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Viksit Bharat @2047: A Competency Framework for Future-Ready Civil Engineers

Kosygin Leishangthem

Assistant Professor, Department of Civil Engineering, Manipur Technical University, Manipur, India.

Abstract:
The Speedy transformation of the construction and infrastructure sector through digitalization, sustainability imperatives, and emerging technologies is transforming the role of civil engineers in India's path to becoming a developed nation by 2047. This study explores the future skills and proposed a competency mapping framework for civil engineers along with smart and sustainable infrastructure development, and the demand for technologies like Building Information Modelling (BIM), Artificial Intelligence (AI), Internet of Things (IoT), and digital twins along with green construction practices and climate-resilient design. The application of these emerging tools and methodologies calls for a review of conventional civil engineering curricula to develop a workforce capable of managing complex data-driven projects and building resilient infrastructure [1].
It highlights significant gaps between current academic curricula and industry requirements and underscores the importance of incorporating interdisciplinarity, digital literacy, and sustainability-focused thinking in civil engineering education[2] [3] [4] [5] [6]. Based on three domains (technical skills, professional skills, and behavioural skills) as well as insights from industry trends, policy directions, and skill development initiatives in India, a competency mapping model is developed to prepare future civil engineers with the necessary skills for the complex and multidimensional challenges of large infrastructure projects as well as sustainable development practices[7] [8][9] [10] [11].
The paper also emphasizes the need for continuous upskilling, industry–academia collaboration, and outcome-based education for a future-ready workforce and highlights the shift from civil engineers as traditional practitioners to innovators addressing complex infrastructure challenges[12] [13][14] [15]. The proposed framework is meant to be a compass for educators, policymakers, and industry stakeholders to harmonize talent development strategies with national priorities, which eventually will lead to a robust, skilled, and future-oriented civil engineering workforce that will help realize the vision of Viksit Bharat @2047 [9] [16], [17].

Keyword: Civil Engineering Education; Competency Mapping, Construction 4.0, Sustainable Infrastructure, Viksit Bharat @2047

1. INTRODUCTION
India is at a pivotal moment in its developmental trajectory, with a 2047 vision of becoming a fully developed nation or Viksit Bharat, which means a shift in the infrastructure sector from physical expansion to an economically strong, socially inclusive, and environmentally resilient model [18]. With a median age of only 28 years, India also has a major demographic dividend, and if the country can skill and educate this young workforce, it can continue to grow its $1 trillion digital economy by 2025 and support sustained

industrial growth[19].

Yet, as we enter the Fourth Industrial Revolution, the traditional brick and mortar identity of civil engineering is becoming obsolete, and the need for a new generation of civil engineers who can adapt to a landscape of automation, sustainability, and interdisciplinary collaboration is more pressing than ever [20][21]. Contemporary infrastructure projects are no longer individual engineering activities but integrated systems that involve the incorporation of digital twins, IoT, and disaster-resilient innovations[1]. Therefore, there is an immediate requirement for a competency mapping framework that aligns the skillsets of Indian engineers with the technological and ecological demands of the 2047 horizon. Such a framework is proposed in this paper, focusing on the development of ***"T-shaped"*** professionals who have deep technical expertise but also broad adaptive skills which is characterized by critical thinking, stakeholder management, and dealing with the complexities of large, multi-dimensional projects [11]. Developing this capacity is vital for national progress and to ensure that Indian engineers can compete effectively in a globalized market [22]. Recent evaluations of undergraduate programs in India indicate a strong imperative to align academic outcomes with global benchmarks in order to enhance the quality of life through the application of science[9][23] and achieve social equity and technological advancements[24]. These competency gaps must be addressed because the sector remains a national priority, and nations such as India and Germany are suffering a shortage of civil engineers, which is exacerbated by declining interest and high academic dropout rates[21]. The aim of this study is to reinvigorate the profession by redefining the civil engineering persona for a sustainable future.

2. LITERATURE REVIEW

2.1 The Global and Indian Pedagogical Landscape

There is a global paradigm shift in the evolution of civil engineering education, but in the Indian context, there are unique structural and perceptual challenges to overcome, as there is a high demand for infrastructure development, but a paradoxical shortage of civil engineers, which is partly due to the widespread perception among students and society that civil engineering is an ***"outdated"*** or ***"brick and mortar"*** discipline that does not have the innovative appeal of the information technology sector[25].

