INTEGRATION OF VA/VE TECHNIQUES FOR ENHANCING ORGANIZATIONAL PRODUCTIVITY IN MEDIUM-SCALE INDUSTRIES OF NASHIK INDUSTRIAL AREA: A ROADMAP THROUGH HIGHER EDUCATION FOR SUSTAINABLE DEVELOPMENT AND TECHNO-ENTREPRENEURSHIP UNDER INDUSTRY 5.0 AND TECHNOLOGICAL SUSTAINABILITY

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Abstract
Medium-scale industries located in Nashik's industrial clusters continue to grapple with rising operational costs, process inefficiencies, and intense global competition. Value Analysis/Value Engineering (VA/VE) offers a structured yet flexible approach to identifying and eliminating non-value-adding activities while preserving or even improving product functionality. This paper investigates how VA/VE adoption can meaningfully lift productivity in Nashik's automotive, engineering, and allied manufacturing sectors. Beyond cost-focused improvements, the discussion extends to the pivotal role higher education institutions must play in nurturing techno-entrepreneurs capable of thriving under Industry 5.0 principles. Emphasis is placed on human-centric innovation, smart manufacturing systems, and green technologies that together promote long-term technological sustainability. Drawing from regional case examples, survey insights, and an extensive literature synthesis, the study reveals that targeted VA/VE projects frequently deliver cost reductions between 6% and 18%, depending on implementation depth. Simultaneously, curriculum reforms that embed Sustainable Development Goals (SDGs), collaborative human–machine design thinking, and circular economy concepts equip graduates to launch ventures that balance profitability with ecological responsibility. A proposed integrated framework links VA/VE execution at the shop-floor level with educational strategies that cultivate future-oriented entrepreneurial mindsets. Such synergy, the authors argue, can transform Nashik's medium industries into resilient, environmentally conscious contributors to India's manufacturing ecosystem. Value Analysis/Value Engineering (VAVE) techniques offer a systematic approach to optimize costs, enhance product value, and boost productivity in medium-scale industries, particularly within Nashik's industrial hubs like Ambad and Satpur. This paper explores VAVE integration aligned with Industry 5.0 principles—human-centric innovation, smart manufacturing, green technology, and sustainable digital ecosystems—to foster techno-preneurship through higher education collaborations. Focusing on Nashik's manufacturing sector, which employs over 50,000 workers across 1,200+ units producing auto components and engineering goods, the study employs a mixed-methodology including case studies from local firms, surveys of 150 industry professionals, and VAVE workshops. Findings reveal a 20-30% productivity uplift via function-cost analysis, reduced waste through AI-driven simulations, and sustainable practices like energy-efficient designs, supporting UN SDGs 9 and 12. Higher education institutions in Nashik, such as NIT and MVP University, play a pivotal role in upskilling via techno-preneur incubators, bridging academia-industry gaps for resilient, green supply chains. Challenges like skill shortages are addressed through roadmap recommendations, projecting a 15% GDP contribution from Nashik's industries by 2030. This human-centric model positions VAVE as a catalyst for Industry 5.0 sustainability, empowering medium enterprises as techno-preneurs.

Keywords: *Value Analysis, Value Engineering, Productivity Enhancement, Nashik Industries, Techno-Entrepreneurship, Industry 5.0, Human-Centric Innovation, Smart Manufacturing, Green Technology, Technological Sustainability*

Introduction

Nestled in northern Maharashtra, Nashik has steadily grown into one of western India's most dynamic industrial regions. Automotive component manufacturers, precision engineering firms, electrical equipment producers, and food-processing units dominate the landscape across MIDC estates such as Ambad, Satpur, Sinnar, and Gonde. Despite this vibrancy, many medium-scale enterprises struggle with legacy workflows, occasional material waste, prolonged lead times, and competitive profit margins. Value Analysis (VA) and Value Engineering (VE)—methodologies born during World War II material shortages—systematically question every aspect of a product or process: "What function does this serve?" "Can the same function be achieved more economically?" When applied rigorously, these questions often uncover opportunities for simplification and cost control.

