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Original Article

Smart Lean Execution and Enhancement Technology for Productivity Optimization in Textile Manufacturing

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Abstract - *In India's current production scenario, the textile manufacturing sector has recently grown, especially in the southern region; yet, the nation still suffers from inefficiencies brought on by antiquated techniques and Non-Value-Added (NVA) activities. Designed for the methodical finding, evaluation, and removal of waste and production bottlenecks in textile operations, the Smart Lean Execution and Enhancement Technique (SLEET) is a fresh approach to proposing a new model. This research study contributes to the body of knowledge on lean implementation by demonstrating how to integrate workstation redesign, Value Stream Mapping (VSM), 5S, and cellular manufacturing into a cohesive whole. Using the SLEET framework allowed a real-world textile production environment to lower operator trip distance from 153 to 117 feet and cycle time from 472 to 438 seconds. Furthermore, the disciplined lean implementation helped to raise overall productivity by 4.84%. Focusing on constant layout reconfiguration, real-time waste monitoring, and dynamic feedback loops, SLEET offers a proposed model that can scale and adapt to meet the dynamic demands of textile manufacturing, unlike traditional lean approaches. The research findings show that a systematic and phased lean implementation strategy may help to achieve both significant productivity improvements and operational efficiency.*

Keywords - *Lean technique, Value Stream Mapping, Workstation design, Continuous improvement, Waste minimization, Textile manufacturing.*

1. Introduction

Given the fierce global competitiveness in the modern textile sector, increasing output per worker is vital. Although South India in particular has seen a boom in textile production, the nation still suffers from old methods of doing things and ineffective systems [1]. NVA, workflow fragmentation, and out-of-date manufacturing techniques account mostly for these inefficiencies [2]. SLEET is a lean manufacturing system that methodically reduces waste to make textile operations current and aims to solve these pressing problems [3]. It uses key lean techniques, including ergonomic office design, VSM, 5S, and cellular manufacturing [4]. The focus is on creating a smart and coordinated manufacturing environment that can adapt to the always-shifting needs of the sector [5]. Using the SLEET approach helps textile manufacturers boost output and lower worker fatigue. In a particular application, the trip distance of an operator dropped from 153 to 117 feet, a significant change [6]. Moreover, the proposed model worked well since the cycle length dropped from 472 to 438 seconds. Under a real-world textile manufacturing scenario, these measurable benefits produced 5.84% more output [7]. Apart from the obvious improvements, SLEET encourages an environment of continuous development and staff involvement [8]. Real-time waste monitoring, dynamic feedback loops, and layout reconfiguration help the framework constantly adapt and maximize the production rate [9]. SLEET is always ready to change; more traditional lean techniques could get boring. Its adaptability helps it to fit the fast and erratic speed of the textile sector [10]. VSM is essential in enabling well-informed decision-making since it lets one see the present and the future [11]. Ergonomic workstations are meant to be comfortable and efficient, so as to prevent workers from becoming tired or making mistakes [12]. 5S procedures in the workplace assure organization, safety, and cleanliness. A fantastic way to maximize production flow and reduce lead times is via cellular manufacturing [13]. SLEET offers a complete and flexible approach for lean transformation [14]. By offering a case study of successful lean integration in the textile sector, this study should contribute to the body of already known information [15]. SLEET marks a tidal change in the textile sector, both domestically and internationally, towards lighter, smarter, and more efficient production methods when all else is said and done [16]. Data-driven decision-making, constantly assessing production data to identify inefficiencies, is one of the pillars of SLEET [17]. This closes the distance between the deployment of lean concepts in real-world industry and their research [18]. SLEET's modular character helps it to be scaled across several textile units, hence allowing its adaptation to various manufacturing setups [19]. Because of their versatility, manufacturers have a strategic edge in responding to changing client expectations and market needs [20]. SLEET is a life-altering journey rather than a framework, and the system here is to reach operational excellence in textile manufacture.

Motivation: Notwithstanding recent growth and great promise, the Indian textile industry is still beset by inefficiencies brought on by outmoded techniques, poorly designed layouts, and inadequate procedures in place to consistently improve efficiency. These challenges lower productivity, increase operating expenses, and impede global competitiveness due to inadequate manufacturing capacity. Motivated by the pressing need to modernize and streamline textile manufacture, this study introduces the SLEET framework, a fresh approach combining clever execution strategies with tried-and-true lean technology. By removing important bottlenecks and adopting continuous improvement, SLEET aims to increase efficiency, reduce waste, and create a production environment that can adapt to new needs and run well going forward.

Problem Statement: Although textile production has progressed, many Indian textile manufacturing companies still rely on antiquated systems, ineffective techniques, and lean approaches lacking complete integration. These defects cause total productivity to decline, cycle times to increase, underutilization of space, and an explosion of non-value-added activities. Conventional lean solutions usually lack the adaptability to offer long-term benefits in an ever-shifting industrial environment. Particularly in textile operations, a lean execution model with intelligence, scalability, and organization is desperately needed. Presenting the SLEET method for textile manufacturing efficiency in analysis and disappearance using a methodical methodology, this work aims to address the problem.

The major contributions of this research article are;

- The manuscript introduces SLEET, a novel integrated lean framework for textile manufacture. VSM, 5S, cellular manufacturing, and workstation redesign are harmoniously combined here. Unlike conventional lean systems that manage various tools independently, the SLEET framework offers a consistent approach that is constantly customized to the textile sector.
- Measuring productivity improvements, the SLEET framework was used in a textile manufacturing environment and shown to be rather successful, reducing operator travel distance by 23.5% cycle time by 7.2% and general productivity by 4.84%. Such results show that the framework helps to raise job site productivity.
- Lean Execution Model for Versatility and Adaptability: SLEET emphasizes constant layout transformation, real-time waste monitoring, and feedback loops, therefore enabling SLEET to adapt to the changing needs of the textile sector. SLEET distinguishes itself from static lean models of yesteryear by its scalability and responsiveness, which offer a road towards long-term operational success.

