require advanced engineering capabilities. Mechanical, chemical, energy and systems engineers will play critical roles in R&D, design, plant engineering, safety, regulatory compliance and operations.

Building a Skilled Workforce & Engineering Ecosystem for Green Growth

With the growing demand for green infrastructure and sustainable industrial facilities, there will be an increasing demand for engineers trained in green engineering, renewable energy systems, environmental compliance, smart manufacturing and sustainable design. This provides opportunities for education institutions, training providers and industry stakeholders to collaborate on developing human capital tailored for the green economy.

Recent Developments & Momentum Under the GIF

In 2025, under the banner of the Green Investment Strategy, the Malaysian Investment Development Authority (MIDA) reported that it had secured RM7.3 billion in potential green investments at the International Greentech & Eco Products Exhibition Malaysia (IGEM 2025), positioning Malaysia as a clean energy and sustainable manufacturing hub in South-East Asia.

- As part of the GIF and broader industrial strategy, the government has rolled out Green Investment Tax Allowance (GITA) and other incentives to encourage local companies and foreign investors to adopt green technologies.
- The green sector has already started generating new jobs: Data from 2024 shows more than 2,000 new green

jobs created nationwide, signalling early-stage success in the transition.

- The ambition is large: Under GIF, by 2030 the target is RM300 billion in green investments - a major scale-up that, if realised, will transform our industrial, energy and environmental landscape.

Challenges & Considerations

While the GIF rolls out with much promise, realising its full potential comes with several challenges, including:

- **Need for technical skills and capacity building.** Many green infrastructure and renewable-energy projects require advanced engineering, design and execution capabilities. Malaysia will need to invest in training, education and talent development to meet demand.
- **Upfront capital and investment risk.** Transitioning existing industries, building new green infrastructure, or retrofitting plants for sustainability often require significant initial investment - some companies may be hesitant without clear long-term returns or incentives.
- **Regulatory and policy clarity.** As green technologies evolve (e.g. hydrogen, CCUS, circular economy), consistent regulation, standards and compliance frameworks must be in place to give investors confidence and ensure environmental integrity.
- **Integration with existing infrastructure and industries.** Much of Malaysia's industry and infrastructure is legacy - integrating green solutions will require careful planning, engineering retrofits and modernisation -sometimes complicated by site constraints, cost and coordination.
- **Market demand and global competitiveness.** For green products and green manufactured goods to succeed, there must be demand from domestic and international markets. Companies need to align production with global ESG expectations and market trends.

How Engineering & Industry Should Engage with GIF

To convert the vision of GIF into reality, the following steps and strategies will be key for engineering firms, industrial players, policymakers and stakeholders:

- **Proactive planning and collaboration.** Engineering companies should proactively position themselves to take on green-technology, renewable-energy and sustainability projects by building expertise, investing in R&D and collaborating with government initiatives, investors and academic institutions.
- **Upskilling and capacity building.** Institutions (universities, technical training centres) should expand curricula in green engineering, renewable energy, environmental design, waste & water management, CCUS, bioenergy and circular economy to supply the growing demand for specialised talents.
- **Leveraging incentives and financing mechanisms.** Businesses (especially SMEs) should take advantage of GIF's incentives such as tax allowances, green-technology financing and support schemes, to upgrade facilities, adopt clean technologies and modernise operations sustainably.
- **Integrating green and industrial strategies.** Industrial planning under broader masterplans (e.g. NIMP 2030) should embed green principles, ensuring new manufacturing clusters, industrial parks and factories are designed with sustainability, energy efficiency and future proofing in mind.
- **Promoting innovation and sustainability-driven design.** Engineers and firms should adopt modern design practices: Smart systems, energy efficient processes, circular economy designs, modular/sustainable construction and life-cycle-based planning, not only for compliance but to gain competitive advantage.

- **Strengthening regulatory frameworks & ESG standards.** Policymakers should ensure clear, enforceable standards for green investments, environmental compliance, emissions control, waste management and green building/industrial certification - giving certainty to investors and industry.

Conclusion: Engineering the Green Future of Malaysia

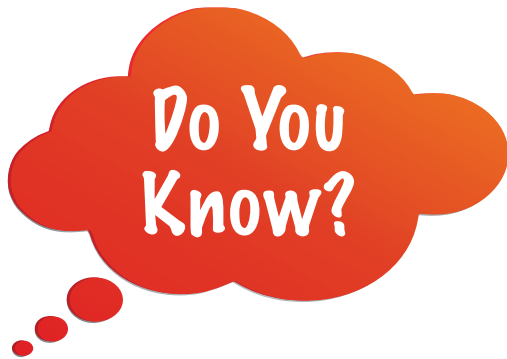
The GIF marks a fundamental shift in Malaysia's industrial and economic direction - from volume driven growth toward sustainability, value-addition and environmental responsibility. It opens a wide field of opportunities for engineers, industrial stakeholders, investors and society at large. By stimulating renewable energy projects, clean tech adoption, green manufacturing, sustainable infrastructure and low-carbon mobility, GIF has the potential to reshape Malaysia's industrial identity for decades to come.