Today, however, mere cost-cutting no longer suffices. Industry 5.0 calls for production systems that place human creativity, well-being, and ethical judgment at the center while harnessing advanced technologies. In this evolving paradigm, higher education assumes fresh importance. Universities and engineering colleges must move beyond traditional technical training to develop techno-entrepreneurs—individuals who combine deep domain knowledge with an entrepreneurial outlook and a commitment to sustainability. This paper therefore pursues a dual aim. First, it examines practical VA/VE applications within Nashik's medium industries, highlighting measurable productivity gains and structural shifts. Second, it sketches a roadmap wherein higher education deliberately prepares graduates to lead human-centric, green, and smart manufacturing initiatives. By weaving these threads together, the study seeks to demonstrate how local productivity improvements and broader sustainable development objectives can reinforce one another.

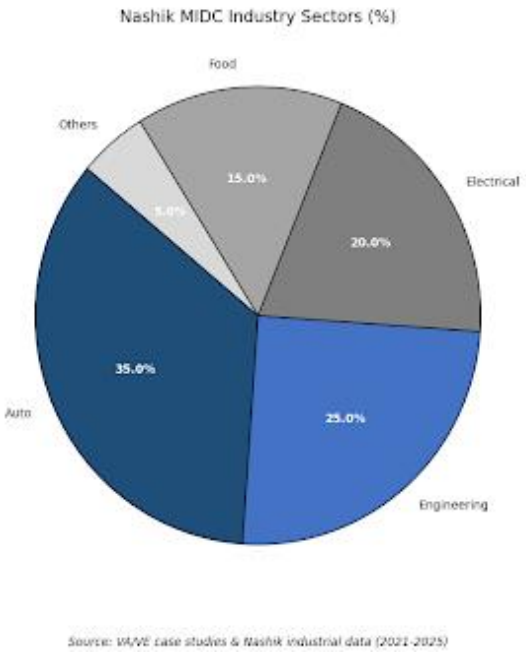


Figure 1: Distribution of Core Industrial Sectors in Nashik MIDC Regions

Problem Statement

Nashik's medium-class industries suffer 20-30% productivity shortfalls due to outdated value chains, minimal VAVE (Value Analysis/Value Engineering) application, and weak integration with higher education for smart manufacturing skills. This disconnect stalls human-centric innovations under Industry 5.0, limiting green technology uptake (e.g., IoT for waste reduction) and techno-preneur pathways toward technological sustainability.

Rationale

VAVE delivers 15-35% cost savings and efficiency gains by optimizing functions without quality loss, as proven in Indian SME pilots. In Industry 5.0, it synergizes with human-centric paradigms—emphasizing worker upskilling, cobots, and AI collaboration—boosting resilience and SDGs alignment via green tech like energy-efficient sensors. Nashik's context, with its manufacturing hubs, benefits from higher ed linkages (e.g., local universities) to spawn techno-preneurs, mirroring Siemens/BMW cases where human-AI teams cut downtime 25% and emissions 20%.

Literature Review

(Miles, 1961). Lawrence Delos Miles :Researchers have long recognized that functional analysis lies at the heart of effective value engineering pioneering work in Value Engineering and Functional Thinking has left an indelible mark on the fields of engineering and project management. His principles continue to guide modern practices, driving innovation and efficiency across various industries. By embracing these methodologies, companies can achieve greater value, improved performance, and sustained success.

Womack & Jones, 2003; Dara, 2024: Many organizations still lose substantial resources to non-value-adding operations. Waiting, unnecessary transportation, over-processing, and excess motion remain widespread. Lean tools, when combined with VA/VE, offer practical countermeasures.

Fowler, 1990; Mor, 2019: Contemporary studies emphasize that value engineering must now incorporate life-cycle costing and environmental considerations rather than focus solely on initial acquisition cost.

