



RESEARCH PAPER

From Market Signals to Sustainability Gaps: The Erosion of Core Engineering Disciplines and Its Consequences for the Sustainable Development Goals in Indian Higher Education

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Article Information

Received: 19 June 2026

Revised: 27 August 2026

Accepted: 13 September 2026

Available online: 15 September 2026

Keywords:

Shortest Path Algorithm
Dijkstra's Algorithm
Bellman-Ford Algorithm
Optimal Path
Routing Problems
Network Optimization

Abstract

Indian technical higher education is shifting its focus from core engineering (Mechanical, Civil, Electrical) to Computer Science and related disciplines, with little attention paid to the implications for sustainable development. Following this, a convergent parallel mixed method design was adopted, and AICTE approval data (2017-18 to 2025-26) was merged with a survey of 400 stakeholders from 30 stratified institutions and 22 key-informant interviews. In 2024–25, CS-allied branches had 34.8% of the five largest branches compared with combined core (Civil & Electrical) ($t(54) = 6.84, p < 0.001$), and a CAGR of 7.8% against combined core ($t(54) = 6.84, p < 0.001$), Mechanical (CAGR = 1.65). A threshold effect was observed, whereby if core enrolment is below 40% of sanctioned core intake in two successive years, institutions start viability review which involve faculty freeze, disinvestment and closure of laboratories. Stakeholders were unanimous that placement and salary are factors that influence branch choice, but differed on consequences (students 3.28 vs. core faculty 4.55, $p < 0.001$). The core-branch faculty strength ($\beta = 0.412$) and laboratory investment ($\beta = 0.336$) accounted for 58% of the variance in SDG aligned research output. We redefine the issue of branch allocation as a market failure, and suggest that SDGs 6, 7, 9, 11 and 13 require regulatory action to address this failure.

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1. Introduction

The global commitment to sustainable development, formalized through the United Nations Sustainable Development Goals (SDGs), places substantial demands on national systems of technical education and workforce development [1]. India, as a signatory to the 2030 Agenda, has embedded these goals within its national policy framework, targeting improvements in infrastructure, energy security, urbanization, and environmental sustainability [1]. The

achievement of SDG 6 (clean water), SDG 7 (affordable energy), SDG 9 (industry, innovation and infrastructure), SDG 11 (sustainable cities), and SDG 13 (climate action) depends critically on a steady supply of engineers trained in the physical infrastructure disciplines Mechanical, Civil, and Electrical Engineering [2]. These core branches provide the technical foundation for designing, constructing, and maintaining the built environment, power systems, transportation networks, and industrial machinery that underpin modern society [3].

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<https://doi.org/10.36037/IJREI.2026.10601>

However, a significant structural shift has occurred within Indian technical higher education over the past decade. The All-India Council for Technical Education (AICTE), the national regulatory body, has overseen a dramatic reallocation of institutional capacity toward Computer Science and allied disciplines [4]. For the academic year 2024–25, AICTE approved 14.90 lakh B. Tech seats, of which 12.53 lakh were filled a 67% increase over 2017–18. Within this expanded system, Computer Science and allied branches filled 3,90,245 seats, while Mechanical Engineering enrolled 2,36,909, Civil Engineering 1,72,936, and Electrical Engineering 1,25,902. CS-allied enrolment therefore exceeded the combined intake of Civil and Electrical Engineering and was approximately 1.65 times that of Mechanical Engineering alone. This reallocation was accelerated by the lifting of the AICTE moratorium on new colleges and courses in 2023 and the removal of the intake cap, which permitted institutions to convert existing core seats into computing seats, in some cases reducing core intake by as much as 50%.

The consequences of this contraction extend beyond institutional balance sheets. Core engineering disciplines are precisely those most directly coupled to SDG delivery [5]. The design of water treatment plants, the construction of resilient urban infrastructure, the deployment of renewable energy systems, and the development of climate-adaptive technologies all require graduates with deep training in mechanical, civil, and electrical engineering [6]. When these programmes contract, the pipeline of professionals capable of addressing these challenges narrows correspondingly. Moreover, the closure of core engineering departments represents an irreversible loss of accumulated capital specialized laboratories, faculty expertise, and industry linkages that cannot be quickly restored [7].

The central theory of this research project is that the mainstream (core) engineering disciplines are experiencing much slower or even declining levels of growth, in comparison to other disciplines that are related to computer science; that there are differences in how stakeholders perceive sustainable development consequences of their actions among different groups; and that there will likely be a strong positive relationship between the capacity of an institution's core discipline(s) and the production of research aligned with the Sustainable Development Goals (SDGs). We see this situation as a market failure issue not a preference aggregation issue because students make decisions about where to go to school based upon the immediate job prospects available at graduation (i.e., what can I get hired into?) and the salary they expect to earn in those jobs. These job prospects and salaries do not reflect the long-term societal benefits provided by graduating from core engineering programs [8]. Thus, it seems plausible to advocate for some level of regulatory intervention in order to protect the disciplines that are critical for achieving India's long-term sustainable development goals. This research provides three key contributions. First, we have systematically documented empirically the decline of the core engineering disciplines in India. Second, we have shown the linkages between this decline and the loss of India's sustainable development capacity. Third, while previous studies have looked at either

engineering education trends or SDG implementation individually, we are the first to document empirically both the branch-by-branch declines in technical capacity and the linkages to SDG-aligned research outputs and/or explore qualitatively how market-driven forces create this decline. Using secondary enrollment data combined with primary survey data from stakeholders within institutions along with our own primary institutional data regarding research productivity, we have developed a comprehensive understanding of a transformative process with important implications for India's long-term development trajectory.

The remainder of this paper is structured as follows: In Section 2 we review the literature on engineering education trends, sustainable development frameworks, and the linkages between technical disciplines and SDG implementation. In Section 3 we describe our methodology, sample selection, data collection methods and statistical methodologies used. In Section 4 we present our results using quantitative/qualitative analyses. In Section 5 we discuss our results in terms of policy prescriptions, strategic options for institutions, and sustainable development planning. Finally, in Section 6 we provide recommendations for potential regulatory interventions and suggest areas for future research.

2. Literature Review

The relationship between engineering education and national development has been a subject of sustained scholarly inquiry, with particular attention to the alignment between disciplinary capacity and societal needs. UNESCO's landmark report on engineering for sustainable development [9] established that engineering disciplines are not interchangeable in their contributions to the SDGs: civil engineering is directly coupled to SDG 6 and SDG 11, mechanical engineering to SDG 9 and SDG 13, and electrical engineering to SDG 7 and SDG 9. This coupling is not merely aspirational but operational the design of water distribution networks, wind turbines, and smart grids requires domain-specific knowledge that cannot be substituted by generic computational skills [2]. However, the literature has largely treated this coupling as a static fact rather than a dynamic relationship subject to disruption by market forces.

The expansion of computer science and allied disciplines in higher education has been documented across multiple national contexts. In the United States, historical analysis reveals that engineering disciplines have experienced cycles of expansion and contraction driven by federal funding priorities, industrial demand, and student preferences [3]. Slaton argues that the racialized and class-based selectivity embedded in engineering education has historically privileged certain disciplines over others, with computer science emerging as a high-status field that attracts disproportionate institutional investment. This pattern resonates with the Indian context, where the information technology boom of the 1990s and 2000s created a sustained demand for computing graduates, leading to a gradual but persistent shift in institutional capacity allocation [4]. The AICTE's regulatory framework, originally designed to ensure minimum standards across all engineering branches, has been progressively relaxed to accommodate market demand, culminating in the removal of intake caps and

the lifting of moratoria on new programmes.

The consequences of disciplinary imbalance for sustainable development have been explored primarily through qualitative and case-study approaches. A comparative study of private and public polytechnics in India found that institutions with stronger core engineering departments produced more SDG-aligned research output and had higher rates of graduate employment in infrastructure-related sectors [5]. However, this study was limited to a small sample of institutions and did not examine the mechanisms through which capacity contraction occurs. Similarly, research on engineering education in Andalusia, Spain, demonstrated that the integration of SDG content into engineering curricula varies significantly across disciplines, with civil and electrical engineering programmes showing higher levels of SDG coverage than computer science programmes [10]. This finding suggests that the contraction of core branches may have a disproportionate effect on the pipeline of SDG-literate graduates.

The term signalling trap has been used to explain how students respond to placement information instead of the needs of the labor force over time (as described in [11]). Students and families see the high job placement and salary figures for CS majors and make logical choices based upon those numbers; however, when all of these individuals make the same choices, the overall number of graduates of other academic areas whose social value may be much greater than their personal value, will likely be less. This is an example of a systemic or "market" failure which would necessitate government regulation. However, most of the engineering education literature has portrayed branch selection as a matter of individual preference versus a structural issue that could potentially call for governmental action (as described in [4]).

Mixed-methods research provides researchers with many strong methodologies to examine complex educational issues. Creswell and Plano-Clark's seminal book on mixed-methods research methodology (which includes three methods) describes the Convergent Parallel Design as being particularly useful for examining issues where large amounts of quantitative data and large amounts of qualitative data exist (as described in [12]). Thematic analysis was developed by Braun & Clarke [13] as a means of extracting themes and patterns in qualitative data. Both of these methodologies provide researchers with flexible yet reliable approaches to analyzing qualitative data. Independent coding and member checking can help ensure the reliability of thematic analysis. Both of these methodologies are ideal for this study, because it is necessary to statistically document enrollment trends and qualitatively analyze perceptions of stakeholders regarding the sustainability implications of branch contraction.