High dropout rates (as high as 49% in Germany) that are typical of developed and developing countries only worsen this shortage[26]. Recent research into undergraduate curricula in India, using the Fuzzy Analytical Hierarchy Process, finds that concrete technology and structural analysis are emphasized as core competencies, whereas computing, programming, and data-driven disciplines are always relegated to the bottom of the priority list [27], which directly contributes to a lack of digital literacy among graduates, which is now a key commodity in the global job market [28].

2.2 Existing Studies on Future Skills in Engineering

The Fourth Industrial Revolution (4IR) is now being described as disruptive, with the need to move from "brick and mortar" engineering to a high-tech discipline[29] [21]; 4IR generic skills (GS4IR) studies have identified creativity, originality, emotional intelligence, and complex problem-solving as necessary for entry-level engineers[3]; specifically in the infrastructure sector, research has highlighted Industry 5.0 skills, which combine human-centricity and social values with advanced technologies such as digital drawing, autonomous robotics, and instrumentation[16][29]. In addition, the American Society of Civil Engineers has predicted that future engineers will need to become "stewards of the natural environment" and "integrators of technology," a combination of analytical thinking and lifelong learning habits[30] [14].

2.3 Competency Mapping Frameworks in Technical Professions

A strong competency framework is necessary to outline the levels of mastery needed in a dynamic marketplace [23]; well-established models such as the Civil Engineering Body of Knowledge offer a foundational framework for technical, professional, and foundational outcomes[14] [23]; newer research suggests expanded frameworks that categorize competencies under five pillars: interdisciplinary knowledge, technical innovation, managerial capacity, problem-solving, and ethical responsibilities [31]; and other dynamic mapping tools focus on the "T-shaped" professional development that integrates deep technical expertise with broad adaptive abilities in areas such as project management and stakeholder engagement[11], [32][1]. In India, models are being developed to benchmark the professional competence of faculty and students against international standards as set by organizations such as the National Board of Accreditation[9].

2.4 Skill Gaps in the Civil Engineering Sector

However, even with such demand for infrastructure, there is still a substantial mismatch between academic output and industry expectations[12], [27]. Studies that employ Fuzzy Analytical Hierarchy Process show that Indian undergraduate programs emphasize concrete technology and structural analysis but devalue computing, programming, and data-driven disciplines[27]. This results in a "digital skills gap," where graduates lack the literacy needed to function in BIM-enabled environments [28]. In addition, industry practitioners report that recent graduates are lacking in "employability skills," including the lack of practical ingenuity and the ability to apply theoretical knowledge to practical complexity[6], [33], [34]. This gap is further compounded by the perception of the field as outdated, which has resulted in high dropout rates in engineering programs worldwide[35][25].

2.5 Policy Frameworks and Structural Barriers

These gaps can be met by international standards such as the Civil Engineering Body of Knowledge, which can be used to map the competencies needed by today's practitioners[23]. Similarly, the National Education Policy 2020 and Skill India Mission are attempts to create industry-academia linkages and to develop vocational proficiency in India, but these policies are met with significant challenges, as approximately 70% of students in rural India lack the digital and physical infrastructure required to receive modern engineering training[19], [24], [36]. To realize the vision of Viksit Bharat @2047, the intent of policy will need to be backed by a systemic change that incorporates the principles of Education 5.0, which emphasizes human values, sustainability, and high-tech skills[35].

2.4 Government Initiatives: NEP 2020 and Skill India

To meet these structural challenges, the Government of India has rolled out transformative initiatives toward achieving the Viksit Bharat @2047 vision[18], [19], such as the National Education Policy 2020, which charts the path for modernizing the system with holistic, multidisciplinary, and outcome-based education[37], [38] with the Academic Bank of Credit for flexible learning, the integration of vocational training with STEM subjects[7], and models like the LASE program at IIT-Bombay, which represents this move toward multidisciplinary excellence [39]. Moreover, the Skill India mission and Make in India initiative seek to address the employability gap with industry-academia partnerships and upskilling of the workforce for a projected $1 trillion digital economy[19], [24], [40]. Policies have placed emphasis on service-learning and research-based pedagogies to ensure alignment of student outcomes with the 2030 Agenda for Sustainable Development [41].