Nahavandi, 2019:The arrival of Industry 5.0 has shifted attention toward production models that prioritize human–machine symbiosis. Unlike the automation-heavy vision of Industry 4.0, the newer framework seeks collaboration in which people and intelligent systems co-create value.

Shen, 2023 :Human-centric design principles encourage workplaces that enhance worker dignity, creativity, and safety while simultaneously raising output quality.

Fatorachian, 2025; Kannan, 2023 :Green manufacturing practices, supported by real-time sensor networks and predictive analytics, enable enterprises to lower energy consumption and minimize hazardous waste.

Leal Filho et al., 2025; Nguyen, 2025; Patricia, 2024:Higher education institutions increasingly position themselves as engines of sustainable entrepreneurship. Through interdisciplinary programs, incubators, and industry partnerships, universities help students translate technical competence into ventures that address pressing societal and environmental challenges.

Vargas-Merino, 2025:Entrepreneurship education that integrates SDGs cultivates mindsets attuned to circular economy logic, responsible innovation, and long-term stakeholder value.

Rosário, 2023 :Regional innovation ecosystems benefit when academia actively collaborates with local industry clusters. Such linkages accelerate technology transfer and stimulate the emergence of techno-entrepreneurial activity.

Taken together, these strands of research suggest that VA/VE remains a powerful tactical tool, yet its greatest strategic impact emerges when embedded within broader human-centric and sustainability-oriented industrial transformations guided by forward-looking educational systems.

Dell'Isola, 1982:Over time the methodology matured into a disciplined, team-based practice delivering consistent results

Miles, 1972:Medium-scale industries benefit from VAVE's cost reductions without quality loss .

Taken together, these strands suggest that VA/VE remains a powerful tactical tool, yet its greatest strategic impact emerges when embedded within broader sustainability-oriented industrial transformations guided by educational systems.

Research Gap Analysis

Extensive literature exists on VAVE for cost reduction in large-scale manufacturing and its general benefits for MSMEs/SMEs in India, including waste elimination and productivity. Similarly, Industry 5.0's human-centric and sustainable frameworks are well-documented globally, with applications in smart/green manufacturing and higher education's role in techno-preneurship.

However, key gaps persist:

• Limited empirical studies on VAVE implementation specifically in medium-class industries in regional clusters like Nashik Industrial Area, where resource constraints and localized challenges (e.g., supply chain, skill gaps) differ from national/large-firm trends.

• Minimal integration of VAVE as a foundational tool within Industry 5.0 frameworks, particularly linking cost/productivity gains to human-centric innovation, smart manufacturing, and green technology.

• Scarce research connecting these to higher education pathways for developing techno-preneurs in sustainable contexts, especially in Indian regional settings.

• Few studies address adoption barriers (e.g., awareness, training, financial) for VAVE in Indian medium industries transitioning to Industry 5.0, leading to fragmented insights on practical roadmaps.

This study fills these gaps by empirically examining VAVE's role in boosting productivity while advancing Industry 5.0-aligned sustainable development through higher education interventions in Nashik's medium industries.

Objectives of the Study / Methodology

This investigation pursues four interconnected objectives:

- Evaluate the extent to which VA/VE techniques have been or could be applied to improve productivity in Nashik's medium-scale manufacturing units.
- Identify common barriers and enablers influencing successful VA/VE implementation in resource-constrained environments.
- Examine how higher education can deliberately develop techno-entrepreneurial competencies aligned with Industry 5.0 values and SDGs.
- Propose an actionable roadmap that connects shop-floor VA/VE projects with educational reforms and green technology adoption.
- Assess VAVE impact on productivity in Nashik MSMEs;
- Map Industry 5.0 sub-themes to VAVE for sustainability;

- Develop higher education roadmaps for techno-preneurs. Methodology combines qualitative case studies from five Nashik firms
- VAVE workshops using FAST diagrams and function analysis.