For the engineering profession - from civil and structural to energy, environmental, process, mechanical, electrical and systems engineering - this is more than an opportunity. It is a call to lead. As green projects proliferate and the nation advances toward its net-zero commitment, engineers will be the architects of Malaysia's sustainable infrastructure, green factories, clean energy systems and smart industry.

If stakeholders act decisively to embrace innovation, invest in skills and align economic growth with environmental responsibility, the GIF can become the catalyst to propel Malaysia into a modern, competitive and sustainable industrial future. 🌱

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Engineering Practices

by
Pang Soo Mooi

1. The Iron Bridge in Shropshire, England, symbolises the fusion of engineering skill, industrial capability and innovative material use during the Industrial Revolution. Beyond its functional purpose, it became the world's first iron suspension bridge.

Completed in 1779 and spanning the River Severn, the Iron Bridge represented one of the most significant milestones in civil engineering history. It was the first bridge in the world to be constructed entirely of cast iron, marking a revolutionary shift from traditional timber and stone construction to metal structures. This not only demonstrated the practical potential of cast iron as a load-bearing material but also laid the foundation for modern metal and steel bridge engineering.

Designed by architect Thomas Farnolls Pritchard and constructed by ironmaster Abraham Darby III, the bridge spanned 100ft in a single arch and remained a testament to early industrial ingenuity. Its successful



completion addressed key engineering challenges, including the careful casting of iron components, joining techniques and ensuring structural stability under dynamic loads. The modular design allowed prefabricated pieces to be assembled on-site, a concept that would influence future industrial construction practices.

The cultural and technological landmark inspired engineers across Europe and the world to explore the structural potential of metals. Its success paved the way for the development of modern steel bridges, suspension bridges and large-scale infrastructure projects.

Today, the Iron Bridge is not only a UNESCO World Heritage Site but also a lasting reminder of the ingenuity and vision of early engineers who had transformed construction through innovation and material advancement.

2. Circular water management: The next step. It's time to change the way we think about water within housing developments, towns and cities and to reverse our dependence on using water only once.

For too long, the linear model of "take, make, consume and waste" had dominated, with water abstracted from the natural environment, made drinkable through treatment, used by humans and then discharged back into the environment.

Currently, over 80% of wastewater generated by society flows back into the environment without being treated or reused.

This model is increasingly unsustainable. On a global level, the United Nations predicts that demand for fresh water will exceed supply by 40% by 2030 if current practices continue. In 2022, England experienced its driest July since 1935 and these drought events are set to repeat as the effects of climate change intensify, bringing higher temperatures and increased evaporation. Concentrated rainfall will become more frequent, but the parched soil won't be able to absorb such large quantities of water, leading instead to runoff and flash flooding.

The idea of a circular water economy has been well established. European Union policy identifies the use of treated wastewater as a potential solution to water scarcity and the International Water Association has taken this further, developing the 5Rs approach to water management: Reduce, reuse, recycle, restore and recover.

Although the blue-green infrastructure movement is gathering momentum, wholesale transformation will require a culture change. There must be a shift from seeing water and its supply, transport and drainage as add-on infrastructure, to viewing these as an integral part of our living environment. Blue-green infrastructure has the potential to help urban communities adapt to the impact of climate change by managing flood risk, mitigating the urban heat island effect and reducing the drought risk.

3. Modular construction is more relevant than ever. The McKinsey Modular is able to address some of the most pressing challenges in construction, such as enhancing the sector's productivity, reducing manpower requirements by up to 40%, accelerating timelines by up to 50%,



enabling cost savings (if done correctly and at scale) and potentially reducing CO₂ emissions.

Recent technological developments and more-tailored solutions are finally allowing modular construction to scale to its potential, leading to enhanced, higher-quality builds as well as a wider variety of building types beyond previously geometrically constrained assets. For instance, new digital platforms are helping to connect customers across the ecosystem with suppliers, as well as allowing companies to more easily customise and optimise designs for specific sites.

Modular construction is gaining traction, with some companies already succeeding. There are growing opportunities for players across the value chain - not only developers, contractors, modular construction companies and investors but also design and engineering firms, building materials companies and distributors. The large number of companies and approaches to modular, as well as a few common factors that have caused some companies to fail, mean that it is important to get things right when moving into or growing in the industry.

If done right, modular has the potential to improve many of the challenges that negatively affect construction, as well as broader challenges such as the housing shortage and the energy transition. It will not be easy to succeed, but there are significant opportunities for those that do.