3.1 DIGITAL TRANSFORMATION AND CONSTRUCTION 4.0

As the construction industry moves toward a high-tech sector, driven by both global competition and labour productivity[28], [42], this "Construction 4.0" era is characterized by the fusion of several disruptive technologies:

- **Building Information Modelling (BIM) and Digital Twins:** BIM is the central source of information throughout the lifecycle of a facility[42], and when coupled with Digital Twins, it enhances the real-time monitoring and predictive maintenance of physical assets, resulting in enhanced structural resilience and operational efficiency[1], [35].
- **Artificial Intelligence and IoT:** The application of Artificial Intelligence (AI) in civil engineering enables enhanced design, monitoring, and predictive analysis of projects (Xu), and when combined with the Internet of Things (IoT), it enables the creation of "smart" infrastructure that can self-diagnose[1].

Table 1: Comparative Evolution—Construction 3.0 vs. Construction 4.0

Feature	Construction 3.0	Construction 4.0 (Automation/Intelligence)
Primary Tools	2D/3D CAD, Electronic Spreadsheets[43].	BIM, Digital Twins, AI, and VR/AR[20], [43]
Data Flow	Fragmented, Manual Data Entry[43].	Real-time, IoT-driven, Interconnected[20].
Site Operations	Human-led Machinery[20].	Autonomous Robotics, 3D Printing, Drones[20].
Decision Making	Experience-based, Reactive[43].	Data-driven, Predictive Analytics[43].

3.2 Sustainability, Resilience, and Circularity

As climate change poses increasing risks to global infrastructure, the role of civil engineer has been extended to include engineering for resilience[1], [25]. Much of the infrastructure that will be planned today will remain in use through 2050, a time when the climate impacts are projected to be far more severe than today[44]. Thus, current engineering education needs to transition from considering sustainability as an elective course to integrating the concepts of sustainability and resilience throughout the curriculum, from first-year courses to advanced design[45].

Practical innovations in this domain include:

- **Advanced materials:** The use of eco-efficient construction materials and the principles of the circular economy to minimize waste and carbon footprints[21], [46].
- **Energy-efficient systems:** For India, the use of energy-efficient HVAC systems is imperative to achieve the sustainable urban development objectives of the Viksit Bharat 2047 mission [47].
- **Climate adaptation:** Building infrastructure that is disaster-resilient from the outset to protect people who are at risk of growing climate-related disasters[45], [48].

4. FUTURE SKILLS REQUIREMENTS FOR CIVIL ENGINEERS

In order to meet the goals of the Viksit Bharat initiative the competence mapping needs to be restructured to focus on three critical areas: technical competence in emerging technologies, advanced professional ma nagement and human centred attributes [49].

4.1 Technical Skills

4. Future Skills Requirements for Civil Engineers

The engineering workforce would have to shift from I-shaped (technical depth) to T-shaped[50], as illustrated in the T-shaped professional diagram for infrastructure development, which includes deep technical depth and a broad, professional and cross-sectoral competence layer[51][51][52].

The Vertical Stem: Technical Depth and Digital Innovation

The vertical part of the T-shape offers the deep technical knowledge required to `launch' the more challenging projects[50][52]. For the Construction 4.0 project, this is not limited to classical mechanics but also entails:

Digital Systems Mastery digital systems mastery, Building Information Modeling, Digital Twins, and AI-driven analytics are now critical to the management of integrated infrastructure systems [42].

Automation and robotics: competence in human-machine interaction, including the use of autonomous vehicles and 3D printing in the field[20].

Eco-efficient materials: specialised knowledge in the development and use of low-carbon, sustainable materials that align with the circular economy[18][44].

Infrastructure informatics: using the Internet of Things and sensor networks to generate smart assets that can monitor structural health in real time[42].

4.2 The Horizontal Bar: Professional Breadth and Cross-Disciplinary Adaptability

Although technical depth will ensure accuracy, the horizontal bar on the T-shaped bar will give the boundary crossing ability required for the high-density infrastructure of the `Viksit Bharat` project[53]. These include:

Interdisciplinarity: working with data scientists, urban planners, and renewable energy experts[51].

Strategic project management: handling large-scale multidimensional projects, risk management, and resource optimization[52]. **Stakeholders and public policy involvement:** dealing with the political and social integration factors that impact contemporary urban development.

Systems Thinking: recognizing emerging patterns and synthesizing the `big picture' of the life cycle of a project, from inception to disaster recovery[1], [52].