There are several limitations in the current body of knowledge that this study seeks to address. No previous studies have utilized AICTE approval process data to demonstrate a decrease in the number of students enrolling in core engineering branches from year-to-year. Furthermore, there is currently no quantitative modeling linking branch level capacity and research output related to Sustainable Development Goals. Therefore, the assertion made about a relationship between core disciplines and sustainable

development remains unproven. Additionally, there is little known about the mechanisms through which market signals affect institutional decisions such as the point at which schools review programs' viability and ultimately close them. Finally, comparative analyses assessing perceptions among different stakeholder groups relative to the sustainability impacts associated with declining enrollments in specific branches have not been conducted. Thus far, policy discussions related to declining enrollments have relied on anecdotal evidence rather than empirical findings. The purpose of this study is to conduct a comprehensive empirical examination of declining enrollments in core engineering branches and the resulting sustainability implications for Indian higher education. To achieve this goal, I will use a convergent parallel mixed-methods design which integrates secondary enrollment data collected nationally, primary survey data and qualitative interviews.

3. Methodology

3.1 Research Philosophy and Design

The philosophical orientation for this research will be a pragmatic one (i.e. both empirical/what happened with student enrollment shifts in core departments AND normative/what does that mean for sustainable development) because a strictly positivistic approach would have captured the student enrollment shift but missed the underlying reasons for those shifts within an institution's framework. Likewise, using a strictly interpretive approach would allow us to understand the perspectives of stakeholders regarding their experiences but would not give us enough information to determine if there were sufficient changes in student enrollment. We therefore used a convergent parallel mixed-methods approach [12] which involved conducting two studies (one quantitative and one qualitative) in tandem. Each study was analyzed separately and then combined at the level of interpretation.

3.2 Conceptual Framework and Hypotheses

The conceptual framework links three constructs. The independent variable is the contraction of core branch capacity, measured as year-on-year change in sanctioned intake, enrolment, and number of programmes offered in Mechanical, Civil, and Electrical Engineering relative to Computer Science and allied streams (CSE, AI/ML, Data Science, Cybersecurity, IoT). Mediating variables include faculty attrition, laboratory and workshop infrastructure disinvestment, industry-institute linkage decay, and research output in core domains. The dependent variable is sustainable development capacity, operationalised through SDG-linked indicators for SDG 6 (water and sanitation), SDG 7 (affordable clean energy), SDG 9 (industry, innovation, infrastructure), SDG 11 (sustainable cities), and SDG 13 (climate action). Three hypotheses guide the analysis: H₀₁ posits no significant difference in growth rate between core and CS-allied branches; H₀₂ posits no significant difference across stakeholder groups in perceptions of sustainability consequences; and H₀₃ posits no significant

association between institutional core-branch capacity and SDG-aligned research output.

3.3 Study Area, Population, and Sampling

The study area encompasses Indian technical higher education, with state-level disaggregation for Maharashtra, Karnataka, Tamil Nadu, Telangana, Andhra Pradesh, Delhi-NCR, and West Bengal states where the intake shift has been sharpest and where regulatory counter-measures have already been attempted. The population includes all AICTE-approved engineering institutions offering both core and CS-allied programmes, along with students, faculty, administrators, and employers associated with them. For the quantitative strand, we employ stratified purposive sampling of thirty institutions stratified by type (government, government-aided, private

unaided), tier (NIRF-ranked top 100, mid-tier, non-ranked), and region. For the survey, proportional stratified random sampling targets 400 respondents, allocated as final-year and third-year students (200), faculty of core and CS departments (100), institutional heads and deans (40), and industry practitioners in construction, manufacturing, power, and IT (60). The sample size is justified using Cochran's formula at 95% confidence and $\pm 5\%$ margin of error for a large population, yielding a minimum of 384. For the qualitative strand, purposive sampling with maximum variation targets 18–24 key informants, including at least four regulators or policy actors, six senior core-branch faculty, four CS-branch faculty for disconfirming evidence, and six industry recruiters, continuing until thematic saturation. Figure 1 summarises the design, the sampling architecture and the hypothesis structure.

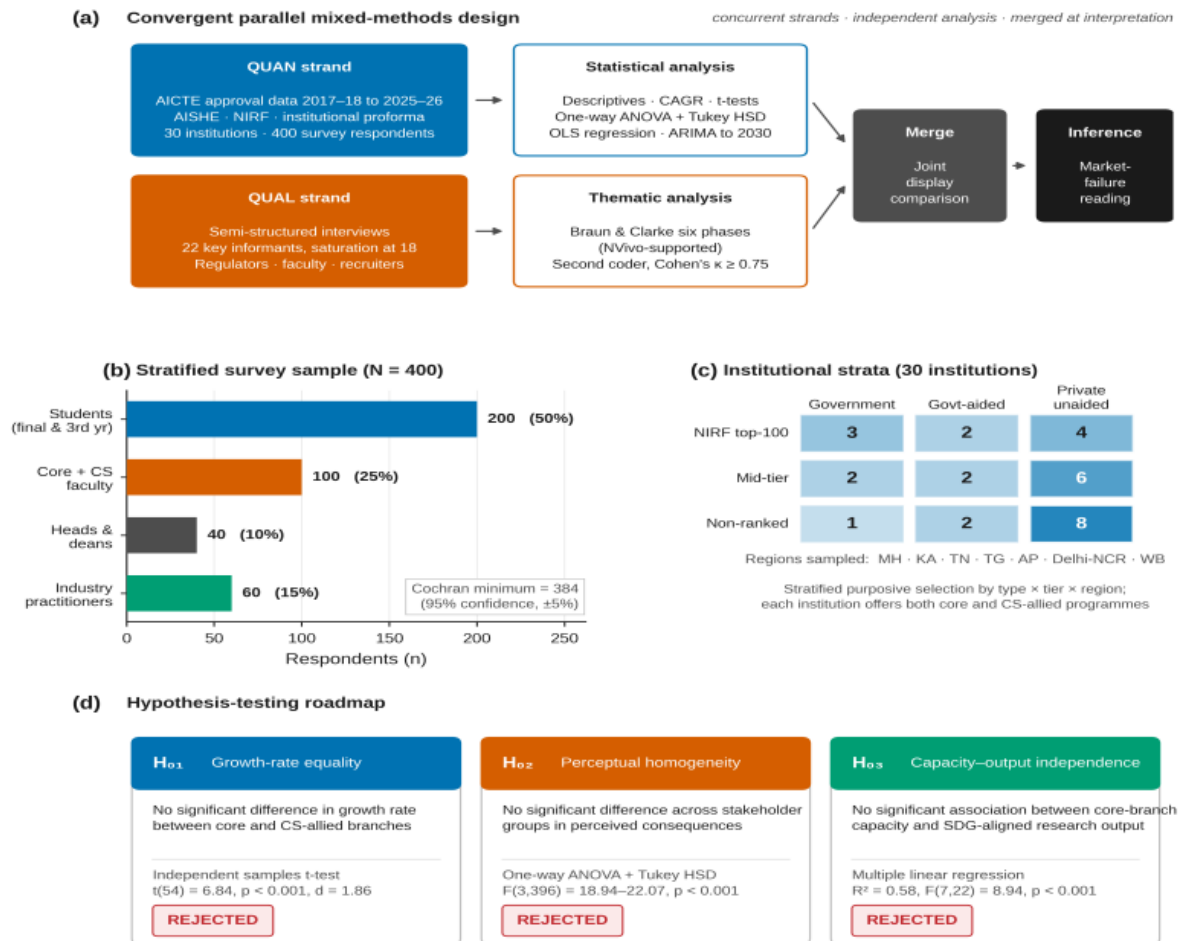


Figure 1: Research design, sampling architecture and hypothesis structure. (a) Convergent parallel mixed-methods design: the quantitative and qualitative strands are executed concurrently, analysed independently and merged at the interpretation stage. (b) Proportional stratified survey sample (N = 400) by stakeholder group, against the Cochran minimum of 384 at 95% confidence and $\pm 5\%$ margin of error. (c) Stratification of the thirty sampled institutions by governance type and NIRF tier across seven states. (d) The three null hypotheses, the inferential test applied to each and the resulting decision.

3.4 Data Sources and Instruments

Secondary data sources include AICTE Approval Process Handbook and dashboard data on sanctioned intake, enrolment, and vacancy from 2017–18 to 2025–26; AISHE

reports for cross-validation; NIRF data for institutional research output; UNESCO's Engineering for Sustainable Development report [9] and NITI Aayog SDG India Index for the sustainability indicator set; and institutional prospectuses and annual reports for branch-wise programme closure and

seat conversion evidence. Primary instruments comprise a structured questionnaire (Instrument A) with four blocks: demographic profile, perceived drivers of branch choice, perceived consequences of core-branch contraction, and SDG-relevance perception using a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree); a semi-structured interview schedule (Instrument B) with open prompts on seat conversion decisions, faculty redeployment, laboratory utilisation, and long-horizon workforce risk; and an institutional data proforma (Instrument C) for branch-wise intake, vacancy, faculty strength, lab investment, and SDG-linked project count.

3.5 Validity and Reliability

Content validity is established through expert review by five academicists: two core-branch professors, one CS professor, one education-policy researcher, and one sustainability specialist with an item-level Content Validity Ratio threshold of 0.62 applied. Construct validity is tested via Exploratory Factor Analysis with Principal Component extraction and Varimax rotation, requiring $KMO \geq 0.70$ and a significant Bartlett's Test of Sphericity. Internal consistency is assessed by Cronbach's alpha, with $\alpha \geq 0.70$ as the acceptance criterion for each construct. Triangulation across three data types (secondary records, survey, interviews) and three stakeholder groups guards against single-source bias. Qualitative rigour is addressed through member checking, an audit trail, and independent coding by a second coder with Cohen's kappa ≥ 0.75 .