1.1. Architecture of the Proposed Method

Input-Textile Manufacturing Unit: Many times, using antiquated techniques, Indian textile manufacturers produce inefficiencies like excessive operator mobility and non-value-added activities. Incorrect designs and insufficient real-time monitoring aggravate these problems even further. Beginning with these operational issues, the SLEET architecture is executed.

SLEET Framework: Lean Implementation Strategy: First, SLEET helps find production bottlenecks and process waste, which is a lean diagnostic tool. Standard data comes from thorough layout, flow, and cycle times analyses. This basic research supports strategic lean interventions meant to eliminate inefficiencies and define measurable improvement objectives within the production environment.

SLEET aggregates lean technologies like cell manufacturing, Visual Management Systems (VMS), 5S, and workstation redesign. Taken all together, they increase visibility, streamline processes, minimize pointless motion, and preserve order and cleanliness, as shown in Figure 1. Coordinated use of these instruments ensures efficient, consistent, higher work floor productivity. SLEET combines dynamic aspects like operator feedback loops, periodic layout reconfiguration, and real-time waste monitoring.

These technologies ensure the manufacturing system stays flexible, data-driven, sensitive to changing production needs and continual operational problems by allowing constant adaptation and adjustment of processes. When SLEET implementation was in progress, drops were operator trip distance of 153 to 117 feet and cycle duration of 472 to 438 seconds. Productivity grew typically at 4.84%. SLEET's flexible nature helps to encourage sustainable development by outperforming inflexible conventional lean models in dynamic textile production settings.

The remaining section of this article is organized as follows: Section 2 reviews past studies on the evolution of hydrogen infrastructure. Section 3 describes the proposed SLEET process. Section 4 looks at and compares our suggested approach with other conventional approaches. Section 5 of the article finishes with a discussion of a possible future study.