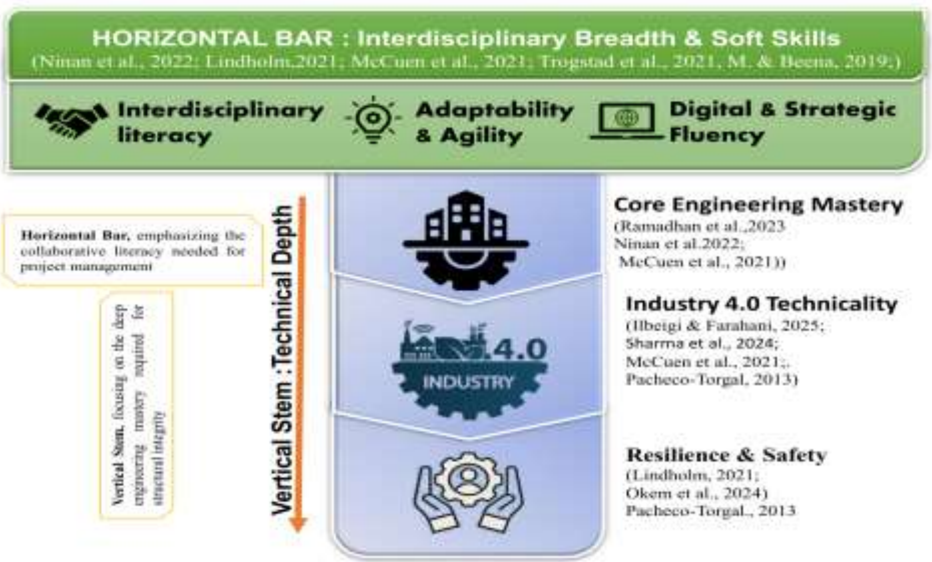

Figure 1: T-Shaped Professional Diagram for Infrastructure Development

4.3 The Integrating Behavioral Domain: Ethical Leadership and Lifelong Learning

The behavioral domain straddles the line between technical depth and technical breadth and ensures the ethical and responsible application of engineering sciences[52].

Ethical stewardship: As engineers, they are also stewards of the natural environment, called upon to achieve a balance between technological progress and social equity and environmental integrity.

Adaptive intelligence: critical thinking and communication skills will be essential to conflict resolution and negotiation in diverse, globalized markets[52].

Lifelong learning mindset: In this rapidly changing world, the only defense against rapid technological disruption is a commitment to lifelong learning[50].

By cultivating these T-shaped characteristics, the engineering workforce in India will transition from being mere technical designers to architects of the trillion-dollar digital economy and smart and resilient cities to serve the infrastructure needs in the landscape of 2047[19], [50].

5. COMPETENCY MAPPING FRAMEWORK

The learning model that has been static in nature cannot help navigate the complexities of the fourth industrial revolution and the sustainability imperatives of the Viksit Bharat (2047) mission. A successful competence mapping framework needs to be inherently dynamic and allow for a non-linear progression from basic academic knowledge to expert-level strategic guidance[32]. It is a framework for articulating the knowledge, skills and attitudes required to operate the infrastructure of tomorrow [31]. With technology cycles shortening, the need to re-skill continually is just as vital as the initial technical training[20].

The proposed framework is divided into three development phases to align the engineering workforce with global standards and national aspirations.

5.1 Foundational Phase: Academic and Ethical Grounding

This phase, typically the undergraduate component, is focused on building a strong intellectual foundation, but modern basic education must also include computational thinking and basic programming,

This first stage, which is largely contained in the undergraduate curriculum, consists of laying down a strong intellectual foundation.

- **Core Engineering Sciences:** While mastery of mathematics, physics, and structural mechanics are still the bedrock of the profession[23], modern foundational training must also include "computational thinking" and basic programming, areas that are currently undervalued in traditional Indian engineering curricula[27].
- **Digital literacy and tool proficiency:** students should be trained to go beyond manual drafting and have early exposure to computer-aided design and basic modelling of building information[23], [28].
- **Professional ethics and social context:** engineers are social actors; this phase stresses the ethical responsibility, the environmental awareness and the social context[9], [11]. This will ensure that future practitioners prioritize human-centred design from the outset[1].

5.2 Application Phase: Technological Integration and Sustainability

As professionals advance to industrial positions, the focus is on applied, cross-sectoral knowledge.

