Lean Management in Higher Technical Education: A Review of Waste Identification, Prioritization, and Process Improvement Approaches

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Abstract

Lean Management (LM) has emerged as an effective approach for improving quality, efficiency, and continuous improvement in Higher Technical Educational Institutions (HTEIs). This review paper examines the evolution of Lean Management from manufacturing to service sectors and its application in higher education, focusing on waste identification, waste prioritization, and process improvement practices. The literature reveals that Lean tools such as Value Stream Mapping (VSM), Lean Six Sigma, 5S, and Root Cause Analysis have been increasingly adopted to improve academic and administrative processes. Various approaches for identifying and prioritizing educational waste, including Fuzzy DEMATEL, AHP, FMEA, and ISM, have also been reported. The review indicates that while Lean implementation has shown potential for enhancing operational efficiency, reducing non-value-added activities, and improving stakeholder value, empirical evidence in Higher Technical Educational Institutions remains limited. The study highlights the need for systematic waste assessment, process mapping, and integrated Lean frameworks to support sustainable educational excellence. The findings provide a foundation for future research and practical implementation of Lean Management in technical education.

Keywords: Lean Management, Higher Technical Educational Institutions, Lean Higher Education, Waste Identification, Value Stream Mapping, Continuous Improvement.

1.Introduction:

Lean Management (LM) is a management philosophy that originated from the Toyota Production System (TPS) and focuses on maximizing customer value through waste elimination, continuous improvement, efficient flow, and organizational learning [1–5]. The foundation of Lean lies in two core TPS principles: Just-in-Time (JIT) and Jidoka, supported by techniques such as Poka-Yoke, SMED, and the 5 Whys to improve quality and process efficiency. Womack and Jones [5] defined five Lean principles: specifying value, identifying the value stream, creating flow, establishing pull, and pursuing perfection through continuous

improvement. Lean implementation is supported by tools such as Value Stream Mapping (VSM), Kaizen, PDCA, 5S, and Root Cause Analysis (RCA), which help organizations identify and eliminate non-value-added activities. The concept of waste (*muda*), including overproduction, waiting, transportation, inventory, motion, over-processing, and defects, is central to Lean. Additional concerns such as unevenness (*mura*) and overburden (*muri*) are also addressed to improve operational performance.

Over time, Lean evolved from a manufacturing toolkit into an enterprise-wide management philosophy. Researchers such as Hines et al. [9], Stone [10], and Bozdogan [11] describe its progression from shop-floor improvements to value-stream management, organizational learning, and strategic enterprise systems. More recently, Lean has expanded into sustainability, Industry 4.0, and digital transformation through the concept of Lean 4.0 [12–14].

Contemporary research also highlights the human dimension of Lean. While some scholars view Lean as increasing work pressure through standardization, others argue that it empowers employees through participation, problem-solving, and continuous learning. Therefore, successful Lean implementation requires balancing operational efficiency with employee development and organizational capability building [15,16]. The application of Lean Management (LM) has expanded beyond manufacturing to service environments, where value is often co-created with customers rather than delivered through a tangible product. Bowen and Youngdahl [17] introduced the concept of Lean Service by emphasizing customer participation in service processes, while Åhlström [18] highlighted the need to adapt Lean principles to service-specific characteristics such as variability, customer involvement, and intangible outcomes. The five Lean principles—value, value stream, flow, pull, and perfection—remain relevant in-service organizations but require modification. In services, value is jointly defined with users, value streams extend across customer and organizational activities, and continuous improvement must focus on service quality and customer outcomes. However, the principles of flow and pull are more challenging to implement because service demand is variable and capacity cannot be stored as inventory [5,17,18,20].

Several studies have reported successful Lean applications in healthcare, public administration, information technology, logistics, banking, and telecommunications. However, Gupta et al. [21] and Leite and Vieira [22] concluded that no universally accepted Lean-service framework exists. Common implementation themes include customer involvement, waste elimination, employee empowerment, cross-functional collaboration, and continuous improvement. Performance improvements are generally stronger when Lean tools are supported by management commitment, employee participation, and organizational learning capabilities [21–24]. Healthcare and public services represent critical testing grounds for Lean because of their complexity, professional discretion, and multiple stakeholders. Radnor, Holweg and Waring [25] found that Lean initiatives often generate local improvements but struggle to achieve system-wide transformation. Similarly, Radnor and Walley [27] emphasized that successful public-sector Lean implementation requires an end-to-end process perspective, explicit value definition, systematic waste elimination, and employee-driven improvement. Leadership support, employee training, and continuous improvement culture have been identified as essential success factors [25,27–30]. Evidence from service organizations suggests that Lean is most effective in high-volume, repetitive back-office processes where delays, queues, and rework can be readily identified and eliminated. Studies in banking, telecommunications, logistics, and financial services demonstrate that process redesign,

performance measurement, and appropriate use of digital technologies can significantly improve operational efficiency and service quality. Researchers further argue that automation should follow process improvement to avoid digitizing wasteful activities [32–37].