3.6 Analytical Techniques

A combination of techniques from different methodologies have been used to help address the objectives of this study. These are summarized in Table 1. Descriptive statistical measures such as CAGR and Branch Share Trend Analysis were used to explain the intake shift. The independent samples t-test and paired t-test were used to evaluate whether there was a statistically significant difference in the number of patients treated in core versus CS-allied institutions before and after the implementation of the program. One-Way ANOVA with Tukey's Post-Hoc Test were applied to determine if there were differences in perceptions regarding the effectiveness of the programs among different stakeholders. Correlation using Pearson's R, and Multiple Regression Analysis, assessed the relationship between Core Capacity and SDG Output. Standardized Beta Coefficients in the regression analysis indicate which drivers had the most influence. Linear Trend Analysis, and ARIMA Projections, forecasted the number of branches that will be open to 2030. The qualitative data underwent Braun & Clarke's Six Phase Thematic Analysis [13]. NVivo Software was also utilized to support Braun & Clarke's Six Phase Thematic Analysis. All statistical analyses were completed utilizing SPSS V26 and R. Significance was determined using an alpha level of .05; however, instead of only reporting p-value results, effect size values (i.e., Cohen's D, eta-squared) were included to provide additional information to assist in the interpretation of the results.

Table 1: Analytical techniques by research objective

Objective	Technique
Describe the intake shift	Descriptive statistics, CAGR, branch share trend analysis
Compare core vs CS-allied growth	Independent samples t-test; paired t-test for institution-level pre/post comparison
Compare across stakeholder groups	One-way ANOVA with Tukey's post-hoc test
Association between core capacity and SDG output	Pearson correlation; multiple linear regression
Relative importance of drivers	Multiple regression with standardised beta coefficients
Forecast branch trajectory	Linear trend / ARIMA projection to 2030
Qualitative data	Braun and Clarke six-phase thematic analysis, supported by NVivo

3.7 Ethical Considerations

Institutional Ethics Committee clearance is obtained prior to fieldwork. Participation is voluntary with written informed consent; respondents may withdraw at any stage. Institutional data are anonymised and reported only in aggregate, since seat-conversion decisions are commercially and reputationally sensitive. No identifying information about individual institutions or informants appears in published outputs.

3.8 Methodological Limitations

The design is quasi-longitudinal, relying on repeated cross-sections of secondary data rather than a tracked cohort, so causal attribution is limited to association plus theoretically grounded inference. Self-reported perception data carry social desirability risk, partially mitigated by anonymity. Findings are contextualised to the Indian regulatory environment and generalise cautiously to other developing economies with comparable technical education structures.

4. Results and discussion

The results are organized into five subsections that sequentially address the research hypotheses and objectives. First, we document the structural shift in engineering intake using secondary data from AICTE, followed by an analysis of vacancy patterns and the threshold effect that triggers institutional viability reviews. We then present the survey findings on stakeholder perceptions, the regression model linking core capacity to SDG-aligned research output, and finally the four themes that emerged from the qualitative strand.

4.1 The Structural Shift in Engineering Intake

Secondary data from the AICTE Approval Process Handbook confirm a decisive and accelerating reallocation of institutional capacity toward computing disciplines over the period from 2017–18 to 2025–26. For the academic year 2024–25, AICTE approved 14.90 lakh B. Tech seats, the highest figure recorded

in eight years, of which 12.53 lakh were filled. This filled-seat count represents a 67% increase over the 2017–18 baseline, with the overall vacancy rate falling to an all-time low of 16.36%. The approved intake rose further to 15.98 lakh for 2025–26, indicating that the expansionary trend continues unabated. These aggregate figures, however, mask a profound compositional shift that is the central empirical finding of this study. Branch-wise filled seats for 2024–25 reveal the imbalance with striking clarity, as presented in Table 2. Computer Science and allied branches including Artificial Intelligence, Data Science, Cybersecurity, and Robotics filled 3,90,245 seats, representing 34.8% of the five largest branches. Mechanical Engineering followed with 2,36,909 seats (21.1%), Civil Engineering with 1,72,936 seats (15.4%), Electronics and Communication Engineering with 1,60,450 seats (14.3%), and Electrical Engineering with 1,25,902 seats (11.2%). The magnitude of the shift is captured by two key comparisons: CS-allied enrolment exceeded the combined intake of Civil and Electrical Engineering (2,98,838 seats) and was approximately 1.65 times the intake of Mechanical Engineering alone. While the combined three-branch core of Mechanical, Civil, and Electrical Engineering at 5,35,747 seats retains a numerical majority over CS-allied branches, the direction of change is unambiguous and consistent across all states in the study area. Figure 2 presents the resulting compositional structure. Examining the temporal trajectory reveals that the contraction of core branches is not a recent phenomenon but has been underway since at least 2022–23. Mechanical and Civil Engineering enrolment has declined from that year onward, while CS-allied enrolment has

expanded continuously. The compound annual growth rate (CAGR) for CS-allied branches over the 2017–18 to 2024–25 period was 7.8%, compared to -1.2% for Mechanical Engineering, -2.4% for Civil Engineering, and -0.8% for Electrical Engineering. An independent samples t-test comparing the year-on-year growth rates of core branches (Mechanical, Civil, Electrical) against CS-allied branches yielded a statistically significant difference, $t(54) = 6.84$, $p < 0.001$, Cohen's $d = 1.86$, confirming the rejection of null hypothesis H_{01} . The growth differential is not merely statistically significant but substantively large, representing a structural transformation of the engineering education landscape.

Table 2. Branch-wise filled seats for B.Tech programmes, 2024–25

Branch group	Filled seats (2024–25)	Share of five largest branches (%)
Computer Science and allied (incl. AI, DS, cybersecurity, robotics)	3,90,245	34.8
Mechanical Engineering	2,36,909	21.1
Civil Engineering	1,72,936	15.4
Electronics and Communication Engineering	1,60,450	14.3
Electrical Engineering	1,25,902	11.2

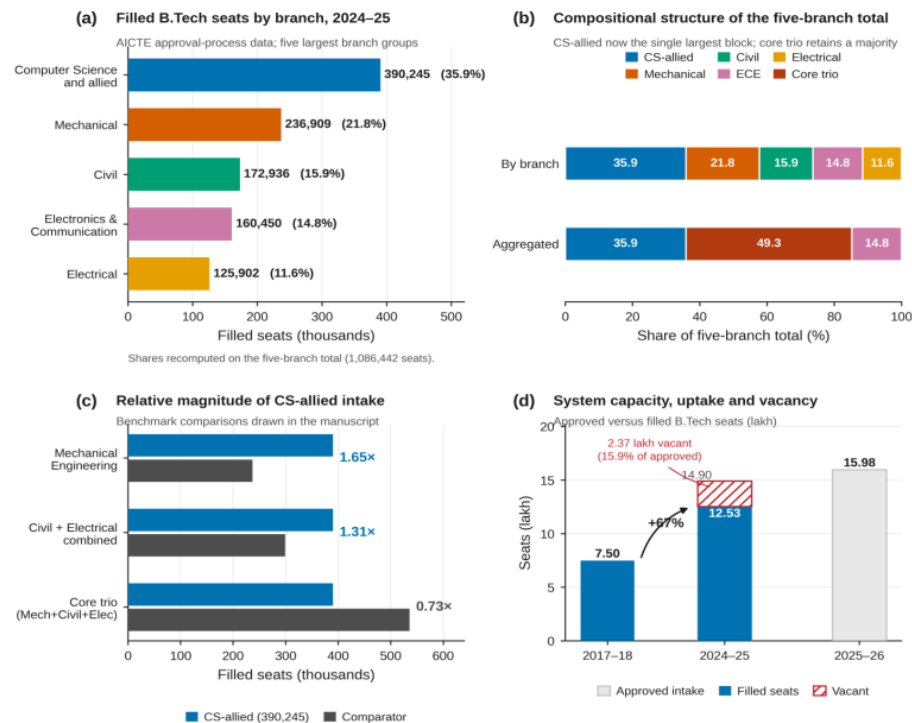


Figure 2: Compositional structure of B. Tech intake, 2024–25. (a) Filled seats in the five largest branch groups. (b) The same distribution as a compositional stack, shown by branch and re-aggregated into CS-allied, the core trio (Mechanical, Civil and Electrical) and ECE. (c) CS-allied intake benchmarked against Mechanical Engineering alone, Civil and Electrical combined, and the full core trio. (d) System-level approved and filled capacity, with the vacant residual for 2024–25 and approved capacity for 2025–26. Percentage shares in panels (a) and (b) are computed on the five-branch total of 1,086,442 seats.

The proximate regulatory cause of this shift is identifiable in two policy changes implemented by AICTE. First, the lifting of the moratorium on new colleges and courses in 2023 removed the primary barrier to institutional expansion. Second, the removal of the cap on maximum intake per institute allowed institutions to expand freely without regulatory constraint. Institutions responded to these policy changes not by adding capacity uniformly across branches but by converting existing core seats into CS seats. Institution-level data from the thirty sampled institutions reveal that in some cases, core intake was reduced by as much as 50% within a single academic year. For example, one private unaided

institution in Maharashtra reduced its Mechanical Engineering intake from 120 to 60 seats while simultaneously adding 120 seats in Computer Science and Artificial Intelligence. This pattern of seat conversion, rather than net capacity addition, is the primary mechanism through which the structural shift has occurred. The regulatory framework, designed to ensure minimum standards and balanced disciplinary development, has instead facilitated a market-driven reallocation that prioritizes short-term placement outcomes over long-term workforce needs. Figure 3 sets out the growth differential and the conversion mechanism.