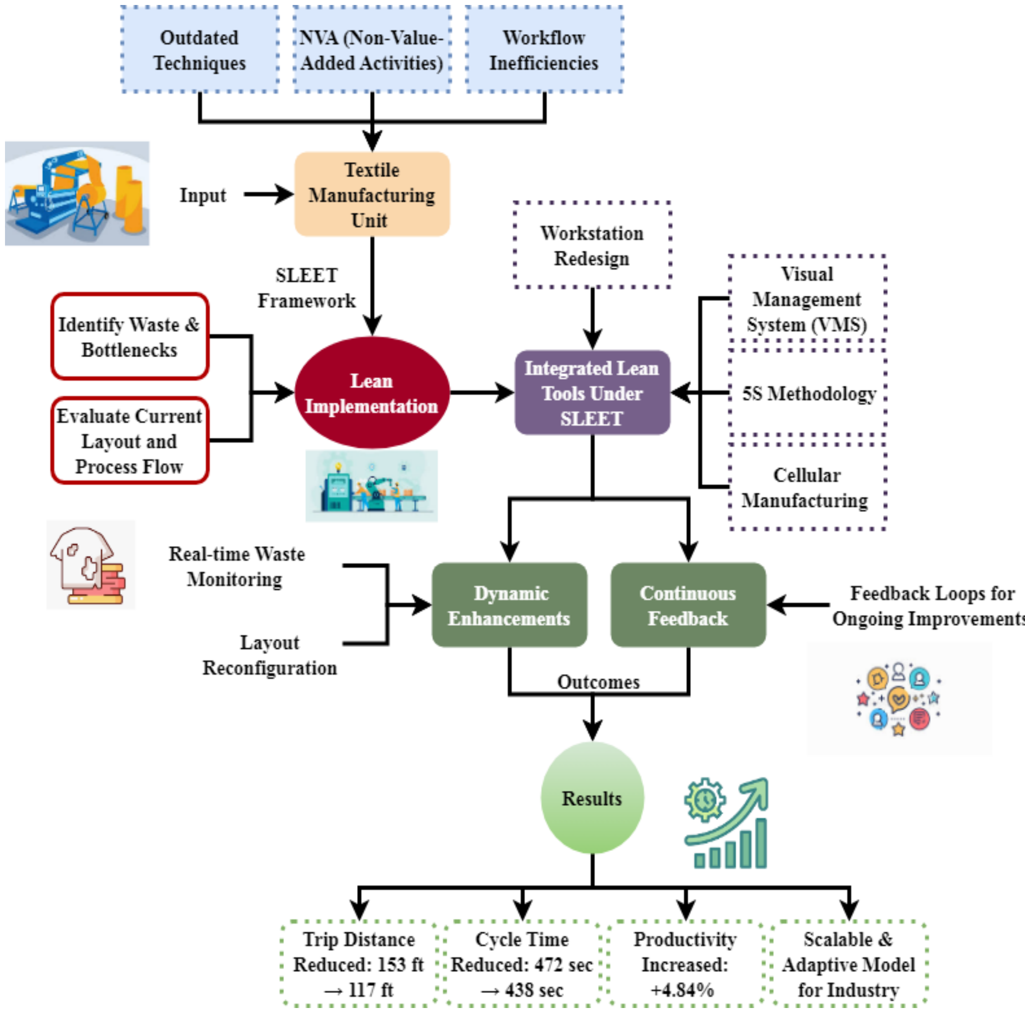

Fig. 1 Architecture of the proposed method

2. Related Works

Lean manufacturing and Industry 4.0 are reportedly becoming increasingly entwined to raise the efficiency, adaptability, and sustainability of manufacturing processes. Many studies center on combining data analytics, the Internet of Things (IoT), and AI with traditional lean technologies, including 5S, VSM, and cellular manufacturing. While some of these models are more specifically suited to textiles, others focus more on smart manufacturing and general decision-making. This exploratory study focuses on how Lean manufacturing combined with Industry 4.0 technologies might create smart factories [21]. The writers mostly highlight the convergence of CPS, the IoT, data analytics, and conventional lean methodologies, including 5S, kaizen, and just-in-time. The article claims that smart factories can be effective in the future if they integrate systems; lean is the backbone, and Industry 4.0 technology is enhancing Real-Time Responsiveness and Decision-Making (RtR-DM). The study presents a theory whereby digital enablers increase operational transparency and automate data flow, hence improving lean efficiency.

This study examines how many lean concepts are used in Smart Manufacturing using a Multi-Case Methodology (SM-McM) [22]. Though both lean and smart manufacturing aim to reduce waste and boost flexibility, the study reveals that the two are not always closely linked directly or deliberately. The authors offer a way to group smart manufacturing techniques based on the adherence quality. To help manufacturers evaluate the possibilities of digital technologies, including artificial intelligence, automation, and the Internet of Things, they propose a "lean-smart alignment matrix" to support lean goals like quality, flow, and continuous excellence. This article explores how lean manufacturing and Industry 4.0 interact to provide a consistent paradigm supporting smart and sustainable manufacturing methods [23]. Lean methods like Kanban and standard work increase decision-making, traceability, and predictive maintenance when combined with data analytics and the IoT, the writers say. Developing a smart lean ecosystem, the proposed approach balances environmental sustainability with economic efficiency by combining lean with digital twin technologies and cloud computing. Human-centred lean methods combined with machine-generated data create a hybrid paradigm that allows continuous improvement.

Within the framework of Industry 4.0, the data-driven decision-making system shown in this case study results from using lean and smart manufacturing ideas [24]. The proposed approach, which uses feedback loops, predictive analytics, and real-time data collection, aims to improve production flow free of waste. The study reveals how lean tools are being digitalized using IoT and Machine Learning algorithms (IoT-ML) to make them more responsive and customized. Process agility has improved, and waste in the final system, which is highly adaptable and efficient, has dropped.

The manuscript proposes a conceptual model for adaptive learning under duress by using distributed input and personal initiative to enhance tactical creativity [25]. Although the military is the main emphasis, the lessons learnt about lean environments suggest that it is good to let front-line employees handle problems and keep improving constantly. Common themes are human adaptation, constant improvement, and system integration, which help grow smart, data-driven, resilient manufacturing environments in industrial and organizational settings. The authors in this research endure the demanding environments, and will address, though not technically perfect, it clarifies human behavior, resilience, and how people create adaptive techniques in response to difficulty [26]. Like lean philosophy's emphasis on self-discipline, endurance, and little, consistent improvements, the results illustrate how pushing constraints influences one's behavioral and mental health. Though it does not provide a particular technique, the book emphasizes the need for mental models and human adaptability in sustained performance, themes pertinent to lean leadership and culture.

By questioning the received wisdom about leadership and operations, this book explores how businesses could seize the possibilities given by the AI-Powered Digital Economy (AI-DE) [27]. The authors provide the concept of an artificial intelligence factory, a place where data loops, digital platforms, and machine learning replace traditional organizational structures. The proposed approach consists of creating organizations in which algorithms carry out mission-critical activities to reach very high degrees of scalability and precision. This article presents a methodical approach for lean manufacturing implementation that fits the particular limitations experienced by the Indian textile industry. Contextual enablers such as employee training and change management enhance more traditional lean technologies such as VSM and 5S inside the framework [28]. The advised method follows a phased approach: evaluation, planning, pilot implementation, and full-scale deployment. Researchers concluded that in applying lean methods, elements unique to every sector, including worker skill, production variance, and consumer demand, must be closely considered.

As stressed in the assessed published articles, lean concepts combined with Industry 4.0 technologies can help to achieve smarter, more sustainable manufacturing [29]. Methods include data-driven decision-making, artificial intelligence-based process optimization, and VMS enabled by the Internet of Things, which are proposed to increase efficiency and reduce waste. In particular, for use within the textile sector and larger industrial environments, there are measurable benefits in adaptability and efficiency with SLEET. Through human-centric methods, real-time feedback, and system-wide integration, traditional or digital models drive ongoing improvement regardless of the industrial environment.

3. Proposed System

In India, antiquated techniques and NVA activities make the textile manufacturing sector ineffective. This is the reason the study offers SLEET, a method of lean implementation with both an intelligent and methodical approach. Included in SLEET, cellular manufacturing, VSM, 5S, and workstation redesign are five. Focusing on real-time waste tracking, layout reconfiguration, and dynamic feedback loops lets this technology enable scalable and adaptive solutions. Modernizing textile techniques is to ensure that improvements in productivity and efficiency are maintained.

$$sp(ig) = \sum_{lc} wcl_{fs}(ro) - 2^{-\frac{lc}{2}} * \partial(2^{-lt}Sp - lc) \quad (1)$$

Equation (1) generally shows the flow capacity of the system. The proposed method gauges system performance sp in terms of throughput as a Key Performance Indicator (KPI) to assess how effectively input generates ig output. Using integrated lean components lc such as effective workstations and cellular layouts, the SLEET architecture ensures faster and smoother wcl_{fs} Unit movement. Throughout, let us signify that the design of the system removes obstacles ro. It demonstrates how firmly lean techniques 2^{-lt} are ingrained into the design.