- **Advanced Digital twins and building 4.0:** practitioners must be able to manage workflows that are integrated with BIM, real-time IoT data, and sensor-based structural health monitoring for increased durability[1], [23].

- **Eco-efficient and circular construction:** during this stage, sustainable construction principles should be implemented, such as eco-efficient building materials and circular-economy practices to reduce waste[46], [48].
- **Interdisciplinary problem-solving:** engineers in the field of civil engineering must be able to collaborate with data scientists and urban planners to effectively design and implement modern infrastructure such as smart grids and renewable energy systems[47], [54]. Here, it refers to being able to manage the profile of the T-shaped profession: a deep technical knowledge and wide competence to integrate various scientific disciplines[11].

Table 2: 3-Phase Competency Mapping Summary

Phase	Development Focus	Key Competency Domains	Strategic Goal
I: Foundational	**Core Academic & Ethical Grounding**	Mastery of current engineering sciences, professional ethics, and fundamental technical skills[23].	Establishing the "Vertical Stem" of technical excellence[31].
II: Application	**Technological Integration**	Proficiency in BIM, digital workflows, and sustainable material application to handle "future situations"[23].	Bridging the gap between theoretical knowledge and Industry 4.0 requirements[31].
III: Strategic	**Visionary Leadership**	Complex problem-solving, project management, and global standardization for smart infrastructure[31].	Developing the "Horizontal Bar" for multidisciplinary leadership and long-term resilience[31].

5.3 Strategic Phase: Visionary Leadership and Global Resilience

At the apex of the framework, the focus moves away from delivery of projects to strategic management and political advocacy.

- **Climate Resilience and Disaster Risk Management:** Senior engineers must be able to plan and execute infrastructure projects with climate-resilient designs that will withstand more frequent natural disasters[1], [45], including long-term planning for urban stability and public safety[1].
- **Global standards and policy leadership:** leadership in the 2047 era will include understanding global accreditation standards (e.g. those by the National Association of Accreditation Institutes) and national development policies[9], [19].
- **Strategic risk and innovation management:** large scale projects with budgets in the billions of dollars will need to be managed with sophisticated risk mitigation strategies and adapt to disruptive innovations (e.g., autonomous construction robots and AI-driven predictive maintenance)[27].

The ultimate goal of this graduated framework will be to ensure that Indian engineering workers are not only technically sound but also socially conscious and globally competitive, and to position them as the principal architects of a new India[9], [24].

6. GAP ANALYSIS AND STRATEGIC RECOMMENDATIONS

The transition to the new Viksit Bharat of 2047 requires a critical assessment of the current alignment of technical education and industrial reality. Although India produces a large number of engineering graduates, there is still a structural mismatch between the pedagogical focus of higher education institutions and the multi-faceted requirements of modern infrastructure projects.

6.1 Curricular-Industry Mismatch

There is a fundamental mismatch between education and industry, with the gap between curricula and industry being widest in areas of highest academic investment and least relevance in the automation age, and the most important industrial competences being least emphasized in current curricula[27].

As the following key data points show, the gap is driven by a persistent built-in bias that research reveals.

- **Traditional dominance:** academic programmes still prioritize certain technology and structural design and analysis (Ranks 1 and 2). Although important, this emphasis often comes at the cost of interdisciplinary and digital integration [27].
- **The computer deficit:** computer science and programming, the foundation of BIM, AI and digital twins are at the bottom of most of the Indian courses, contrary to the needs of the 4.0 era[27].
- **The Digital Skills Gap:** The resulting prioritization results in a significant digital skills gap, with graduates technically able to apply classical mechanics but not able to function within a BIM environment or to manage a data-driven project ecosystem[42].

The identity of the civil engineer is changing, as the sector enters the fourth industrial revolution, and modern infrastructure projects are no longer standalone physical objects but integrated systems that need a T-shaped workforce to navigate the challenges of automation and sustainability[11]. This disconnect is evident from the priority gap figure above; while the academy produces brick-and-mortar specialists, the future demands architects of digital and resilient systems for the year 2047[20]. Therefore, unless these curricula are radically reordered (with the upgrading of computing, programming, and data science), India's engineering workforce will remain ill-suited for the $1 trillion digital economy that Modi envisions for Vikas Bharat[19].