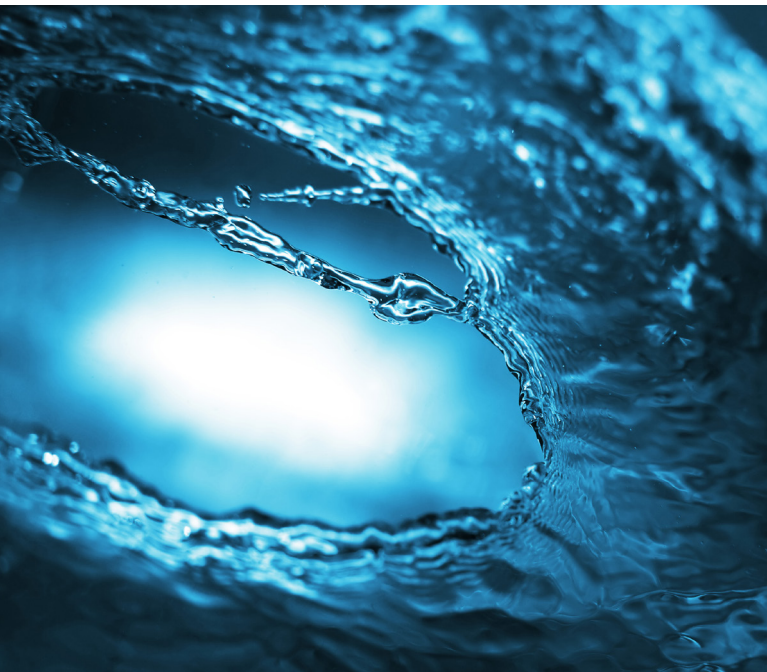
4. **Water-Energy Nexus Engineering.** The water-energy nexus highlights the interdependence between energy generation and water resources. Engineers in this field design systems that minimise water use in power generation and optimise energy efficiency in water treatment and distribution. Uniquely, it bridges environmental, civil and energy engineering to address two global challenges simultaneously: Water scarcity and energy security. Technologies such as solar desalination, hydro-powered microgrids and wastewater-to-energy recovery systems exemplify this integrated approach. In regions facing climate stress, such as South-East Asia, water-energy nexus solutions help sustain both agriculture and urban growth. Engineers use smart sensors and AI modelling to monitor usage and optimise resource allocation. This practice reflects a paradigm shift toward integrated resource management, ensuring sustainable supply chains that support economic growth while protecting vital natural systems.

5. **Shaping the Future of Construction.** The Engineering & Construction (E&C) sector has been slower to adopt and adapt to new technologies than other global sectors. While innovation has occurred to some extent at enterprise or company level, overall productivity in the sector has remained nearly flat for the last 50 years. As an industry based on competitive procurement models, E&C has historically taken a conservative approach to product design and delivery, leading to silos in project management and a somewhat fragmented industry.

This slow pace of innovation matters, because of the great scope and scale of E&C. The industry accounts for about 6% of global GDP and is growing. In parts of the developing world, such as India, it can account for more than 8% of GDP. E&C is the largest consumer of raw materials and other resources, using about 50% of global steel production and more than 3 billion tonnes of raw materials. Any improvement in productivity and successful adoption of modern innovative processes will have a major impact. For example, a 1% rise in productivity worldwide can save US\$100 billion a year.

The E&C industry can take advantage of new technologies and work processes to move the industry forward. The “Future of Construction Project” requires the commitment and encouragement of many active participants in our industry, people who believe in a modern E&C industry that will benefit all.

6. **ASEAN Tigers Rise - Global construction 2030.** New ASEAN Tigers are rising. Indonesia, Myanmar and Vietnam will show growth rates of 6% pa or higher as we move towards 2030. The ASEAN construction market is expected to exceed US\$1 trillion by 2030, with growth driven by labour intensive light manufacturing industries moving across the South China Sea to Asia’s emerging markets, where wages are around half of what they are in China.



7. **Future of Construction - The Next Global Stage.** Construction is at the crossroads of tradition and innovation. While the industry still relies on time-tested methods, new technologies are driving efficiency, sustainability and safety improvements. Let's explore the breakthroughs shaping construction as we know it.

Innovation in Construction. Construction is undergoing a massive transformation, driven by advancements in technology, sustainability and project delivery methods. While the foundation of construction remains the same, creating functional, safe and comfortable spaces, the tools and techniques used are evolving rapidly. Today's construction industry embraces automation, 3D printing, robotics and AI to streamline processes and improve outcomes.

Sustainable Building Practices. As the need for environmentally responsible development grows, construction is becoming increasingly focused on sustainability. This includes using eco-friendly materials, designing energy-efficient buildings and integrating renewable energy solutions into construction projects. Let's take a look at sustainable practices shaping the construction industry and how they're helping reduce the sector's environmental impact.