$$\int |AE(ld)|^2 mc = \sum_{id} |AE_{er}(eal)|^2 + ^{\sum_{id} er} \quad (2)$$

This Equation (2) generates an overall architectural efficiency AE score considering the layout design ld, VSM, 5S zones, and monitoring cells mc as distinct subsystems. It is based on the theory that the SLEET structure's every functional block helps to produce the result er. Analyzing subsystem performance helps one to assess the effectiveness of the architectural layout eal, which is basic in this modular design idea. Balanced and tuned modules help to raise the general effectiveness of the system.

$$AS(sp) = \sum_i \left|p_{fo}(sd)\right|^2 + \phi(2^{-sp} fl - ae) \quad (3)$$

This Equation (3) gauges throughout time the dependability of the architectural system's performance

AS(sp). Architecturally sound design is defined by both great production and dependability in the face of operational unpredictability p_{fo}. By comparing the architecture's usual performance with its standard deviation sd, the indicator gauges its resilience. The index increases when all the components of the SLEET technique, including dynamic feedback loops fl and the VMS, are operating together harmoniously. It helps to identify the insecure architectural elements ae.

3.1. Design and Framework of SLEET

Hybrid construction to meet the growing needs of the textile industry, SLEET methodically combines dynamic execution strategies with basic lean manufacturing concepts. Among the tried-and-true approaches integral to the SLEET model are cellular manufacturing, 5S office organization, workstation redesign, and VSM. The methodology begins by mapping the current production flows to identify NVA tasks and bottlenecks.

Its modular architecture makes it simple to fit several plant layouts, batch sizes, and product kinds usually used in the textile sector, illustrated in Figure 2. SLEET provides a flexible framework on which lean components could interact with one another and respond to real-time data inputs in place of rigid lean models. This makes it even more crucial in environments where output expectations are erratic and remaining competitive calls for a quick response. It then advises restructuring the area to enable more effective operator mobility and less wasted effort, therefore improving the running conditions. SLEET is unique because of its adaptability, which is essential for its emphasis on lean technologies implemented in a way that permits flexibility and constant development.

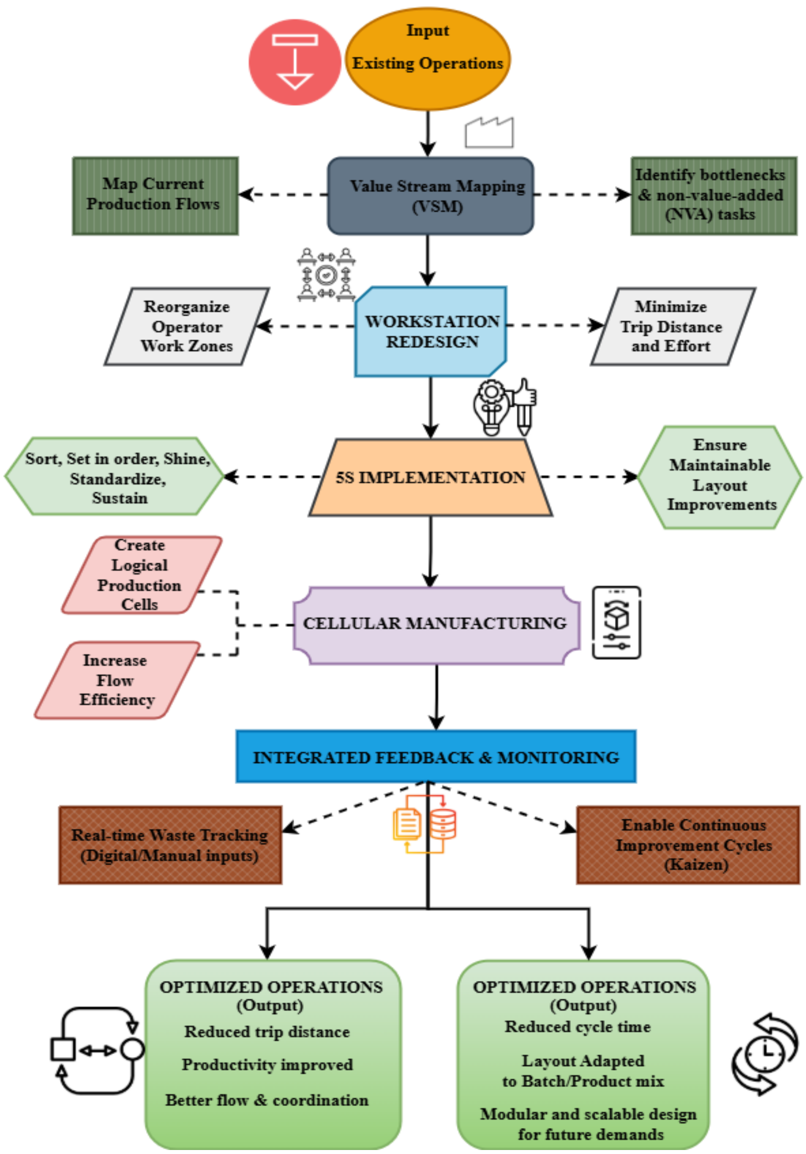

Fig. 2 Design and framework of SLEET

$$V'e_{(ct)i} = LT_d\,(dr * vc)_{rpp}, rpp = 1,2, \ldots., ws, \in \{SL\} \quad (4)$$

Equation (4) will assist in determining the value of the entire effort for the client $V'e_{(ct)i}$. Using lean technologies LT like 5S and VSM, SLEET's design seeks to drastically cut the time lost not being utilized for value creation.