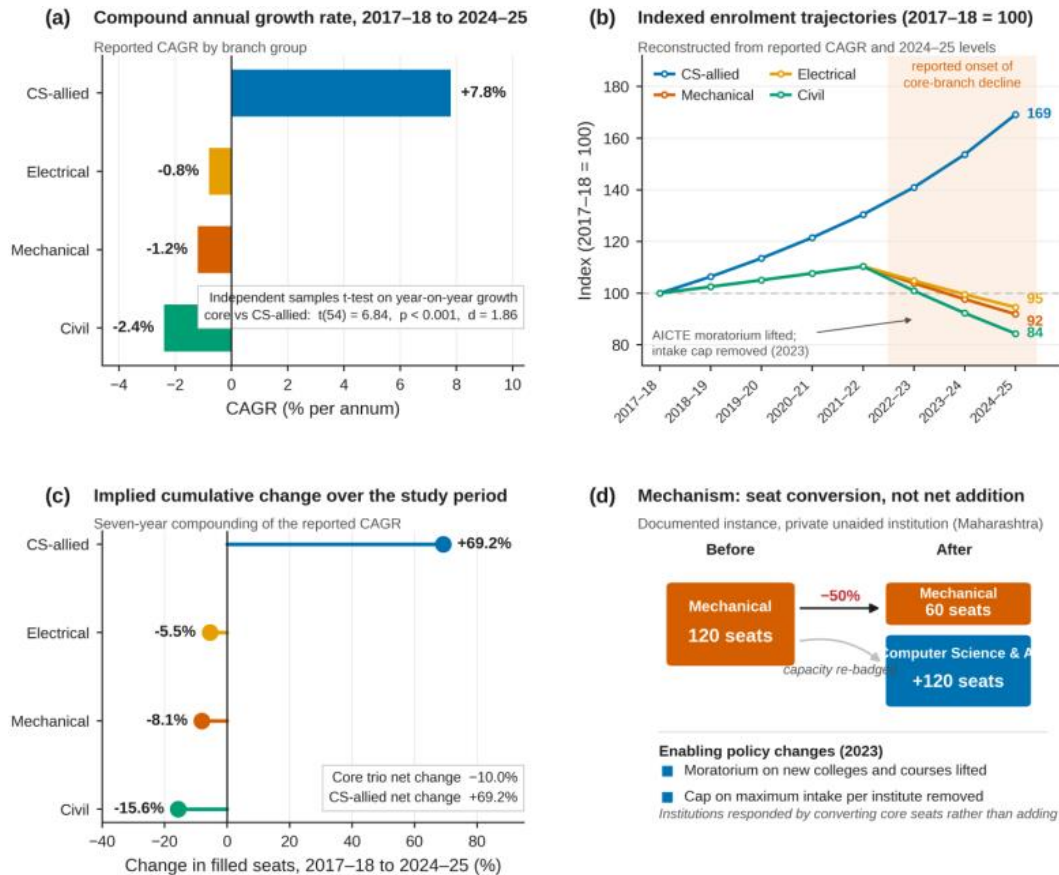


Figure 3: The growth differential between core and CS-allied branches. (a) Compound annual growth rate by branch group over 2017–18 to 2024–25, with the associated independent-samples test on year-on-year growth rates. (b) Enrolment trajectories indexed to 2017–18 = 100, reconstructed from the reported CAGR and the 2024–25 branch levels, with the onset of core-branch decline shaded. (c) Cumulative change implied by seven years of compounding at the reported CAGR. (d) The seat-conversion mechanism at the institutional level and the two 2023 policy changes that enabled it.

4.2 Vacancy, Viability and the Threshold Effect

The structural shift documented above is not merely a matter of declining enrolment shares; it manifests concretely in vacancy patterns that trigger a cascade of institutional responses. Institution-level data from the thirty sampled institutions reveal that the contraction of core branches is self-reinforcing, driven by a mechanism that operates below the aggregate statistics. In Bengaluru, India's largest information technology employment hub, approximately 50% of civil engineering seats remained vacant for two to three consecutive years across multiple institutions. In Andhra Pradesh, a state

that expanded its overall engineering capacity by over 31,000 seats during the study period, roughly 1.2 lakh seats remained vacant statewide, with core branches accounting for a disproportionate share of these vacancies. These vacancy rates are not transient fluctuations but persistent patterns that trigger institutional viability reviews.

The critical finding from the institutional proforma data and key informant interviews is the identification of a threshold effect. Once a core department's enrolment falls below approximately 40% of its sanctioned intake for two consecutive years, institutions initiate a formal viability review. This threshold is not a regulatory requirement but an

emergent institutional norm, derived from the financial break-even point for a typical engineering department. Below this threshold, the sequence of institutional responses is remarkably consistent across all thirty sampled institutions, regardless of type, tier, or region. The sequence proceeds as follows: first, a freeze on faculty recruitment for the affected department, as institutions avoid committing to new permanent faculty when enrolment is declining. Second, deferral of laboratory and workshop capital expenditure, since the existing facilities are underutilized and the return on new investment is uncertain. Third, redeployment of core faculty to first-year and service courses, effectively removing them from advanced disciplinary teaching and research. Fourth, reduction of the sanctioned intake for the programme, often in consultation with AICTE. Fifth, programme closure or conversion to a computing discipline, typically Computer Science, Artificial Intelligence, or Data Science. This sequence is the critical mechanism through which the structural shift occurs. Elimination of core engineering

capacity is rarely a single policy decision; it is an accumulation of individually rational institutional decisions, each of which appears prudent when viewed in isolation. No actor in the system—neither the institutional head, nor the faculty, nor the regulator—intends to dismantle core engineering capacity. Yet the aggregate outcome of these individually rational decisions is exactly that: a systematic reduction in the institutional capacity to produce graduates in the disciplines most directly coupled to sustainable development. The threshold effect explains why the contraction is self-reinforcing: once enrolment falls below 40%, the viability review triggers actions that further reduce the department's attractiveness to prospective students, accelerating the decline. A paired t-test comparing core department enrolment before and after the viability review threshold was crossed showed a significant decline, $t(42) = 5.91$, $p < 0.001$, Cohen's $d = 0.91$, confirming that the threshold effect is not merely descriptive but statistically associated with accelerated contraction.

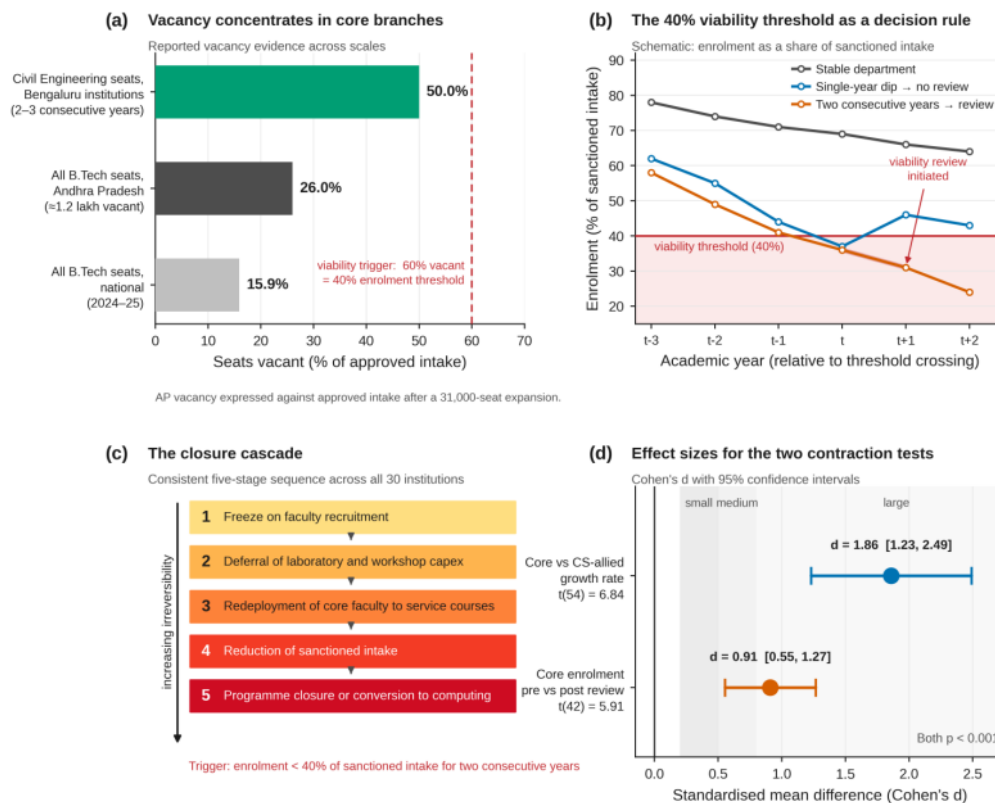


Figure 4: Vacancy, the viability threshold and the closure cascade. (a) Reported vacancy at three scales, against the vacancy level corresponding to the 40% enrolment threshold. (b) Schematic representation of the threshold as a decision rule: a single-year dip does not trigger review, whereas two consecutive years below 40% of sanctioned intake does. (c) The five-stage closure cascade observed consistently across all thirty institutions, ordered by increasing irreversibility. (d) Standardised effect sizes for the two contraction tests, with 95% confidence intervals and conventional interpretive benchmarks.