Smart Construction Technologies. The future of construction is digital. Technologies like Building Information Modelling (BIM), robotics and drone-based surveying are transforming how projects are planned, managed and executed. These innovations are not only improving efficiency and reducing costs but also enhancing the quality and safety of construction projects. Explore how these smart technologies are set to dominate the construction landscape in the coming years.



8. **Roman Aqueducts: Mastery of Hydraulic and Structural Engineering.** The Roman aqueduct system, built between 300 BCE and 300 CE, is one of the most remarkable engineering achievements of antiquity. Designed to supply cities with clean water, these aqueducts combined precise surveying, innovative structural techniques and durable materials, enabling water to travel tens of kilometres solely by gravity.

Achieving a steady flow required extremely gentle gradients, often less than 1%, over long distances. Roman surveyors employed tools such as the groma for right angles, the chorobates for measuring slopes and the dioptra for angular measurements. This precision ensured a consistent flow, avoiding stagnation or erosion.

While most aqueducts ran underground, they had to traverse valleys and uneven terrain. Romans perfected the semi-circular arch which distributed weight evenly and allowed the building of tall structures with minimal material. Construction involved wooden centering to support the arch until the keystone locked it in place. Multi-tiered arcades, exemplified by the Pont du Gard in France, showcase their mastery of large-scale structural design.

Roman engineers also revolutionised materials. They used pozzolanic concrete, a mixture of volcanic ash and lime, to create strong, long-lasting foundations and water channels. Inner conduits were lined with opus signinum, a waterproof mortar made from crushed pottery and lime, to ensure smooth flow and to prevent leakages.

In addition to arches, aqueducts included underground tunnels and inverted siphons for deep valleys, demonstrating a sophisticated understanding of hydraulics. Water distribution within cities relied on castella (settling tanks), pipes and sluices to direct water to baths, fountains and homes.

Many Roman aqueducts remain visible or functional today, highlighting their durability and advanced engineering. Their design principles - precision surveying, hydraulic mastery, arch construction and durable materials set the foundation for civil engineering and influenced water systems for centuries, making the Roman aqueducts a lasting symbol of ancient technological excellence.

9. **Dujiangyan Irrigation System:** A Masterpiece of Ancient Hydraulic Engineering. The Dujiangyan Irrigation System, constructed in 256 BCE during China's Warring States period, stands as one of the world's oldest and most remarkable examples of hydraulic engineering. Designed by Li Bing, the governor of the Qin state, the system transformed the Min River in Sichuan Province into a sustainable water source for agriculture, flood control and transportation and it has remained operational for over 2,200 years without a conventional dam.

Unlike many ancient water projects that relied on massive barriers, Dujiangyan harnessed the natural flow of the river to manage water distribution. Its brilliance

lies in its ability to simultaneously prevent flooding, divert water for irrigation and control sediment deposition, all through ingeniously engineered channels and levees. Its design reflects a profound understanding of hydrodynamics long before formal fluid mechanics existed.

The system comprises three key components. The Fish Mouth (Yuzui) Levee splits the Min River into two channels: The inner channel for irrigation and the outer for flood discharge. Its wedge shape allows seasonal adjustments to water flow, ensuring crops receive sufficient water while mitigating flood risks. The Flying Sand Weir (Feishayan) functions as a natural sediment filter, allowing excess silt to flow back into the river, preventing blockage of the irrigation network. Finally, the Bottle-Neck Channel (Baopingkou) regulates the volume and velocity of water entering the farmland, maintaining a consistent and controlled flow.

Construction relied on stone, earth and timber, with workers manually excavating and shaping the riverbed. Li Bing's design leveraged natural river dynamics to achieve its goals, minimising the need for ongoing maintenance while remaining adaptive to seasonal variations in rainfall.

Today, Dujiangyan irrigates over 5,300 sq km of farmland and remains a model of sustainable engineering. Recognised as a UNESCO World Heritage Site, it exemplifies how ancient civilisations applied observation, ingenuity and practical engineering to solve complex environmental challenges. Its enduring success continues to inspire modern water management and demonstrates the timeless power of intelligent design harmonised with nature. 🌿

Guangji Bridge

Living Legacy of Ancient Ingenuity

by
Dato Ir. Fong Tian Yong



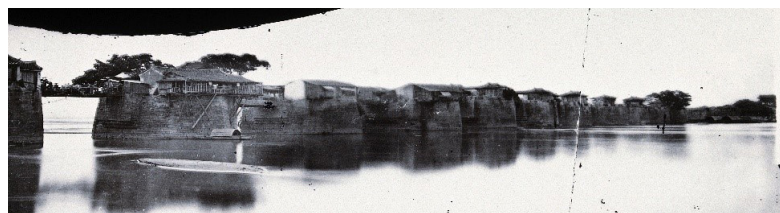
Guangji Bridge, also known as Xiangzi Bridge, in Chaozhou, Guangdong Province, China, was built during the Southern Song Dynasty in 1171 AD under the order of Zhao Ruyu, the then governor of Chaozhou.