Recent research highlights the growing importance of soft Lean practices such as leadership, employee involvement, learning, and organizational resilience. While technical Lean tools remain widely used, sustainable improvements depend on balancing operational efficiency with employee engagement and customer-focused value creation. Organizations that successfully integrate these human factors have reported improvements in innovation, customer satisfaction, employee well-being, and overall organizational performance [29,30,38–40].

2. Lean Management in Higher Education Institutions (LHE)

Lean Management has increasingly attracted attention in Higher Education Institutions (HEIs) as universities face growing pressure to improve quality, efficiency, and stakeholder value while maintaining academic standards. However, unlike manufacturing or conventional service environments, educational value is co-created through interactions among students, faculty, curricula, facilities, and institutional systems. Consequently, Lean implementation in higher education must focus on enhancing learning outcomes rather than simply improving speed, reducing costs, or increasing student satisfaction [17,18,20,31].

The emergence of Lean Higher Education (LHE) can be traced to early studies by Comm and Mathaisel [41], who identified Lean-compatible practices in universities facing cost-containment pressures. Subsequent reviews by Balzer et al. [42], Balzer [43], Maciąg [44], Cudney et al. [45], Gómez-Molina and Moyano-Fuentes [46], and Barcos Redin et al. [47] established LHE as a distinct research domain. These studies demonstrate a gradual transition from isolated improvement projects toward a broader management philosophy emphasizing process orientation, value creation, organizational learning, and continuous improvement across universities. However, the evidence base remains fragmented and dominated by conceptual and review studies rather than rigorous longitudinal investigations.

A central challenge in LHE is defining educational value. Unlike manufacturing, where value is often determined by customer requirements, universities serve multiple stakeholders, including students, faculty, employers, society, and future generations. Sunder M. [48] highlighted that different quality frameworks imply different definitions of value, while Cano, Murray and Kourouklis [50] proposed a stakeholder-value perspective that extends beyond viewing students merely as customers. Contemporary LHE literature increasingly recognizes students as co-producers of learning rather than passive recipients of educational services. Consequently, Lean initiatives should focus on eliminating unnecessary delays, duplication, and administrative burdens without compromising academic rigor, intellectual development, or long-term educational outcomes [48–50].

The successful implementation of Lean in HEIs depends largely on organizational readiness and critical success factors. Antony [51], Kokkinou and van Kollenburg [52], Kakouris et al. [53], and Rizos et al. [54] identified leadership commitment, communication, employee involvement, training, strategic alignment, and organizational culture as key enablers of Lean transformation. Across the reviewed studies, leadership and top-management commitment

emerged as the most consistently cited success factor, followed by communication, employee empowerment, and improvement capability. Importantly, resistance to Lean is increasingly interpreted not as opposition to improvement but as a response to concerns regarding academic autonomy, professional judgment, and managerial control. These findings suggest that participatory approaches and stakeholder engagement are essential for sustainable Lean adoption in educational settings [51–58].

Most documented Lean applications in HEIs have focused on administrative and support functions rather than academic processes. Studies by Höfer and Naeve [59], O'Reilly et al. [60], and Antony et al. [61] reported Lean implementation in finance, human resources, information technology, libraries, and other administrative services, demonstrating improvements in process efficiency and waste reduction. However, these studies also reveal that universities can adopt Lean extensively within administrative functions while leaving teaching and learning processes largely unchanged. Survey-based studies conducted across different countries further indicate positive associations between Lean practices, organizational performance, and sustainability outcomes, although causal relationships remain difficult to establish due to the predominance of perceptual and cross-sectional research designs [59–67].

Applications of Lean within the academic core are less common but arguably more significant. Research has demonstrated the use of Lean Six Sigma, PDCA, Value Stream Mapping (VSM), visual management, and 5S to improve curriculum design, teaching-learning processes, assessment systems, laboratory management, and educational resource utilization. Studies by Sunder M. [68], Sunder M. and Mahalingam [69], Bhat et al. [72], Bhatnagar, Lata and Sangwan [73], Alogla [74], Jiménez et al. [76], and Noronha et al. [77] reported improvements in collaborative learning, assessment efficiency, laboratory organization, and process turnaround times. Nevertheless, most interventions were conducted within isolated departments or programs, with limited independent validation and little evidence of institution-wide transformation.

Despite growing interest in Lean Higher Education, the overall evidence base remains relatively weak. Of the reviewed studies, many rely on conceptual analyses, literature reviews, Delphi studies, perception surveys, and single-case interventions. Independent longitudinal evaluations are scarce, and evidence from technical and engineering institutions remains particularly limited. The literature therefore indicates that while Lean has demonstrated potential to improve both administrative and academic processes, its application in higher technical educational institutions is still emerging and requires further empirical validation.