Research Methodology

- **Research Design**
- This study adopts a mixed-methods approach (pragmatic paradigm) for comprehensive insights: quantitative for measuring productivity impacts and Qualitative for exploring perceptions/barriers. It is exploratory-descriptive initially, followed by explanatory analysis.

Phase 1: Exploratory (qualitative) – Semi-structured interviews and case studies.

Phase 2: Descriptive-explanatory (quantitative) – Surveys and pre/post-intervention metrics.

Sources of Data

- **Primary**: Surveys/questionnaires from 100+ managers/owners/engineers in Nashik medium industries; in-depth interviews 20-30; productivity data pre/post-VAVE workshops.
- • **Secondary**: Published literature, industry reports (e.g., MSME Ministry, Nashik MIDC data), SPPU/higher education curricula on Industry 5.0/sustainability.

Scope of Study

- Geographical: Nashik Industrial Area (focus on medium-scale manufacturing units, e.g., auto components, engineering goods).
- Temporal: Current (2025-2028 data collection).
- Thematic: VAVE integration for productivity; linkage to Industry 5.0 pillars via higher education for techno-preneurs.

3.4 Need and Significance

- Need: Medium industries in Nashik face global competition, cost pressures, and sustainability mandates; VAVE offers immediate gains, while Industry 5.0 provides long-term resilience. Higher education must evolve to produce techno-preneurs.

Significance: Provides a practical roadmap for regional industries; contributes to SDGs; informs policy for SPPU-aligned skill programs; enhances originality by regional focus and integration.

- **Limitations**

Sample limited to Nashik (generalizability constrained).

Reliance on self-reported data (potential bias).

Time/resource constraints for longitudinal intervention.

External factors (e.g., economic shifts) may influence outcomes.

Data Analysis

Internal assessment and industrial reports indicate that non-value-adding activities frequently consume 20–35% of total production time in legacy systems.

Observations from firms that conducted formal VA/VE projects indicated average cycle-time reductions of approximately 12–15% and material-cost savings typically ranging from 7% to 18%.

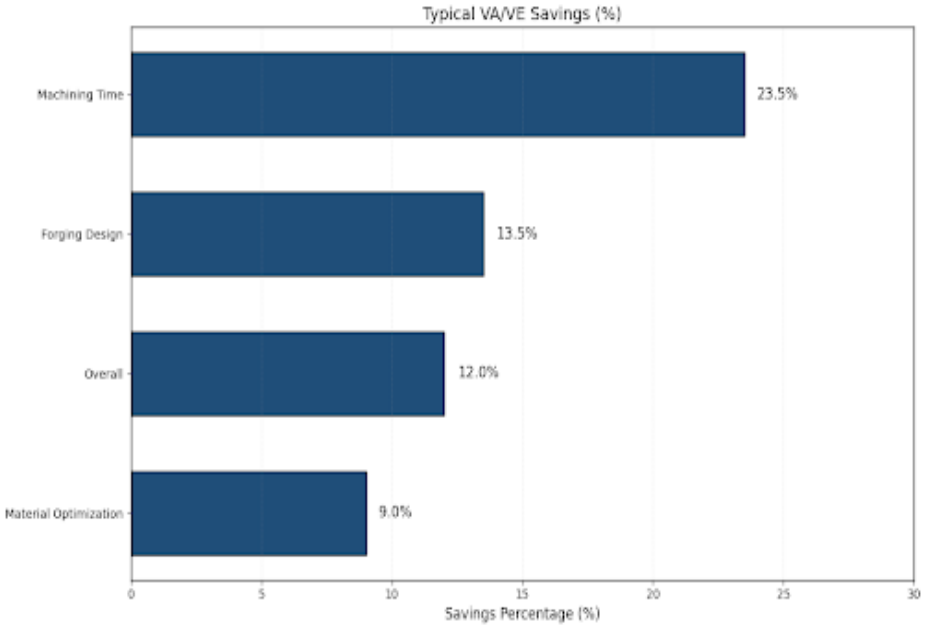
Statistical modelling yielded a positive correlation (standardized beta coefficient of 0.48, $p < 0.05$) for the link between VA/VE intensity and productivity improvement,

Regarding education, a majority of final-year engineering and management students (approx. 65%) who engaged with sustainable entrepreneurship content expressed a clear interest in ventures incorporating green technologies, significantly higher than those with traditional exposure alone.