It spans the Han River, connecting east and west Chaozhou. It is one of China's four famous ancient bridges, together with Zhaozhou Bridge, Lugou Bridge and Luoyang Bridge.

Over the centuries, Guangji Bridge underwent multiple structural reinforcement and restoration works, notably in the Ming Dynasty (16th century) and Qing Dynasty (18th century). Its unique hybrid structure of fixed stone piers and movable pontoon sections made it an engineering marvel of its time.



Undated picture of the pontoon bridge in early 1900.



Another undated picture of Guangji bridge stone piers without the connecting deck.

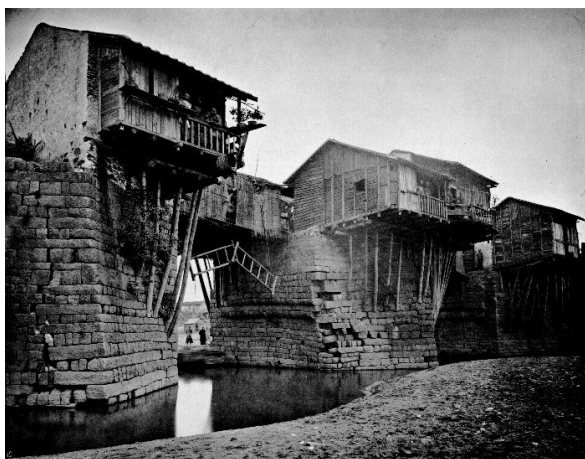
Challenges in Construction

At the bridge site, the Han River is over 500m wide. The region experiences strong seasonal currents, especially during the monsoon floods in summer when torrential rains swell the river, increasing flow speed and risk of erosion.

The proximity to the South China Sea causes water level fluctuations, complicating foundation stability. With its fast current, the Han River posed immense difficulty during construction using traditional bridge-building techniques in ancient times.

The builders had to conceive a structure resilient enough to endure the powerful currents while still allowing the safe passage of boats. Seasonal floods were a constant challenge and often swept away temporary platforms, compelling the repeated reinforcement of the bridge foundations to ensure its stability. In the 12th century, advanced construction techniques such as deepwater foundations and reinforced concrete were yet available, so the use of stone piers and wooden structures were required.

Due to its complexity and unique design, construction of the bridge required extensive labour and resources over multiple decades. The movable wooden platform sections required constant repair works due to exposure to water, wind and boat traffic.



Initially, the constructed brick piers were unable to withstand the seasonal strong current.

For the stone pile foundations, workers drove wooden piles into the riverbed and then laid large stone blocks on top to form piers. Some piers were designed in a boat shape with the pointed section facing the oncoming current to reduce water resistance during floods. Iron rods and dovetail joints were used to strengthen the structure.



View of a stone pier with an arrow-shaped upstream face designed to deflect the oncoming current and reduce structural stress. The granite beam rests directly atop the pier.

Transporting Granite Beams from Quarry

The granite beams used for the Guangji Bridge ranged from 10m to 18m in length with an average width of 1m and a height of 1.2m. They weighed between 20 and 50 tons each. The stones were sourced from nearby mountain quarries, especially Raoping and Fenghuang Mountains, which were less than 30km from Chaozhou. Workers mined the stone with iron chisels, wedges and hammers. They inserted metal or bamboo wedges into pre-cut grooves and soaked these with water so that expansion would split the rock naturally along grain lines. Once freed, the stone beams were rough-shaped and measured precisely at the quarry to fit the bridge design. Shallow holes or grooves were chiselled into the sides to allow insertion of wooden beams or hemp ropes for hauling.

Transporting the granite beams from the quarry to the Han River was an enormous task, requiring hundreds of labourers and teams of

oxen or water buffalo. The beams were placed on wooden sledges and dragged over logs which acted as rollers. Workers lubricated the path with mud, animal fat, or water to reduce friction.

On slopes, workers constructed temporary timber tracks or earthen ramps to ease the downhill movement. On flatter terrain, the beams were pulled using ropes by teams of labourers who coordinated their movement to the rhythm of drums or gongs. This slow but steady overland journey could take days for a single beam, with resting stations established along the route.

At the riverbank, a temporary loading ramp would be constructed using logs and soil, sloping gently into the water. To move the stone beams onto water transport, the workers assembled flat-bottomed boats or barges side by side, lashing them with wooden beams and hemp ropes to create a stable floating platform. The beam was then slid from the ramp onto the floating platform, with the help of wooden rollers and levers for controlling movement. Workers took great care to balance the load evenly across several boats to prevent capsizing.

The tidal nature of the Han River became the workers' greatest ally. The builders timed transportation and positioning with the tides, turning a natural challenge into a powerful lifting tool. The heavy granite beams were loaded onto the rafted boats during high tide, when the water level was at its peak. Once loaded, the boats were carefully towed or guided to the bridge site using ropes from both banks, poles and anchor lines.