This theoretical approach holds that it is imperative to remove pointless procedures$(dr * vc)_{rpp}$. Reducing the time that does not provide value helps to increase production costs and processing efficiency. This supports layout issues in workstation ws design.

$$pd\,(id)_i = fw_i * re(\prod_i) * \iint cr_i\, ct\,, C = 1,2, \ldots N \quad (5)$$

Equation (5) will help us to see how well the present design performs in comparison to the ideal $pd\,(id)_i$. The SLEET framework's main goal fw_i is to bring the real execution re time closer to the ideal $cr_i\, ct$, conventional time. Variability should be minimized, assuming a lean-enhanced process and a well-designed layout. When the two times are rather near, one can create an improved system. The justification for the need for cellular C manufacturing integration is immediately below.

$$Ipt = ld\left(\sum_j mx * PG(vl)_i\right) < \left|\sum_j pr * Ipt(mg)_i\right| \quad (6)$$

This ratio helps one to ascertain the proportion that significantly influences production time Ipt. Lean design ld aims to maximize mx value-added activities while reducing or eliminating needless delays. Reevaluating the flows and configurations of workstations helps the SLEET design tip those scales in favor of processes generating value $PG(vl)$. Equation (6) offers a consistent measure for comparing pre- and post-redesigning pr results. The metric guides pr the improvement aims within the SLEET framework organizing.

3.2. Implementation Strategy and Phased Approach

Effective deployment of the SLEET architecture depends on a planned, incremental rollout plan tailored to textile manufacturing conditions. The SLEET technique advocates a sequential approach whereby every stage is extensively studied, validated, and enhanced before advancing to the next.

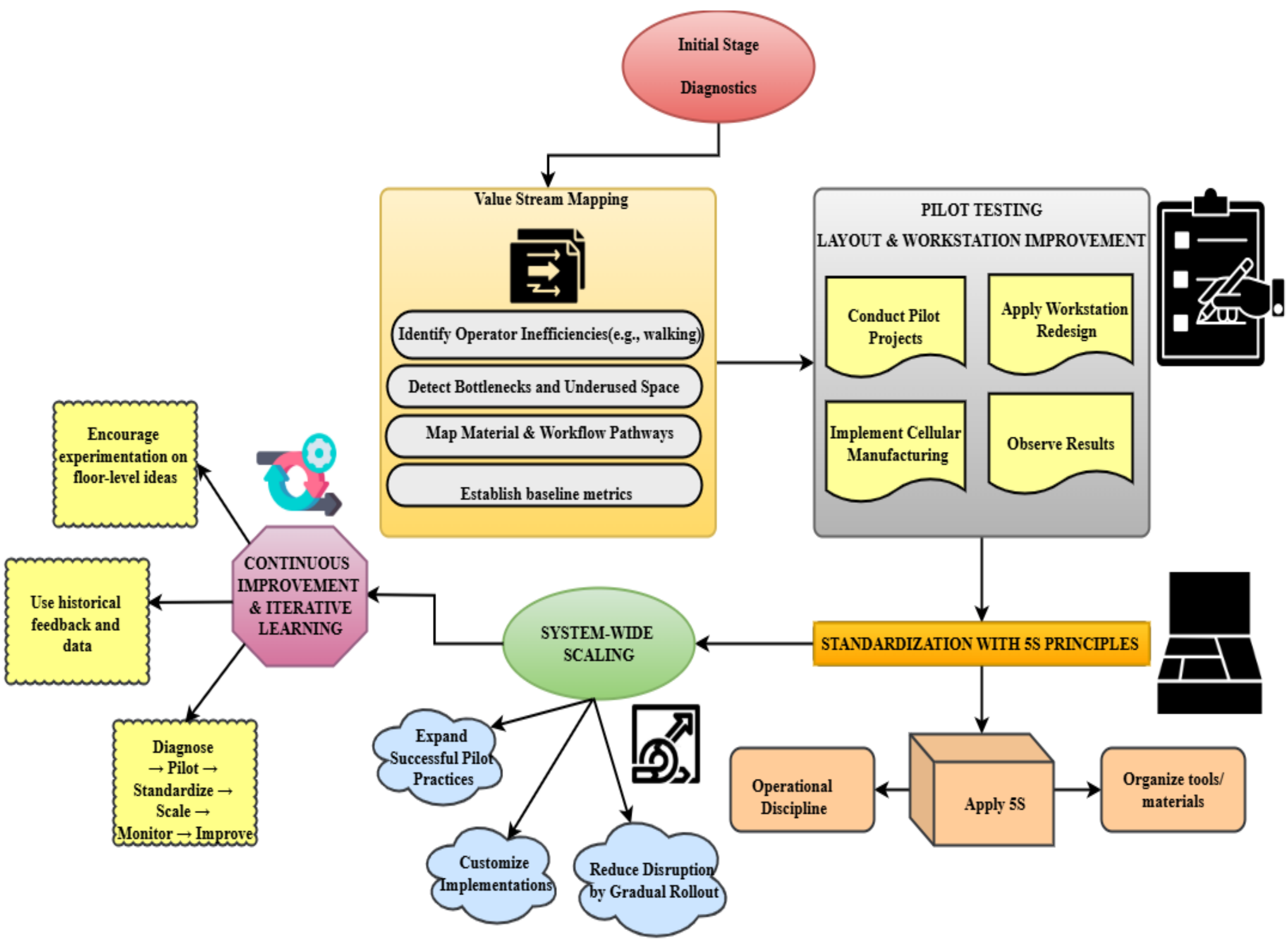

Fig. 3 Implementation strategy and phased approach

This is not the case for concurrently using all lean strategies. Value Stream Mapping helps first identify key inefficiencies, including too many mobile operators, bottlenecks, or underused space during the diagnostic examination before deployment. Phase two will show, in small-scale pilot projects, the effectiveness of workstation reconfiguration and cellular manufacturing. Layout changes are done with an eye toward better material flow and shorter operator travel distances, as demonstrated in Figure 3.