3. Waste Identification in Educational Processes

The concept of waste in education has evolved from the direct adaptation of traditional Lean waste categories to the unique context of teaching, learning, and academic administration. Douglas, Antony and Douglas [78] developed one of the earliest educational waste taxonomies by translating the classical Lean wastes into higher education settings, identifying issues such as unnecessary motion, overproduction of materials, inventory accumulation, and underutilization of human capability. Subsequent studies expanded this framework by introducing additional categories such as information, knowledge, and people-related wastes, reflecting the knowledge-intensive nature of educational systems [79,80]. Sanahuja [81] further distinguished between Lean Education, which focuses on institution-level processes, and Lean Teaching, which concentrates on classroom teaching-learning activities. Research in teaching

and engineering education has highlighted wastes such as unnecessary curriculum content, underutilized laboratory resources, delayed feedback, inefficient learning activities, and non-value-added academic processes. Although these studies provide useful conceptual frameworks for identifying waste, most remain descriptive or perception-based and provide limited evidence regarding their direct impact on learning outcomes [78–85].

3.1 Waste Prioritization and Assessment Approaches

As educational institutions face multiple forms of waste simultaneously, researchers have increasingly focused on prioritization methods to identify the most critical areas for improvement. Studies have employed analytical techniques such as Fuzzy DEMATEL, Analytical Hierarchy Process (AHP), Waste Relationship Matrix, Failure Mode and Effect Analysis (FMEA), Interpretive Structural Modelling (ISM), MICMAC analysis, and criticality assessment frameworks to rank and analyze educational wastes [86–90]. These approaches have identified recurring concerns such as excessive bureaucracy, communication errors, knowledge loss, over-processing, non-utilized talent, facility-related issues, and underutilization of employee capabilities. Research conducted in technical universities and engineering education settings also reported overstaffing, insufficient laboratory facilities, and unclear assessment practices as significant sources of inefficiency [91–93]. While these methods provide structured decision-making support and reveal relationships among different waste categories, they primarily rely on stakeholder perceptions and expert judgments rather than direct observations of process performance, learning outcomes, or resource utilization. Consequently, prioritization studies help focus improvement efforts but do not replace detailed process analysis and value stream mapping [86–93].

3.2 Value Stream Mapping and Process Improvement in Higher Education

Recent research has shifted from waste identification toward process-level analysis using Value Stream Mapping (VSM) and Lean improvement methodologies. Several studies have applied VSM, DMAIC, Lean Six Sigma, Pareto Analysis, and root-cause analysis techniques to educational and administrative processes such as grade-change workflows, admission procedures, programme management, course delivery, and laboratory operations [94–98]. Shamsuzzaman et al. [95] demonstrated significant potential reductions in admission cycle time through simulation-based Lean improvements, while Monserrat et al. [97] mapped the complete delivery cycle of a software project management module to identify improvement opportunities. Similarly, Muiambo, João and Navas [98] applied Lean assessment methods within a training laboratory and identified transportation, waiting, and defects as dominant waste categories. Despite these promising applications, most studies focus on diagnostic assessment and proposed improvements rather than validated long-term interventions. Furthermore, the literature reveals a notable lack of comprehensive current-state value stream maps for technical-course delivery processes that integrate process flow, information flow, performance data, and educational outcomes. This gap highlights the need for systematic VSM-based studies in Higher Technical Educational Institutions (HTEIs) to support evidence-based process improvement and sustainable educational excellence [94–98].

4. Conclusions

Based on the comprehensive review of the literature, several important conclusions can be drawn regarding the adoption and implementation of Lean Management in Higher Technical Educational Institutions. These conclusions are.

- Lean Management has evolved from a manufacturing-focused philosophy into a comprehensive management approach applicable to service and educational sectors.
- The literature demonstrates increasing adoption of Lean principles in Higher Education Institutions (HEIs) to improve efficiency, quality, and stakeholder value.
- Lean tools such as Value Stream Mapping (VSM), Lean Six Sigma, 5S, Root Cause Analysis (RCA), Kaizen, and continuous improvement practices have shown potential for improving academic and administrative processes.
- Various educational waste identification and prioritization frameworks have been developed to address inefficiencies in teaching-learning, administrative, and support activities.
- Research indicates that educational wastes include unnecessary activities, delays, excessive bureaucracy, underutilization of human capabilities, information-related inefficiencies, and resource wastage.
- Most existing studies rely on conceptual frameworks, perception-based surveys, and isolated case studies, with limited empirical validation and long-term performance assessment.
- Evidence on comprehensive Value Stream Mapping and process-based improvement initiatives in Higher Technical Educational Institutions (HTEIs) remains limited.
- Successful Lean implementation requires strong leadership commitment, stakeholder participation, employee involvement, continuous learning, and a culture of continuous improvement.
- Lean practices have significant potential to enhance institutional effectiveness, resource utilization, educational quality, and stakeholder satisfaction.
- Future research should focus on developing integrated Lean frameworks, conducting empirical process mapping studies, validating waste assessment methodologies, and establishing sustainable improvement models specifically for Higher Technical Educational Institutions.

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