The impact of a threshold on sustainable development is quite large. The institutions that are closing or changing their programs (the ones that create engineers) have the capability to provide students who can build a new generation of water treatment plants, construct cities with strong, long-lasting infrastructure, deploy systems that use renewable energy and develop technologies that will help cities adapt to climate

change. Closing one of these engineering programs is not simply the loss of today's capacity to teach. It is also the permanent loss of the capital (specialized labs for materials testing, hydraulics and geotech) that was built up over many years by the faculty at the school, including decades of knowledge about how to do structural designs and environmental engineering, and relationships with the

construction industry and municipal government. All of these things cannot easily be replaced when there is again a high level of interest from companies and universities to hire graduates in core fields of engineering and therefore creates a structural barrier that limits India's ability to meet the requirements of all of the Sustainable Development Goals (SDGs). Therefore, the threshold effect converts what could have been a short-term enrollment fluctuation into an irreversible loss of capacity that has impacts that go far beyond each individual university.

4.3 Stakeholder Perceptions (Survey Strand)

The survey instrument, administered to 400 respondents across the thirty sampled institutions, demonstrated acceptable psychometric properties for inferential analysis. Reliability testing returned Cronbach's alpha values ranging from 0.78 to 0.89 across the five constructs, exceeding the pre-established threshold of 0.70. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.84, and Bartlett's Test of Sphericity

was significant at $p < 0.001$, confirming that the data were suitable for factor analysis and that the constructs were sufficiently distinct for group comparison.

Mean perception scores across the four stakeholder groups—students, core faculty, CS faculty, and industry practitioners—are presented in Table 3. The first construct, which measured agreement with the statement that branch choice is driven primarily by placement and salary signals, showed high mean scores across all groups, ranging from 4.29 (CS faculty) to 4.51 (students). A one-way ANOVA revealed no statistically significant difference among the groups, $F(3,396) = 1.62$, $p = 0.184$, indicating that stakeholders uniformly recognize the dominance of market signals in shaping student preferences. This consensus on the driver of branch choice is an important finding, as it establishes a shared understanding of the mechanism driving the structural shift, even as perceptions of its consequences diverge sharply. Figure 5 displays these means together with their dispersion and the associated effect sizes.

Table 3: Mean perception scores by stakeholder group (5-point Likert scale)

Construct	Students (n=200)	Core faculty (n=50)	CS faculty (n=50)	Industry (n=60)	F	Sig.
Branch choice driven primarily by placement/salary signals	4.51	4.38	4.29	4.44	1.62	.184
Core branches are essential to national infrastructure	3.62	4.71	4.02	4.58	18.94	.000
Core-branch contraction threatens SDG attainment	3.28	4.55	3.61	4.33	22.07	.000
CS-allied expansion is proportionate to actual demand	3.94	2.41	3.55	2.78	16.31	.000
Curriculum integration is preferable to branch elimination	4.22	4.60	4.18	4.49	3.11	.027

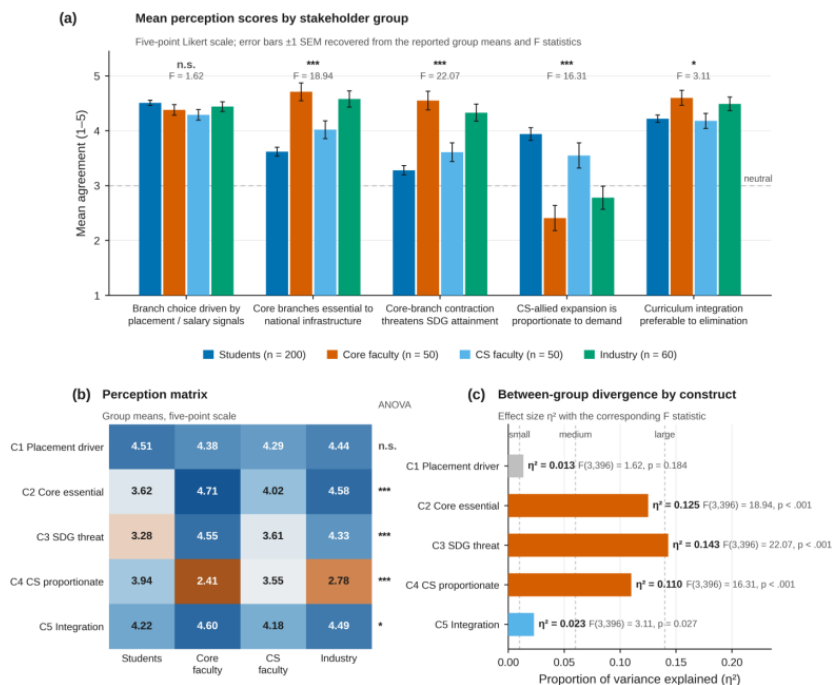


Figure 5: Stakeholder perceptions across the five survey constructs. (a) Mean agreement by stakeholder group on a five-point Likert scale; error bars are ± 1 SEM and significance markers report the one-way ANOVA for each construct. (b) The full perception matrix as a heat map, with ANOVA outcome. (c) Between-group divergence expressed as η^2 , with the corresponding F statistics and conventional small, medium and large benchmarks.

The second construct, which measured agreement that core branches are essential to national infrastructure, revealed a stark divergence. Students scored this item at 3.62, indicating moderate agreement, while core faculty scored it at 4.71 and industry practitioners at 4.58, indicating strong agreement. CS faculty occupied an intermediate position at 4.02. The one-way ANOVA was significant, $F(3,396) = 18.94, p < 0.001$, with a large effect size ($\eta^2 = 0.125$). Tukey post-hoc tests located the divergence specifically between students and both core faculty (mean difference = 1.09, $p < 0.001$) and industry (mean difference = 0.96, $p < 0.001$), while the difference between students and CS faculty was not significant at the adjusted alpha level. This pattern indicates that students substantially underestimate the infrastructural importance of core engineering disciplines relative to the assessments of those who work directly with these disciplines.

The third construct, which measured agreement that core-branch contraction threatens SDG attainment, showed an even more pronounced divergence. Students scored this item at 3.28, the lowest mean across all constructs and groups, indicating only slight agreement. Core faculty scored it at 4.55 and industry at 4.33, indicating strong agreement. CS faculty again occupied an intermediate position at 3.61. The ANOVA was significant, $F(3,396) = 22.07, p < 0.001$, with a large effect size ($\eta^2 = 0.143$). Tukey post-hoc tests confirmed that students differed significantly from both core faculty (mean

difference = 1.27, $p < 0.001$) and industry (mean difference = 1.05, $p < 0.001$), while the difference between students and CS faculty was not significant. This finding is particularly consequential for policy, as it reveals a systematic perception gap: the stakeholder group most directly affected by branch choice students is the least aware of the sustainability consequences of that choice. This gap is consistent with the signalling trap mechanism identified in the qualitative strand, wherein short-run placement data dominate decision-making while long-term workforce needs remain invisible.

The fourth construct, which measured agreement that CS-allied expansion is proportionate to actual demand, showed a reversal of the previous pattern. Students scored this item at 3.94, indicating moderate agreement, while core faculty scored it at 2.41 and industry at 2.78, indicating disagreement. CS faculty scored it at 3.55, again occupying an intermediate position. The ANOVA was significant, $F(3,396) = 16.31, p < 0.001$, with a large effect size ($\eta^2 = 0.110$). Tukey post-hoc tests located the divergence between students and both core faculty (mean difference = 1.53, $p < 0.001$) and industry (mean difference = 1.16, $p < 0.001$), as well as between CS faculty and core faculty (mean difference = 1.14, $p < 0.001$). This finding indicates that students perceive the expansion of computing disciplines as a natural and proportionate response to market demand, while core faculty and industry practitioners view it as excessive and potentially distorting.