The 5S ideas then help to arrange and preserve better, more effective work surfaces. When gains are observed, the approach is progressively extended across departments, so there is little interruption. This strategy depends mostly on engaging staff members. Their feedback will help to enhance implementation, and they will be taught to fit new processes. VMS enable more transparency and real-time monitoring of events. Apart from lowering possible bad consequences, the stepwise approach increases morale and guarantees long-term manufacturing enhancement. Iterative improvement is a regular feature of the usual running process since one can learn from past failures and try new ideas.

$$\partial(2^{-sp}Cd - sp) = \int |TM(lr)|^2 sp{:}\rightarrow IP \quad (7)$$

Lean adoption in stages is evaluated using this standard productivity sp by Equation (7). A theoretical guide for contrasting declining resource use with increasing productivity pr. Using a phased approach that progressively reduces input (time, motion, labor) $TM(lr)$, one can either maintain or increase production IP.

The productivity indicator shows improvement when every lean phase is embraced. This formula generates a strategic benchmark at the end of every stage, which can be used as a guide to help decide whether to move ahead or turn around.

$$\sum_{ft=\frac{o}{ea}} pd(ct) : \rightarrow GL(tx * wt)_i + \sum_j ea * pd(ro)_i \quad (8)$$

This way, the full time needed to finish a process is dissected. One element at a time is handled in pd phased development; for instance, cutting transportation time by rearranging the layout $\sum_{ft=\frac{o}{ea}} pd(ct)$. The goal is to progressively lower lead time without taxing the system too much. Equation (8) helps one at every level to identify which delays are worth tackling $GL(tx * wt)_i$, and rational organization ro of improvement efforts is advised.

$$\iint oe_i er = pe_d(pr * dr)_{oee} + PS(CM)_i \quad (9)$$

Complete metric, Optimal Equipment Effectiveness (OEE) gauges equipment and resource use during $oe_i er$ deployment in Equation (9). Three measures that fit SLEET's phased emphasis $oe_i er$ time use, performance rates, and defect rates $pr * dr$ are combined here. Every SLEET stage aims to handle one of these facets. Lean concepts allow this theoretical model to help gauge operational health. It guarantees that when one modifies a process, it truly improves it. OEE serves as a control measure to evaluate results at every phase of deployment $PS(CM)_i$.

3.3. Real-Time Monitoring and Feedback Integration

One basic novelty of the SLEET system is the use of real-time waste monitoring and dynamic feedback loops. Common in conventional lean systems, depending on static data or periodic audits, could lead to delays in reacting to production floor problems.

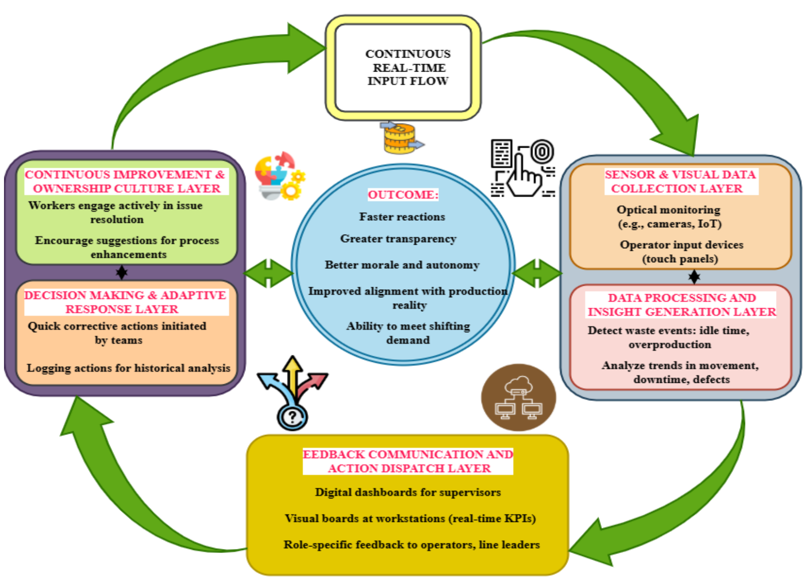

Fig. 4 Real-time monitoring and feedback integration

SLEET meets this demand by documenting real-time performance measures, material movements, and deviations by aggregating optical and digital monitoring devices. Rather than having to look retrospectively, operators and supervisors may now view issues, including idle time, overproduction, or delays, as they arise. The data is sent into feedback loops so that, over time, the process may be optimized and rapid corrections as needed may be made, as revealed in Figure 4. Workers translate the system's insights into action, therefore fostering an ownership culture and ongoing progress. Users of visual boards, digital dashboards, and alarms can communicate KPIs and outliers. More open communication between departments and shifts results in improved cooperation.

$$LS(fe' - bd'') = (fed - qd'') * bs(fe - vodt'') \quad (10)$$

It gauges the time needed to find and resolve a problem. For responsive lean systems LS, SLEET's real-time feedback environment makes it necessary to reduce both durations $(fe' - bd'')$. The efficiency of the feedback loop increases with quick detection $(fed - qd'')$, and the resolution of problems in Equation (10). Alert and monitoring system design benefits bs from an equation that guides design, and this justifies expenditures in digital tools and visual ones$(fe - vodt'')$. A system with a well-designed feedback loop is an adaptive and nimble one.