The high tide allowed boats to float close enough to the pier tops without grounding. At the correct pier, the beam was aligned directly above the stone pier platform using guide ropes and poles. The beam was supported by the boat raft directly underneath.

Beams Lowered with Falling Tide

Next was the most remarkable part of the operation: The use of natural tidal subsidence to lower the heavy granite beams gently into their final position.

At high tide, workers positioned the raft precisely beside or between two stone piers. The beam rested above the pier caps, held by the boats' buoyancy. Ropes from both shores and anchors fixed the boats in place to prevent drift during tidal changes.

As the tide gradually subsided, the water level dropped and the boats settled lower relative to the pier. With each inch of falling water, the granite beam descended slowly and steadily until it rested perfectly on the pier surface.

Workers then inserted wooden rollers and wedges between the beam and pier top to adjust its exact position and level. Once secured, the boats were detached and floated away with the next rising tide, leaving the beam firmly secured. This tidal method avoided the need for heavy lifting equipment, using instead the buoyancy of water and the predictable rhythm of the tides as a natural crane.

Once the beams were positioned, stonemasons completed the alignment by inserting small chocks or wedges to level the beam to ensure even load distribution. In some cases, molten lead or lime mortar was poured into gaps to fix the stones firmly. Each successful beam placement marked a major milestone, often accompanied by ritual ceremonies and offerings, as it symbolised harmony between human effort and the rhythm of nature.



Broken stone beams are displayed at bridge site, with descriptions inscribed at the plaque in front.

In 1958, the floating pontoon section was replaced by a steel truss, but in 2007, it was restored to its traditional design for cultural preservation.

The bridge was originally built with floating boats connected by chains to form the pontoon bridge. Later, 18 stone piers were constructed on the western section, providing a stable foundation. The eastern section still used movable boats, allowing for the flexible opening and closing to let ships pass.

Replacement of Eastern Channel with Permanent Stone Piers

The deep eastern channel of the Han River, with a forceful current, formed the principal waterway for ships arriving from the South China Sea. Building a solid stone bridge with multiple piers across this stretch would have been an immense engineering challenge and a serious hindrance to large vessels and the thriving trade that sustained the prosperity of Chaozhou.

The pontoon section solved both problems, making the bridge easier to construct under such challenging conditions and allowing it to be easily opened and closed. To allow a ship to pass, boats would be rowed to disconnect the pontoon section and to tow it aside, creating a temporary passage. After the ship had passed, the boats were reconnected.

Eastern Channel Transition from Pontoon to Stone Piers

Replacing the eastern pontoon with stone piers was not a single event but a gradual process that unfolded over more than 50 years, driven by a combination of persistent destruction and a growing will to find a permanent solution.

The wooden pontoon bridge, while practical for navigation, was highly vulnerable as it was frequently damaged or destroyed by floods, typhoons and tidal surges. It required constant and expensive maintenance and replacement of the boats.

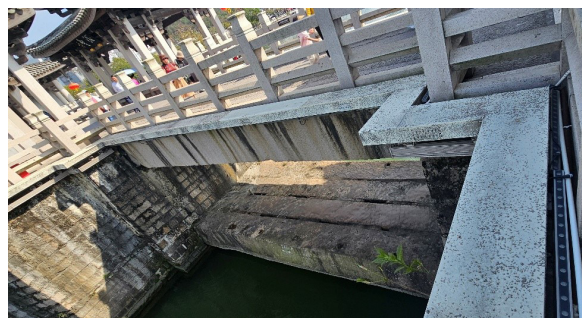
Major floodings would routinely wipe out the entire pontoon section, severing the vital cross-river link. This cycle of destruction and repair became unsustainable.

The decisive effort to replace the pontoon bridge with stone began in the Jiaping era (1522–1566) of the Ming Dynasty. It was led by a local senior official, Tan Lun, who was widely credited with initiating the ambitious project. Following yet another catastrophic flood, Tan championed the construction of a permanent stone bridge to replace the vulnerable boats.

The greatest challenge remained unchanged - establishing stable stone foundations in the deep and fast-flowing eastern channel. To overcome this, builders employed techniques advanced at the time, sinking massive stone blocks and driving wooden piles to form a secure base for the piers. They also used oyster lime mortar, a traditional and remarkably strong binding material characteristic of southern Chinese marine architecture.

The work was slow, dangerous and expensive, frequently halted due to lack of funds, technical difficulties and more flooding which damaged the uncompleted work. It was a classic “two steps forward, one step back” endeavour.

The eastern section, now comprising 13 solid stone piers, was finally completed and fully integrated with the rest of the bridge in 1560. The original 24 boats at the eastern channel were now replaced by a stone structure.



Double layers of granite beams provided greater stability.