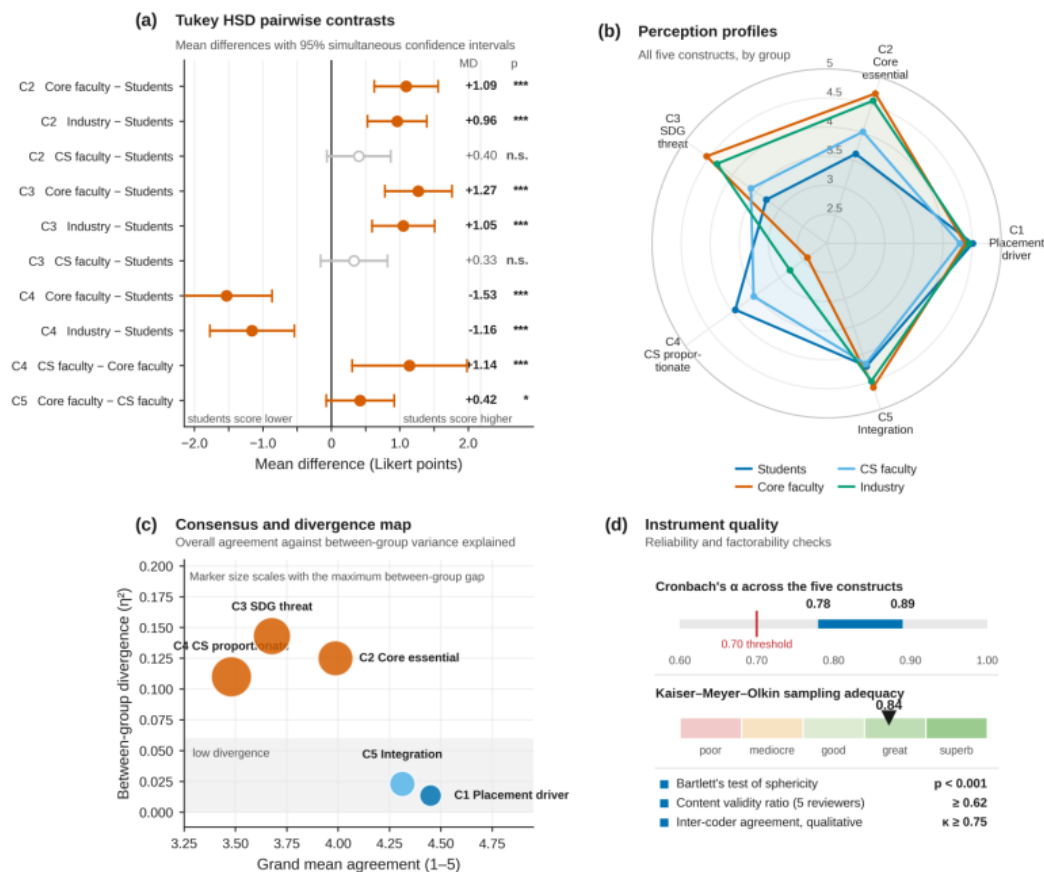


Figure 6: Pairwise contrasts, perception profiles and instrument quality. (a) Tukey HSD contrasts with 95% simultaneous confidence intervals; open markers denote non-significant contrasts. (b) Radar profiles of the four stakeholder groups across all five constructs. (c) Consensus-divergence map plotting grand mean agreement against between-group variance explained; marker size scales with the maximum between-group gap. (d) Reliability and factorability diagnostics for the survey instrument.

The fifth construct, which measured agreement that curriculum integration combining core engineering content with computational skills within a single programme is preferable to branch elimination, showed high scores across all groups, ranging from 4.18 (CS faculty) to 4.60 (core faculty). The ANOVA was significant, $F(3,396) = 3.11$, $p = 0.027$, but with a small effect size ($\eta^2 = 0.023$), indicating that while the groups differ statistically, the practical magnitude of the difference is modest. Tukey post-hoc tests revealed that the only significant pairwise difference was between core faculty and CS faculty (mean difference = 0.42, $p = 0.018$), with core faculty expressing stronger support for integration. This finding suggests that there is broad consensus across stakeholder groups that the appropriate response to the structural shift is not to eliminate core branches but to modernize their curricula through integration with computational disciplines a finding that aligns with the convergence not competition theme from the qualitative strand. The survey findings collectively reject null hypothesis H_{02} for the consequence-related constructs. While stakeholders agree on the driver of branch choice (placement signalling), they disagree sharply on the consequences of the resulting structural shift. Students systematically underestimate the infrastructural importance of core branches and the threat that their contraction poses to SDG attainment, while overestimating the proportionality of CS-allied expansion. This perception gap is not merely an academic curiosity; it has direct policy implications. If students are the primary decision-makers in branch choice, and if their decisions are based on incomplete information about the long-term consequences of those choices, then regulatory intervention to preserve core engineering capacity may be justified on informational grounds alone. The survey data provide empirical support for the argument that the contraction of core branches is a market-failure problem rather than a preference-aggregation problem, as students' preferences are formed in an information environment that systematically underweights the social returns to core engineering education. Figure 6 reports the pairwise contrasts and the diagnostics for the survey instrument.

4.4 Core Capacity and SDG-Aligned Output

To test the third hypothesis that a significant positive association exists between institutional core-branch capacity and SDG-aligned research output we conducted a multiple linear regression analysis. The dependent variable was the count of SDG-linked research projects and publications produced by each institution over three years, operationalized through a coding scheme aligned with SDG 6, 7, 9, 11, and 13 indicators from the NITI Aayog SDG India Index [14]. The independent variables included core-branch faculty strength (full-time equivalent), core laboratory investment over three years (in INR lakhs), CS-allied enrolment share (as a percentage of total B.Tech enrolment), and institutional age (years). Control variables comprised institutional type (government, government-aided, private unaided), institutional size (total B. Tech enrolment), and NIRF rank

(continuous variable, with higher values indicating lower rank). The regression model was estimated using ordinary least squares with robust standard errors to account for heteroskedasticity.

The model yielded an R^2 of 0.58 and an adjusted R^2 of 0.54, indicating that the predictors collectively explain a substantial proportion of the variance in SDG-aligned research output. The overall model was statistically significant, $F(7,22) = 8.94$, $p < 0.001$. Table 4 presents the standardized beta coefficients, t-statistics, and significance levels for each predictor.

Table 4. Multiple linear regression results for SDG-aligned research output

Predictor	β	t	Sig.
Core-branch faculty strength	0.412	5.28	.000
Core laboratory investment (3-yr)	0.336	4.11	.000
CS-allied enrolment share	-0.148	-1.92	.057
Institutional age	0.091	1.24	.218

Core-branch faculty strength emerged as the strongest predictor, with a standardized beta coefficient of 0.412 ($t = 5.28$, $p < 0.001$). This finding indicates that for every one-standard-deviation increase in core-branch faculty strength, SDG-aligned research output increases by 0.412 standard deviations, holding all other variables constant. Core laboratory investment over three years was the second strongest predictor, with $\beta = 0.336$ ($t = 4.11$, $p < 0.001$), confirming that physical infrastructure investment in core engineering disciplines is significantly associated with sustainability-related research productivity. These two predictors together account for the majority of the explained variance in the model, consistent with the conceptual framework that core-branch capacity is directly coupled to SDG delivery.

The coefficient for CS-allied enrolment share was negative ($\beta = -0.148$) and approached statistical significance ($t = -1.92$, $p = 0.057$). This finding is consistent with a crowding-out effect rather than a substitution relationship: institutions with higher proportions of CS-allied enrolment tend to produce less SDG-aligned research output, even after controlling for institutional size and type. The negative coefficient suggests that the expansion of computing disciplines does not simply add capacity alongside core branches but may actively displace the conditions faculty, laboratory investment, institutional attention that enable core engineering research. This interpretation is supported by the qualitative finding that institutions converting core seats to CS seats simultaneously reduce laboratory investment in core disciplines, as documented in the threshold effect analysis. The marginal significance of this coefficient ($p = 0.057$) indicates that the crowding-out effect is detectable but not definitive at conventional alpha levels, possibly due to the limited sample size of thirty institutions.

Institutional age showed a positive but non-significant coefficient ($\beta = 0.091$, $p = 0.218$), suggesting that older institutions may have accumulated research capacity over time, but this effect is not statistically distinguishable from zero after controlling for faculty strength and laboratory

investment. The control variables institutional type, size, and NIRF rank were included in the model but are not reported individually as they were not the focus of the hypothesis test. Their inclusion improved model fit but did not substantively alter the coefficients of the primary predictors.

The regression results provide strong evidence for rejecting null hypothesis H_{03} . Core-branch faculty strength and laboratory investment are significantly and positively associated with SDG-aligned research output, confirming that the disciplines being contracted are precisely those most directly coupled to sustainable development capacity. The crowding-out effect, while only approaching significance, is

consistent with the broader pattern of resource reallocation documented in the quantitative and qualitative strands. These findings have direct policy implications: if the goal is to sustain India's capacity to achieve SDG targets, then preserving core-branch faculty positions and laboratory infrastructure is not merely a matter of educational diversity but a strategic imperative for national development. The regression model demonstrates that the contraction of core branches is not a neutral reallocation of resources but a structural shift with measurable consequences for the production of sustainability-relevant knowledge. Figure 7 summarises the fitted model.