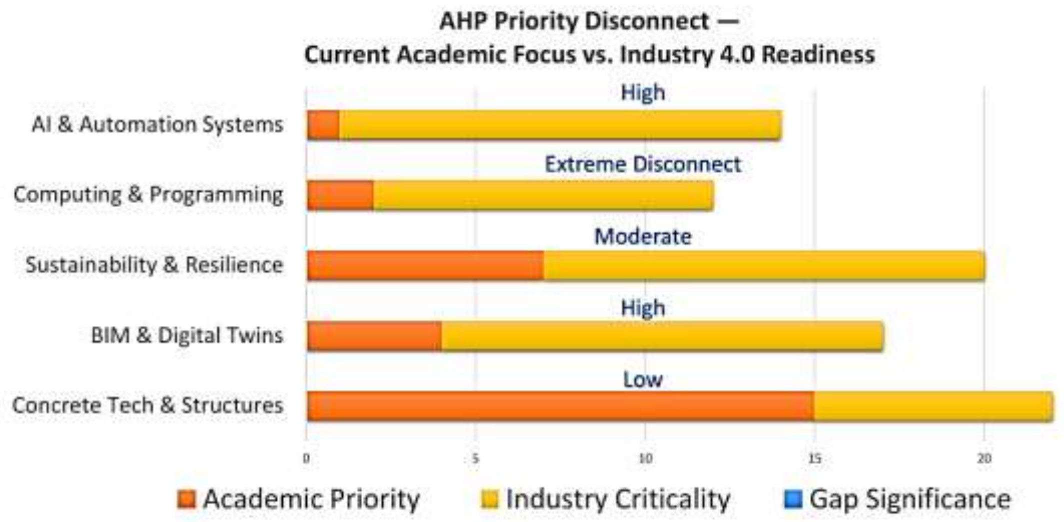

Figure- 2 Curricular-Industry Priority Gap

6.2 Strategic Policy Integration and Standardization

Addressing these gaps requires more than incremental changes, and need strong quality frameworks and policy-driven reforms.

- **The Aswal model of quality assurance:** The Aswal model [36] is proposed to provide a standardised methodology to ensure that educational outcomes are consistent across India, given the variability in its institutional environment, and to ensure that infrastructure and quality of teaching are up to national benchmarks to amplify the impact of NEP 2020 [36].
- **Industry-Academia Ecosystems:** Strengthening these links between classrooms and construction sites is important to expose students to disruptive technologies, and mandatory internships, industry-led certification schemes and joint research initiatives focusing on real-world challenges are an essential part of the strategy [24], so that the demographic dividend of Indian youth is translated into a highly employable and skilled workforce[19], [24].

6.3 Continuous Professional Development: Faculty and Practitioners

This fast-paced technological innovation results in a degree that may be less valuable in 10 years if not accompanied by a culture of lifelong learning [32].

- **Re-skilling of faculty:** engineering faculty should be provided with career development programs in order to up-skill in emerging fields such as autonomous robotics, sustainable energy engineering, and smart grid integration to effectively teach the new generation[34], [54].
- **Lifelong learning frameworks:** To transition from static job roles to dynamic skill profiles for the professionals, and being able to adapt to new tools such as artificial intelligence-driven project management and climate-friendly city planning, will become a defining feature of the successful engineer[22], [32].

These strategies can help India break out of traditional barriers and develop a workforce that can deliver the innovative, sustainable, and smart infrastructure required of a developed nation in 2047[24].

7. DISCUSSION

The results of this study illustrate a transformative time for the Indian civil engineering profession; as India approaches its 100th centenary in 2047, the classical understanding of the engineer is being transformed by the digital and sustainable forces.

7.1 Interpretation of Findings: The Digital-Sustainability Convergence

Analysis reveals that the deficit is not due to the lack of interest in infrastructure, but to a deep divergence in the perception of innovation (Pacheco-Torgal). Even though the sector is moving towards building 4.0, characterized by building information modelling, digital twins and AI-driven predictive analytics, the Indian academic curriculum remains static [1], [27]. The results of the fuzzy analysis of the hierarchy process indicate that the basic sciences are sufficiently covered, whereas the digital competencies necessary to control complex, contemporary projects are systematically underestimated [27], [28]. Furthermore, the results demonstrate that sustainability cannot be left behind as infrastructure constructed today must be able to withstand the climate-influenced landscape of 2050 and beyond, and resilience must be incorporated into every step of the engineering life cycle(Salzman et al.; Pacheco-Torgal).