The design of the bridge is a combination of stone piers, wooden beams and floating pontoon sections, a rare and innovative design in Chinese bridge history. The eastern part of the bridge can be manually opened by removing floating sections, allowing large boats to pass. The bridge is lined with 24 pavilions, each with distinct architectural styles, used historically for rest stops, trade and religious activities. With its blend of functional engineering and artistic design, the bridge became an iconic symbol of Chaozhou's rich cultural heritage.



View of the middle section of the bridge where pontoons link the two ends of the stone-pier decks.

Structure of the Pontoon Section

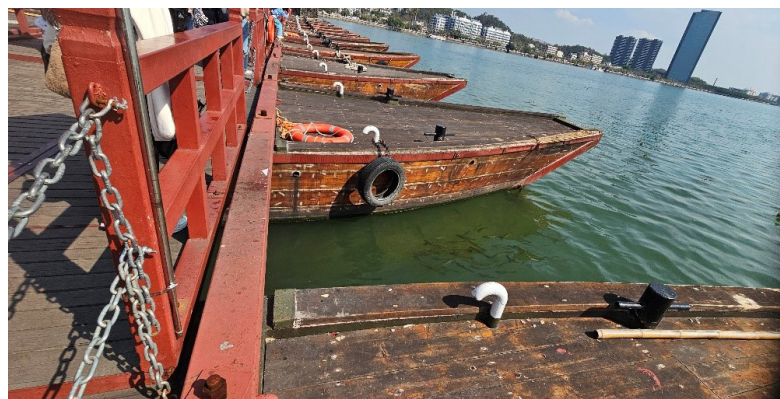
The pontoon section of Guangji Bridge typically consists of a row of boats (pontoons) aligned across the river. These boats are connected in groups of four to six in a row, forming manageable units. The connection between the boats is achieved with two parallel longitudinal metal bars, positioned along both sides of the pontoon line. These bars act as tie-beams, maintaining alignment, transferring loads from the deck and preventing the boats from drifting apart in the current or under heavy traffic load.

Each pontoon is fitted with attachment plates or rings near the gunwales, where the longitudinal bars are fastened. The deck planks rest across the boats, forming the walking surface for pedestrian traffic.

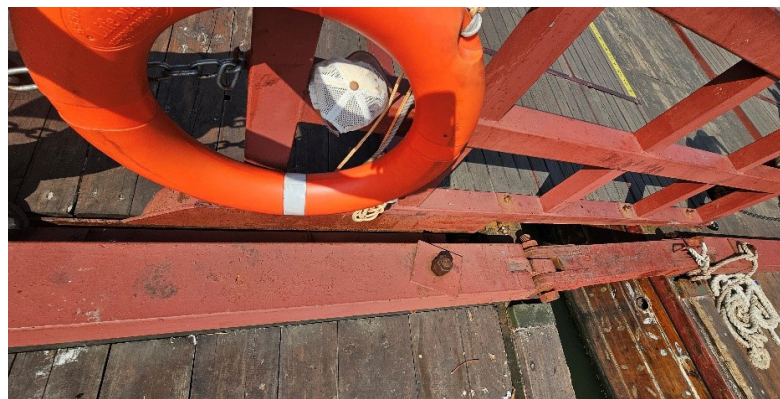
A distinctive feature of the pontoon system is the use of special mechanical joints along the connecting bars. These joints are designed to be opened quickly and re-locked securely, enabling the efficient shifting of the boats during navigation periods.

Each pair of boats is connected by clevis plates and a removable tapered metal pin. The pin allows limited articulation under waves or current action and can be swiftly removed to separate two adjacent boats. These joints make it possible to open a section of the pontoon row in a matter of minutes rather than hours, an essential feature for a busy river crossing which has to accommodate both land and water traffic.

Opening or closing the pontoon section follows a practiced sequence developed over centuries of use. Before operation, the bridge deck panels above the chosen joints are removed or lifted.



Pontoons are tied together using two parallel metal bars with wooden deck for pedestrian traffic



The mechanical pin-joints can be opened to detach two sets of boat pontoons.



View of the bridge from eastern bank of Han River.

Personnel and goods are cleared from the section to be opened. Workers remove the safety cotters or wedges from the joint pins and withdraw the locking pins or sleeves. The parallel bars are thus separated, freeing one or more boats for movement. Using ropes, poles and shore-mounted winches, the freed group of boats is manoeuvred laterally or pivoted downstream to create an open navigation channel.

The boats are guided by anchoring ropes or pivot chains attached to fixed mooring points, ensuring controlled movement even in strong river currents. Once the required opening width is achieved, the detached boats are anchored temporarily using bow and stern ropes or small stone anchors. The open channel allows sail boats and rafts to pass through safely.

After river traffic has cleared, the mooring lines are eased and the boats are winched or pulled back into alignment. Guide ropes and tapered iron collars assist in precise repositioning of the bars and decks. The pins or sleeves are reinserted, wedges tightened and the deck panels replaced to restore the continuous bridge surface.