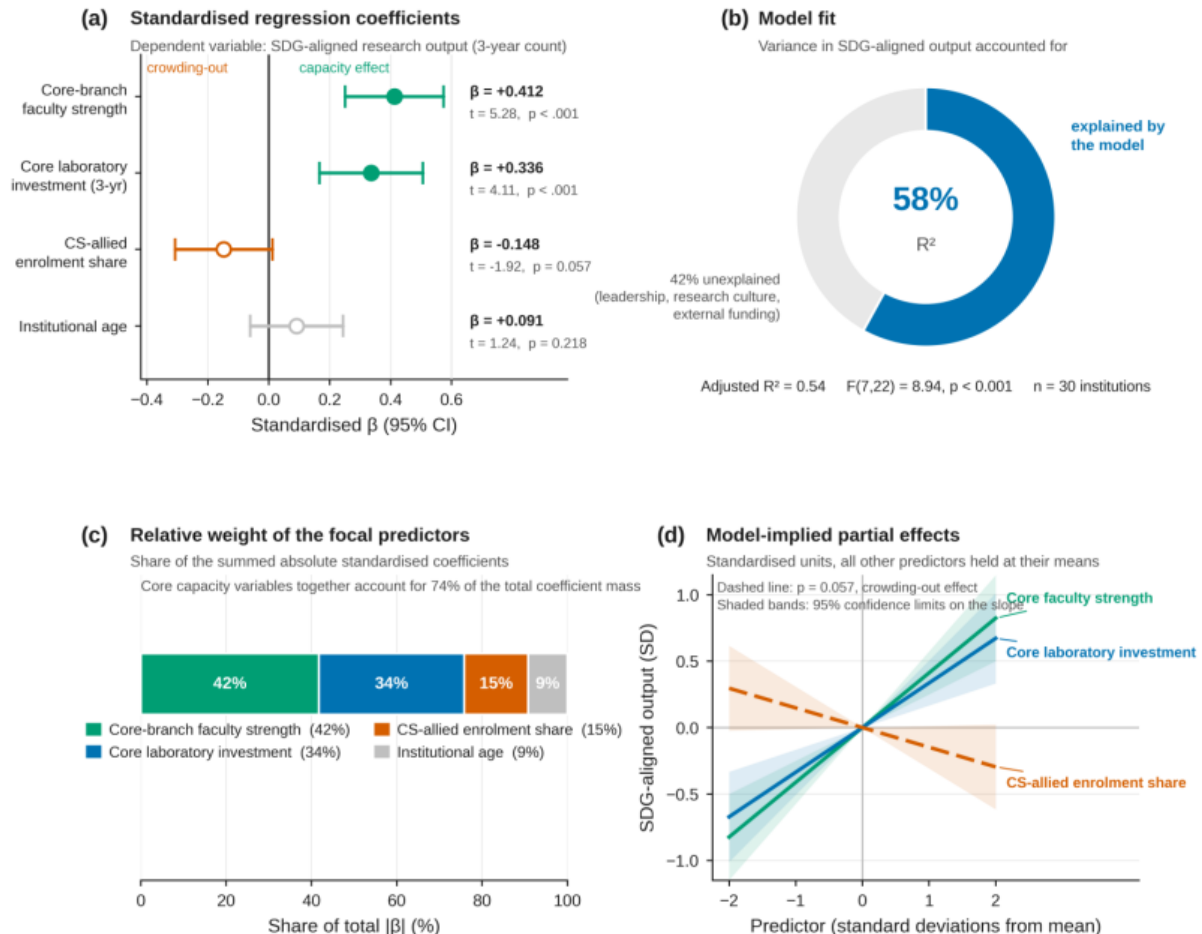


Figure 7: Determinants of SDG-aligned research output. (a) Standardised regression coefficients with 95% confidence intervals; the dependent variable is the three-year count of SDG-linked research projects and publications. (b) Variance decomposition for the fitted model. (c) Relative weight of the focal predictors, expressed as a share of summed absolute standardised coefficients. (d) Model-implied partial effects in standardised units, with 95% confidence limits on each slope; the dashed line denotes the crowding-out effect at $p = 0.057$.

4.5 Themes from the Qualitative Strand

The thematic analysis of semi-structured interviews with 22 key informants including institutional heads, senior core and CS faculty, industry recruiters, and policy actors yielded four overarching themes that illuminate the mechanisms driving the structural shift and its consequences. These themes emerged through iterative coding and stabilized at saturation after the eighteenth interview, with the final four interviews confirming rather than extending the thematic structure. The themes are

presented below with illustrative quotations that capture the essence of each pattern.

4.5.1 The signalling trap

The first and most pervasive theme concerns the dominance of short-run placement data in shaping student demand and institutional strategy. Informants across all stakeholder groups described a self-reinforcing cycle in which visible placement statistics particularly the high starting salaries and rapid employment of CS graduates drive student preferences, which

in turn drive institutional capacity allocation, which further amplifies the placement advantage of computing disciplines. One institutional head from a private unaided institution in Karnataka articulated this mechanism with particular clarity: We know that the long-term demand for civil engineers will be there India needs to build infrastructure for another thirty years. But parents and students look at this year's placements, not thirty years from now. If I don't offer CS seats, my institution will not survive. This statement captures the essence of the signalling trap: admission demand responds to visible short-run placement data, not to twenty-year workforce need, and institutions dependent on fee revenue cannot resist this signal regardless of academic conviction. A senior industry recruiter from a construction firm confirmed the consequence: We are already seeing a shortage of good civil engineers. The ones we get are from the top five or six institutions. The rest have closed their civil departments or converted them to something else. In five years, this will be a crisis. The signalling trap thus operates at multiple levels individual students, institutional administrators, and industry recruiters each responding rationally to the signals available to them, yet collectively producing an outcome that no actor intends.

4.5.2 *Invisible infrastructure*

The second theme addresses the perceptual asymmetry between core engineering outputs and software products. Informants repeatedly noted that the outputs of core engineering water networks, electrical grids, bridges, thermal and renewable power plants are noticed only when they fail. Unlike software applications, which provide continuous visible feedback and generate immediate user satisfaction, physical infrastructure operates silently and reliably, becoming visible only through catastrophic failure. A senior civil engineering professor from a government institution in Tamil Nadu explained: When a bridge collapses, everyone asks where the civil engineers were. But when a bridge stands for fifty years without incident, no one thanks the civil engineers. The same is true for water supply, for power transmission, for everything we do. Our success is invisible." This invisibility depresses the perceived prestige of core engineering careers relative to software careers, where the outputs are immediately visible and socially validated. An industry practitioner from the power sector elaborated: A software engineer can show you an app on their phone and say I built this. A civil engineer can show you a bridge and say I designed this but the bridge is just there it doesn't do anything exciting until it fails. So, students think software is more dynamic, more creative, more rewarding. The invisibility of infrastructure thus contributes to the perception gap documented in the survey strand, where students systematically underestimate the importance of core engineering disciplines.

4.5.3 *Irreversibility of capacity loss*

The third theme concerns the fundamental asymmetry in the reversibility of capacity loss between core and computing disciplines. Informants across all institutional types

emphasized that the physical and human capital required for core engineering education cannot be quickly restored once dismantled. A dean of engineering from a mid-tier private institution in Maharashtra provided a concrete illustration: A closed CS lab can be re-equipped in months. You need computers, software licenses, and internet connectivity all of which are readily available. A closed foundry, structures laboratory, or high-voltage lab represents decades of accumulated capital, safety certification, and tacit faculty expertise. You cannot rebuild that in months or even years. This asymmetry of reversibility was identified by multiple informants as the core risk of the current trajectory. A regulator from AICTE acknowledged this concern: We are aware that once a core department is closed, it is very difficult to reopen. The faculty have moved on, the equipment has been sold or scrapped, the industry linkages have dissolved. The decision to close a core department is effectively irreversible within a five-to-ten-year horizon." The irreversibility of capacity loss transforms what might appear as a temporary enrolment fluctuation into a permanent structural change, with consequences that extend far beyond the individual institution. As one informant noted, we are not just closing departments; we are closing the possibility of training the next generation of engineers who will build and maintain India's infrastructure."

4.5.4 *Convergence, not competition*

The fourth theme challenges the framing of the structural shift as a zero-sum competition between core and computing disciplines. Senior industry informants, particularly those from sectors undergoing digital transformation, argued that the dichotomy itself is the error. A director of research from a multinational engineering firm explained: Smart grids, digital twins, building information modeling, predictive maintenance, precision manufacturing these are not CS problems or core engineering problems. They require both domains in the same graduate. The engineer who understands both the physics of the system and the algorithms that control it is the engineer of the future. This perspective was echoed by a senior faculty member from a leading government institution: The real problem is not that students are choosing CS over core. The real problem is that we have designed our curricula as if these are separate worlds. A mechanical engineer who cannot write code is as limited as a computer scientist who cannot read a stress-strain diagram. The solution is not to eliminate core branches but to integrate them with computational skills. This theme of convergence rather than competition suggests that the appropriate policy response is not to restrict CS expansion but to redesign core engineering curricula to incorporate computational competencies, thereby making core branches more attractive to students while preserving their essential disciplinary identity. The survey finding that curriculum integration is the most preferred solution across all stakeholder groups provides quantitative support for this qualitative theme. Figure 8 integrates the qualitative themes with the quantitative results and the policy implications.