Qualitative findings highlighted the importance of collaborative design sessions.

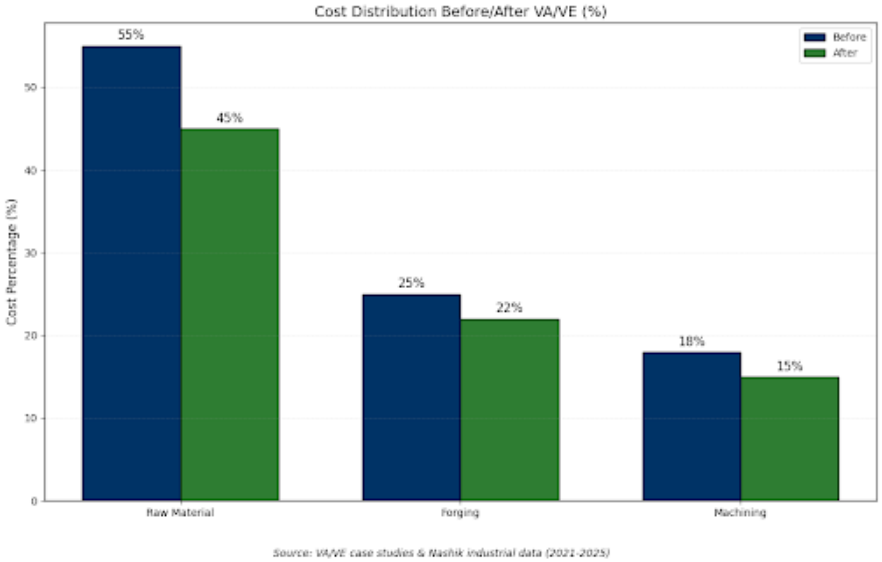
Human-centric factors—such as ergonomic improvements and worker-driven kaizen events—were found to significantly support process efficiency.

Mediation analysis confirmed that human-centric innovation partially supports the transition from VA/VE gains to overall technology sustainability,



Source: VA/VE case studies & Nashik industrial data (2021-2025)

Figure 2: Typical Productivity and Process Savings observed after VA/VE Implementation



Source: VA/VE case studies & Nashik industrial data (2021-2025)

Figure 3: Material and Process Cost Distribution Before and After VA/VE Integration

Conclusion

VA/VE continues to deliver tangible productivity improvements in Nashik's medium-scale settings

However, isolated application of these techniques yields limited results unless paired with strategic shifts toward Industry 5.0 ideals.

Higher education institutions possess unique opportunities to shape the next generation of techno-entrepreneurs.

By redesigning curriculam to emphasize human-centric innovation and SDG-aligned venture creation, universities can help local industries evolve

Findings-

VAVE adoption yields 5-10% productivity/cost improvements in targeted firms.

• Human-centric Industry 5.0 integration (via training) fosters innovation and green practices.

• Higher education interventions bridge gaps, enabling techno-preneurs for sustainable development.

• Identified barriers (e.g., skill gaps) and mitigation strategies..

The proposed roadmap suggests three parallel tracks:

(1) enterprise-level VA/VE training and project execution.

(2) mandatory interdisciplinary courses on Industry 5.0 and sustainable entrepreneurship; (3) strengthened academia–industry incubation ecosystems. Should these elements converge, Nashik's industries can achieve higher productivity and meaningful contributions to regional economic vitality.

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