Conclusion

Guangji Bridge stands as one of China's most remarkable historical and engineering landmarks. Preserved today as a treasured part of the nation's cultural heritage, it continues to attract visitors from around the world. The bridge



An exhibit on site shows the winch used in earlier days to manoeuvre sets of boat pontoon during the opening and closing stages.

is a powerful testament to the ingenuity, skill and resilience of ancient Chinese engineers who triumphed over formidable natural challenges.

The ingenious tidal-lowering method used to position the massive granite beams exemplifies the builders' profound understanding of the environment. By carefully observing tidal patterns and applying the principles of flotation and balance, they were able to manoeuvre multi-ton stones with astonishing precision -an accomplishment still admired by modern engineers.

This harmonious interplay between natural forces and human innovation has allowed Guangji Bridge to withstand centuries of floods, tides and time, securing its legacy as a masterpiece of adaptive engineering and cultural endurance. 🏞️

Fascine Road Work in Johor (1962)

by
Cheo Hong Keyong



In the 1960s, fascine work (sometimes spelt facine) was a traditional civil engineering method used in road construction in Malaya, especially in swampy, waterlogged, or soft ground areas where normal earthworks could not provide a stable foundation.

The technique was adapted from older European and military engineering practices but applied locally to overcome Malaya's difficult tropical terrain. It was a practical and low-cost engineering solution before the introduction of modern soil stabilisation technologies.

It was widely used in rural road-building projects and plantation access roads before more modern soil stabilisation and geotextile methods were available.

Earth, sand, or laterite was dumped on top of a fascine mattress. The fill material compacted the fascine, squeezing water out and forming a relatively firm base. Additional layers of fascines could be added if settlement was excessive. Once a stable platform was achieved, laterite gravel or crushed stone was added for the road surface. With the advent of geotextiles, prefabricated vertical drains and modern soil stabilisation, fascine work declined after the 1970s. 🏠

Reference

1. Annual Report of the PWD 1962

KYODO PIPE STANDARD GALVANISED STEEL CONDUIT



BS 31 CLASS B (SCREWED) / MANUFACTURER'S STANDARD

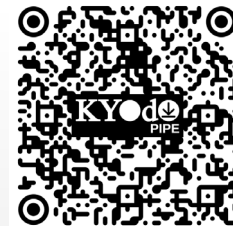
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	MINIMUM		MAXIMUM		MINIMUM		MAXIMUM						MINIMUM		MAXIMUM	
in	mm	in	mm	in	mm	in	mm	in	kg/m	kg/ft	lb/ft	PER INCH	mm	in	mm	in
¾	18.76	0.7387	19.05	0.7500	1.52	0.060	1.63	0.064	0.713	0.217	0.479	16	12.70	0.5000	14.29	0.5625
1	25.11	0.9887	25.40	1.0000	1.52	0.060	1.63	0.064	0.972	0.296	0.653	16	15.88	0.6259	17.46	0.6875
1¼	31.46	1.2387	31.75	1.2500	1.52	0.060	1.63	0.064	1.240	0.376	0.830	16	17.46	0.6875	19.05	0.7500
1½	37.80	1.4880	38.10	1.5000	1.73	0.068	1.83	0.072	1.680	0.511	1.130	14	19.05	0.7500	20.64	0.8125
2	50.50	1.9880	50.80	2.0000	1.93	0.076	2.03	0.080	2.510	0.765	1.690	14	22.23	0.8750	23.81	0.9375

MS 275 / BS 4568 CLASS 3 (SCREWED) / MANUFACTURER'S STANDARD

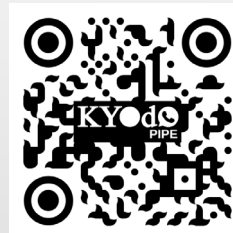
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	MINIMUM	MAXIMUM		MINIMUM	MAXIMUM		MINIMUM	MAXIMUM
mm	mm	mm	mm	kg/m	kg/m	mm	mm	mm
20	19.7	20.0	1.6 ± 0.15	0.643	0.783	1.5	13	15
25	24.6	25.0	1.6 ± 0.15	0.811	0.995	1.5	16	18
32	31.6	32.0	1.6 ± 0.15	1.069	1.301	1.5	18	20

MS IEC 61386-1 / MS 61386-21 CONDUIT SYSTEM FOR CABLE MANAGEMENT

NOMINAL SIZE	OUTSIDE DIAMETER		INSIDE DIAMETER	EXTERNAL THREAD LENGTHS
	MINIMUM	MAXIMUM	MINIMUM	MINIMUM
mm	mm	mm	mm	mm
20	19.7	20.0	1.6 ± 0.15	13
25	24.6	25.0	1.6 ± 0.15	16
32	31.6	32.0	1.6 ± 0.15	18



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