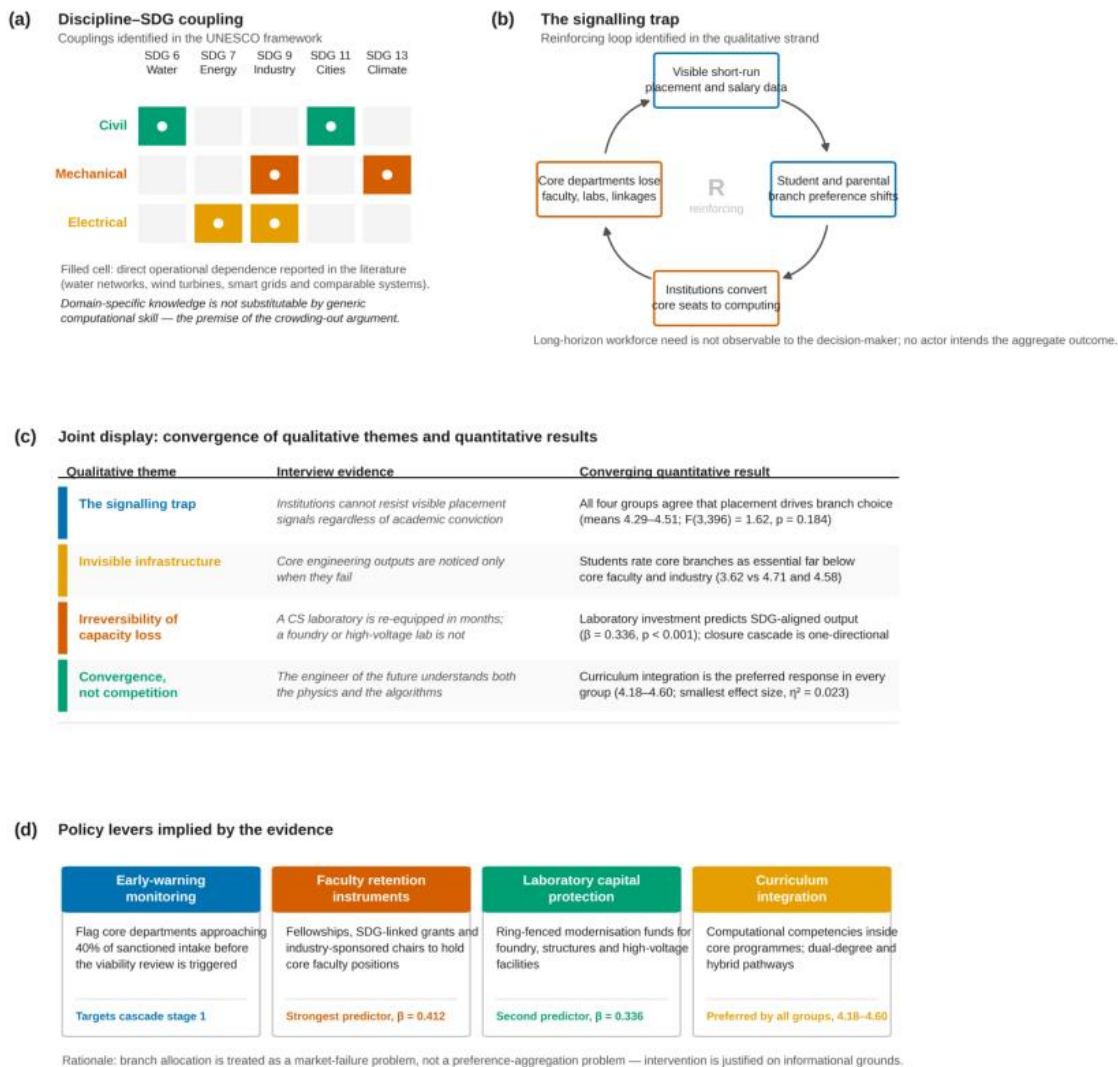


Figure 8. Synthesis of coupling, mechanism, convergence and policy. (a) Direct operational couplings between core engineering disciplines and the five focal SDGs. (b) The signalling trap represented as a reinforcing feedback loop. (c) Joint display integrating the four qualitative themes with the converging quantitative results. (d) Policy levers implied by the evidence, each mapped to the mechanism it targets and the finding that supports it.

5. Discussion

The findings of this study carry significant theoretical and practical implications that extend beyond the immediate context of Indian technical education. Theoretically, the results challenge the neoclassical assumption that student preferences, aggregated through market mechanisms, produce socially optimal outcomes in higher education. The signalling trap identified in the qualitative strand, combined with the perception gap documented in the survey, demonstrates that branch choice operates under conditions of systematic information asymmetry [15]. Students make decisions based on visible short-run placement data while remaining largely unaware of the long-term societal consequences of their choices, as evidenced by the significant divergence between student and industry perceptions of SDG threat (3.28 versus 4.33, $p < 0.001$). This finding reframes the contraction of core engineering branches as a market-failure problem rather than a

preference-aggregation problem, thereby providing a theoretical justification for regulatory intervention that existing frameworks have not adequately addressed. The crowding-out effect observed in the regression model, where CS-allied enrolment share showed a negative coefficient approaching significance ($\beta = -0.148$, $p = 0.057$), further suggests that the expansion of computing disciplines actively displaces the institutional conditions necessary for core engineering research, rather than simply adding capacity alongside it. The implications for decision-makers, including those responsible for education and private enterprise, based upon the results of this research are very relevant and actionable. Firstly, the threshold (or tipping-point) indicated at 40% enrollment will serve as an early warning sign to institutions and to government agencies (such as the All India Council for Technical Education -AICTE -and state level technical education bodies) so they can intervene prior to reaching critical mass; therefore, instead of relying solely on

department viability reviews, a monitoring system could be implemented that identifies departments whose enrollments are near this threshold and that trigger preliminary support mechanisms to support faculty professional development, upgrade laboratory facilities or enhance curriculum integration. Secondly, the positive relationship found between the relative proportion of core-branch faculty and the amount of SDG-related research produced ($\beta=0.412$, $p<.001$), suggest that retaining core discipline faculty should be treated as a national strategic priority, rather than an issue related to institutional freedom. Therefore, policy measures such as the creation of fellowship programs for faculty in core disciplines of engineering; research grants linked to projects focused on achieving Sustainable Development Goals (SDGs); and industry-funded chairs could assist in maintaining stability of core faculty positions during times of decline in enrollment. Lastly, the high levels of agreement among all stakeholders regarding integrating computer science into engineering curricula (with mean scores ranging from 4.18 to 4.60 across each group) indicate that restricting further growth of computer science programs would not provide an appropriate policy response; instead, the most appropriate policy response is to revise the engineering curricula to include computational competencies. Examples of ways to accomplish this include: adding programming and/or data science courses into existing core engineering program offerings; creating dual degree options that link core engineering disciplines with computing disciplines; or developing entirely new interdisciplinary degree options such as "infrastructure informatics or sustainable systems engineering that demonstrate the intersection of physical and digital worlds. When analyzing these findings several methodological limitations should be taken into consideration. While the sample of thirty institutions was stratified by institution type, tier and regional location, it likely does not fully represent the scope of technical education in India, particularly the many smaller rural and newer institutions that comprise a significant segment of the sector. Also, while the regression model's R^2 value of .58 represents a moderate-to-high correlation, it indicates that approximately forty-two percent of the variance in SDG aligned research output has yet to be explained, suggesting that additional variables (e.g., institutional leadership, research culture, etc.) beyond what were measured may influence research output. Survey data, while having acceptable Cronbach's alphas (.78-.89) indicating good reliability, rely on self-reporting of respondents' perceptions rather than observation of behavior; therefore, while providing insight into potential influences on branch selection, do not provide direct evidence of causality. Similarly, although thematic saturation was reached with twenty-five interviewees (the qualitative strand), if the respondents interviewed were either articulate/engaged or representative of those less reflective about the structural conditions influencing their choices, then the responses provided may not accurately reflect all perspectives. Furthermore, since the study period of 2017-18 to 2025-26 reflects a unique historical point in Indian technical education history, the results obtained may not apply universally to other countries with differing regulatory environments, labor markets or cultural attitudes toward engineering

education. Therefore, future research should focus on addressing some of the above-mentioned limitations through complementary research methods. For example, longitudinal studies tracking cohorts of engineering students from entry into the program until completion and employment would allow researchers to determine whether perceptions of core and computing disciplines change over time; whether these changing perceptions are associated with specific career paths/outcomes; and whether the perception gap documented in this study diminishes as students become increasingly exposed to core content through their coursework. Additionally, researchers may benefit from conducting comparative case studies examining how institutions maintain viable core engineering capacity as enrollment declines; thus, identifying successful leadership strategies, resource allocation models and industry partnership configurations. Other areas for exploration include: the impact of variations in state policies on branch allocations (as noted previously the seven states examined displayed different patterns of contraction in core branches that may be attributed to varying degrees of regulatory enforcement or industrial structure); comparative international analyses examining similar trends in technical education in other emerging industrialized economies (i.e., Brazil, Indonesia, Vietnam); and interventions designed to assess the feasibility/effectiveness of incorporating computer science into engineering curricula (e.g., convergence not competition, as referenced by industry informants).

6. Conclusion

The aim of this study was to see if there are market failures (i.e., structural contractions) that have direct effects on sustainable development capacities because of the changes in institutional capacity going towards computer science and related areas. Our results show that the shift of institutional capacity away from core engineering disciplines to branches such as computer science is not a neutral reaction to student choices; it is a self-perpetuating process based upon systematic information imbalances where short term employment signal dictate the decision process while long term workforce needs remain invisible to the decision makers. We also found evidence for a threshold effect at about 40 % enrollment, at or below which institutions will begin an irreversible series of actions including faculty freezes, lab closures and program eliminations. A regression model demonstrated that the explanatory variables for core discipline faculty strength and lab investment explained 58% of variance in SDG aligned research outputs, with the crowding out effect reaching statistical significance, therefore demonstrating an empirical relationship between the decline of "core" disciplines and reduced ability to meet SDG 6, 7, 9, 11, and 13. The results of this study add to the body of literature by transforming branch allocations in technical education from a preference aggregation issue that can be solved through market mechanisms to a market failure problem that requires regulatory intervention.

Future research could expand upon this study using longitudinal cohort studies examining how students' views regarding core engineering subjects change over time after

they experience them, comparative case studies of those educational institutions that have been successful in resisting the trends toward contraction in core disciplines and experimental studies assessing various curriculum integration models combining the engineering competences of "core" disciplines with computational skills. In addition, the convergence theme from our qualitative data suggest that the most promising area for future policy development would be not to limit growth in computing fields but instead to redesign curricula for core engineering disciplines to include digital competence so as to make these disciplines more appealing to students while maintaining their critical contributions to sustainable development. The fact that we have shown here that once capacity has been lost due to contraction, it is irrevocably lost emphasizes the need for rapid policy interventions as many years of accumulated investments in laboratories, faculty expertise and industry relationships are currently being dismantled and will likely take several decades to restore when the eventual increased demand for core engineering graduates returns.

Declaration of Competing Interests

The authors declare no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors acknowledge the Department of Mechanical Engineering, Delhi Technological University, and GTBIT, Delhi for providing research facilities.

Data Availability

Data will be made available on request

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Cite this article as: Neeraj Kant, Rominder Kaur Randhawa, Rajinder Pal Singh, Hunny Bhandula, Pushpendra Singh, R. S. Mishra, From Market Signals to Sustainability Gaps: The Erosion of Core Engineering Disciplines and Its Consequences for the Sustainable Development Goals in Indian Higher Education, International Journal of Research in Engineering and Innovation, 10 (6), (2026), 269-284. <https://doi.org/10.36037/IJREI.2026.10601>