$$ce(qt - se'') = \left(hp' - pd(ei - pr'')\right) * cr(ld - mk'') \quad (11)$$

Here, the above given equation regarding the confidence ce of real-time data using this theoretical Equation (11), derived from quality and systems engineering$(qt - se'')$. In SLEET, a signal is any helpfulhp' Performance data pd noise is any input, either inaccurate or pointless $ei - pr''$. Having a high SNR indicates that the input is clear and useful, so it enhances lean decision-making. Monitoring systems are shaped based on this ratio $cr(ld - mk'')$. By increasing the visibility of the signals, one can increase the remedial measures. It summarizes the principles of real-time lean monitoring.

$$\sum_j as * dg(id)_i * \iint tm_i lr + TR(fc)_i \quad (12)$$

Equation (12) helps one ascertain the degree of inefficiency-driven waste of scheduled time $\sum_j as * dg(id)_i$. The SLEET system uses real-time monitoring to help lower $tm_i lr$ unscheduled downtime. Faster and more accurate input will enable the fast resolution of events causing downtime. This theoretical ratio supports the favorable contribution made by the feedback mechanism towards operational availability, $TR(fc)_i$. Results depend on the speed of reaction of the operators and the degree of mechanical performance. Reduced downtime reflects robust monitoring integration into lean processes. SLEET can adapt to changes in demand, labor capability, and product complexity due to this real-time feedback mechanism. Ultimately, this continuous flow of valuable information maintains the lean system in step with the pragmatic reality of the textile production system and prevents it from being fixed.

3.4. Performance Improvements and Productivity Gains

Applying the SLEET architecture in a real-world textile production system showed notable performance improvements. The main metrics investigated were operator mobility, distance travelled, cycle time, and total productivity. Before the installation, operators had to waste a lot of time moving between poorly constructed workstations. Due to layout reconfiguration and cellular manufacturing ideas, the travel distance was reduced from 153 to 117 feet.

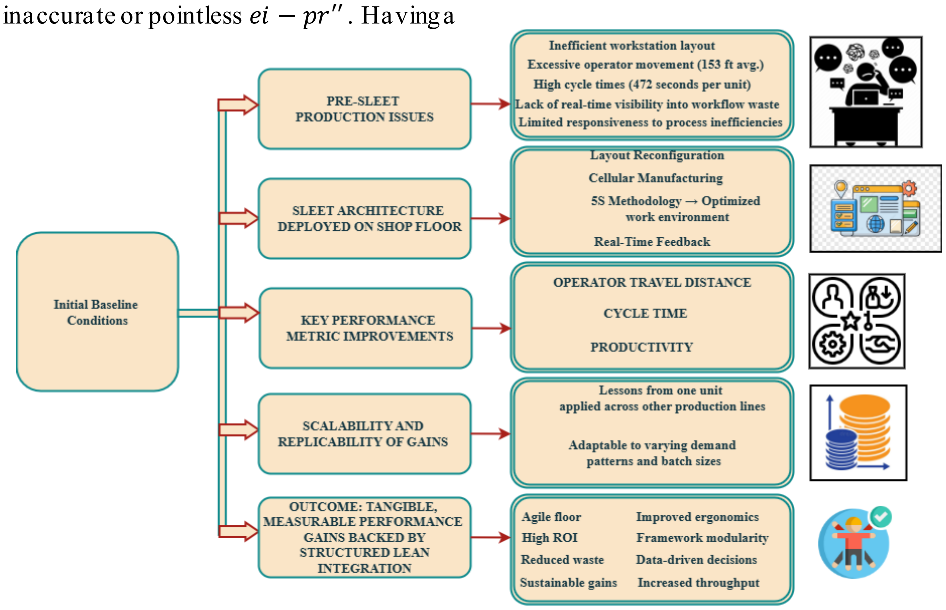

Fig. 5 Performance improvements and productivity gains

Faster job completion and reduced fatigue followed from this. Shorter wait times and better procedures caused the cycle time, a crucial measure of manufacturing speed, to drop from 472 seconds to 438 seconds, as shown in Figure 5. Reduced waste, more effective job distribution, and better workflow all helped the factory's general output climb 4.84%. This development resulted from SLEET's built-in feedback systems and disciplined lean techniques rather than one event.

Another advantage of the scalability of the method was that gains may be used in other units or modified to satisfy fresh production requirements. Given these quantifiable gains, SLEET is a practical lean implementation tool for the textile sector. Not only that, but it demonstrates how effectively the framework can apply lean ideas using a rigorous, logical approach that finally produces observable results.

$$AL(pa' - lct) = RA(pd - bc) * cs(UP'' - pso) \quad (13)$$

Equation (13) offers the performance advantage that lean initiatives could bring about. SLEET emphasizes lowering cycle times to boost throughput $AL(pa' - lct)$. This equation is used to confirm that the rearranging RA and procedural modifications were successful once they have been carried out $(pd - bc)$. Comparatively speaking, cs, it is simpler to evaluate several divisions since it presents a uniform picture of development. Time savings arise from process optimization $(UP'' - pso)$.

$$ec_f - st(cg - tpr'): \rightarrow nv * ws(nv.ese'') \quad (14)$$

Equation (14) helps one evaluate the ergonomic ec_f and motion-related advantages st of rearranging the configuration. Journey minimization helps to lower operator fatigue and boost speed in textile production $cg - tpr'$. This theoretical measure was created to assign a numerical value to the effectiveness of the workstation $nv * ws$ redesign of the SLEET model. Reducing physical strain helps to keep workers content and devoted. The measure is applied as evidence of spatial efficiency ese''. Lean ideas have validity when motion waste and performance results show a direct correlation.

$$Lei'(cl - qy) = cl(ra - pp(ei')) * [cl' - ohp] \quad (15)$$

This percentage-based Equation (15) helps one to evaluate the general effectiveness of the lean implementation Lei'. Including those for movement, cycle length, quality, and production, all the results of the improvements are incorporated $(cl - qy)$. This becomes a rapid assessment of general SLEET performance progress $ra - pp$. Lean investment and continuous quality enhancement have strong justification ei. Figure 5 illustrates that all the lean tools have a major impact taken together. Simply said, it is a gauge of how effectively methods of productivity optimization have performed ohp.