7.2 Implications for Educators: From Theory to Outcome

For educators, the message is clear: the siloed engineering approach is a thing of the past. The study also recommends a shift to outcomes-based education, in which academic achievement is based on whether the student is meeting global career outcomes (M. and BEEN).

- **Rebalancing curricula:** There is a need for higher education institutions to dramatically upweight computer science, data science and project management [27].

- **T-shaped learning:** Faculty should strive to develop T-shaped learners, who have the technical knowledge to design a bridge but also the general soft skills to navigate the political and social inclusion factors[11], [32].
- **Multidisciplinary excellence:** institutions should take advantage of the flexibility in the national education policy 2020 to encourage multidisciplinary learning environments, where engineering students collaborate with data scientists and renewable energy specialists[7], [37].

7.3 Implications for Industry: Investing in Human Capital

The industry must move beyond being a passive consumer of graduates and become an active participant in the skill-building ecosystem.

- **The need for re-skilling:** Companies must continue to invest in professional development as technology cycles shorten[32]. Industry leaders should create frameworks for Industry 5.0 Skills that combine human creativity and self-driving vehicles[20], [29].
- **Capacity building:** Strengthening industry-academia linkages, such as more rigorous traineeships and joint research laboratories, will help bridge the practical skills gap identified by recent graduates[6], [24].

7.4 Implications for Policymakers: Bridging the Divide

Policymakers face the dual challenge of standardization and accessibility.

- **Standardization:** The NEP 2020 will be implemented across the country; thus, it would be good to use the Aswal model to standardize the quality and learning outcomes[36].
- **Digital Divide:** 70 percent of rural students are digitally deprived of the resources necessary to compete for the high-tech jobs market (Singh and Sadhana), which is a policy concern for closing this gap in order to make the Skill India programme successful at the national level[24].

7.5 Alignment with India's Vision 2047: The Path to Viksit Bharat

The Viksit Bharat 2020 vision, therefore, is really a challenge in human capital, particularly in the engineering sector, which has to shift from the traditional building to creating smart, sustainable and resilient infrastructure. The Roadmap to 2047, as summarized in the SWOC Matrix, needs to be strategically aligned with national economic and environmental objectives based on matching technical capabilities[19].

The demographic dividend (young working-age population) is the biggest growth engine for India, and the digital dividend (the country is already well embedded in the leading-edge digital public infrastructure of the world) is an opportunity for capitalizing on India's fintech and connectivity leadership[19]. In our framework, this force is addressed by our redefining the civil engineer as a digital native rather than as a builder, so that the next generation of engineers could drive the $1 trillion digital economy by mastering the vertical-stem technical skills, particularly BIM-life cycle management and digital twin integration, to manage complex, data-rich urban systems in 2047[11].

The results from the SWOC analysis show two important structural barriers: a major gap between industry and academia, and a continuing rural-urban gap, with roughly 70% of rural students not being exposed to high-level technical resources[19]. Vijk Bharat can be achieved through the outcome-based learning model proposed by Hafzal et al.[24] ... Our competence mapping framework fills these gaps by standardizing the plan so that rural graduates have future skills comparable to their urban counterparts, including AI-driven project management and sustainable materials science, thereby reducing the high level of technical unemployment[19], [27][24].

The National Education Policy 2020 offers the requisite policy window to correct this brick-and-mortar bias in the present-day education system and to integrate multidisciplinary training, where engineers develop a horizontal bar model of a T-shape (including urban policy, ethical leadership and stakeholder management)[11][24]. Additionally, by leading the global green transition through carbon-neutral design and circular economy principles, India can position its engineering workforce as a global exporter of sustainable knowledge to an aging international economy[19]. Dealing with issues: coping with a dynamic global situation Fourth, the Roadmap must tackle the issues of climate vulnerability and technological obsolescence[32][19]. Given the greater risks to infrastructure longevity from natural disasters, the Framework also focuses on `Resilience and Safety` in training engineers in climate-adaptive design and health monitoring of structures[1]; and to mitigate the rapid pace of the fourth industrial revolution, promoting a lifelong learning mindset to ensure that competences of 2025 are relevant in the high-tech environment of 2047[32], [42].

Finally, the vision of a developed India calls for a transition from a degree-oriented education to a skills-oriented labour market[24], and by aligning its engineering workforce with the strategic vision of the SWO matrix, India can ensure that its road to 2047 is not only technologically advanced, but inclusive and resilient[19][18].

Table 3: SWOC Matrix for India's Infrastructure and Education Roadmap (Viksit Bharat @ 2047)

Category	**Key Strategic Factors**	**Data-Driven Insights**
Strengths	Demographic & Digital Leadership	• Demographic Dividend: India possesses a massive, young workforce capable of driving a $1 trillion digital economy[19]. • Digital Public Infrastructure: Global leadership in fintech and digital connectivity provides a foundation for smart city growth[19]. • Economic Influence: Rising status in international policy forums (G20) and global supply chains [19].
Weaknesses	Educational & Structural Gaps	• Industry-Academia Mismatch: Current engineering curricula often fail to meet the "outcome-based" demands of Industry 4.0 [24]. • Rural-Urban Divide: Approximately 70% of the rural student population faces significant barriers to digital and technical literacy[19] • Underemployment: High rates of structural unemployment among technical graduates due to missing specialized skills[19].
Opportunities	Policy Reform & Sustainability	• NEP 2020: The shift toward multidisciplinary education and flexible credit systems allows for integrated engineering and management training[24]. • Green Transition: Potential for global leadership in renewable energy and carbon-neutral infrastructure[18]. • Global Knowledge Hub: Opportunity to become the primary exporter of skilled technical talent to aging global economies[24].

Challenges	Environmental & Tech Constraints	• Climate Vulnerability: Increasing frequency of disasters threatening the longevity of aging and new infrastructure[1]. • Technological Obsolescence: The rapid pace of the Fourth Industrial Revolution outstripping faculty retraining and curriculum updates[32]. • Geopolitical Volatility: Fluctuating global material costs and supply chain disruptions affecting large-scale project timelines[19].

8. CONCLUSION

8.1 Summary of Key Findings

The journey toward the Viksit Bharat of 2047 needs a complete reengineering of the Indian infrastructure workforce. The key observations here are that India has the demographic dividend with a median age of 28 years, but it can only be leveraged by aggressively tackling the digital skills gap. Technological integration, such as building information modelling (BIM), digital twins, and artificial intelligence (AI) for predictive analytics, has moved from a niche area to a core competency. Moreover, the imperatives of climate resilience and the inclusion of renewable energy systems, such as smart urban heating and cooling HVAC solutions, have become a prerequisite for development. However, undergraduate programmes still have structural mismatches in that they still favour traditional basic sciences over the computational, managerial and interdisciplinary skills required by global industry.

8.2 Importance of Future-Ready Civil Engineers

Civil engineers have moved from the role of the technical designer to a T-shaped professional: an integrator of high-tech digital systems and an environmental and building manager[30].; they are the future-ready engineers who will be the architects of the trillion-dollar digital economy and the resilient smart cities, who will be called upon to balance the complex environments of stakeholders, deliver social justice, and design infrastructure that is safe and operational as the risk of climate-induced catastrophes increases.; Finally, only a workforce that accepts lifelong learning as the only viable defences against rapid technological disruption can achieve success with the national missions of India.

8.3 Final Recommendations

By adopting these recommendations, India can cultivate a resilient, innovative, and highly skilled civil engineering workforce capable of delivering the world-class infrastructure required for a developed nation in 2047.

To realign the engineering profession to meet the technological and environmental imperatives of 2047, the following strategic actions are advised:

1. **Develop a dynamic competence framework for engineers:** Academics and professional bodies should adopt a tiered mapping model to transition engineers from digital literacy to strategic leadership in climate-resilient urban planning [1], [31], [32].
2. **Outcome-based learning reform:** engineering institutions should rebalance curricula to prioritize computational science, data science and project risk management, and to ensure that learning outcomes are in line with the global accreditation standards set by the National Board of Accreditation[34], [55].
3. **Standardisation through the Aswal model:** the Aswal model should be used by policymakers to ensure that the 2020 national education policy is implemented consistently across institutions, and in particular to address the resource gap that currently affects 70 percent of rural students[19], [36].
4. **Strengthened industrial-academia ecosystems:** compulsory industrial traineeships, collaborative research and continuous re-skilling of faculty should be institutionalized to keep up with the rapid ad-

vances in autonomous robotics and sustainable energy [24], [54].

By adopting these recommendations, India can develop a highly qualified, innovative and resilient civil engineering workforce that will deliver the world-class infrastructure required for a developed country by 2047.

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