The SLEET architecture effectively combines common lean technologies such as Visual Standard Management (VSM), Five Sigma (5S), cellular layout, and ergonomic redesign to improve flow and eliminate waste in textile manufacture. Practised, it reduced operator travel distance and cycle time, so boosting productivity by 4.84%. Unlike rigid lean systems, SLEET promotes iterative development with dynamic design and ongoing monitoring.

4. Results and Analysis

The results and analysis part of this article presents the pragmatic consequences of implementing the SLEET framework in a real-world textile manufacturing environment. With lean techniques like cellular manufacturing, VSM, 5S, and workstation redesign, SLEET seeks to lower inefficiencies and boost output. This part shows how consistent SLEET deployment results in measurable performance gains in fields such as operator mobility, cycle time, and general efficiency. The data-driven analysis verifies that SLEET maximizes textile processes.

Dataset Description: With Kaggle's Productivity Prediction of Garment Employees dataset, grasp all there is to know about garment manufacturing and worker output. It covers several crucial elements for assessing and enhancing production processes: department, day, team, planned, actual, and productivity. Although information was gathered personally from a garment manufacturing company, the dataset presents a reasonable image of operational dynamics. This tool is excellent for applying machine learning techniques to forecast employee output and increase industrial efficiency. Researchers and practitioners using this dataset can help to develop lean approaches and evaluation systems such as SLEET [30].

4.1. Analysis of Trip Distance

The lower operator trip distance reveals improved ergonomics and workstation design. SLEET achieved minimizing unnecessary transportation via creative reconfiguration and cellular manufacturing. This lowers operator tiredness as well as task completion times, as shown in Figure 6. The 23.5% drop in distance indicates, as a basic lean goal, that waste is being removed in motion. This change has enhanced operational flow, indicating good spatial optimization. It demonstrates how exact layouts improve workers' performance and output in real-time production contexts.

$$(DO - tl'') = em(fq' - di) * rp\{un: \rightarrow ot' = 0\} \quad (16)$$

This Equation (16) helps one to depict the whole distance operator's travel in order to $(DO - tl'')$, produce a good. Examining movement frequency and the distance per trip helps one to measure effective layout design $em(fq' - di)$. SLEET uses this to reinterpret procedures, rp, therefore reducing unnecessary operator travel$\{un: \rightarrow ot' = 0\}$. The direct results of reducing these two factors are decreased tiredness and improved efficiency. The equation helps spatial planning in lean systems.

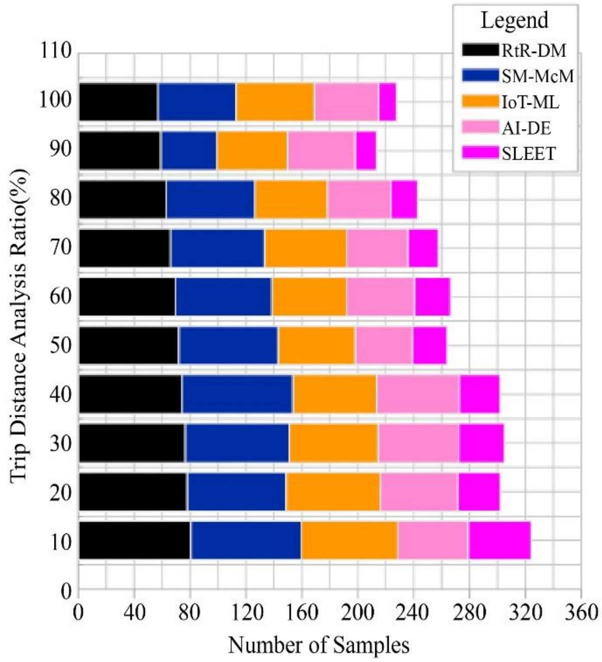

Fig. 6 Trip distance analysis

4.2. Analysis of Cycle Time

Essentially, less intricate task sequences and more effective processes produce a reduced cycle time. SLEET was able to remove pointless steps and reduce textile production delays by using VMS and 5S approaches. The 34^{th} second gain clearly shows faster work completion and improved process control, as shown in Figure 7.

This change yields higher machine use and more throughput. Furthermore, consistent production rates and delivery of good quality. Here is evidence of SLEET's ability to lower operating cycle variance and standardize processes.

$$[p.el(c' - i.dd'')] = el' - Ld(si - xiwf'') \quad (17)$$

Equation (17) helps to separate the primary elements $p.el$ of the cyclec' time, such that inefficiencies can be discovered $i.dd''$. This kind of breakdown helps SLEET to apply lean designs Ld and significantly reduce mobility and waiting times, and to work faster, maximize every phase of the cycle $(si - xiwf'')$.

The equation helps one ascertain the reason for manufacturing delays. This prepares the ground for ongoing research and development. The decrease in cycle time directly influences output and efficiency.

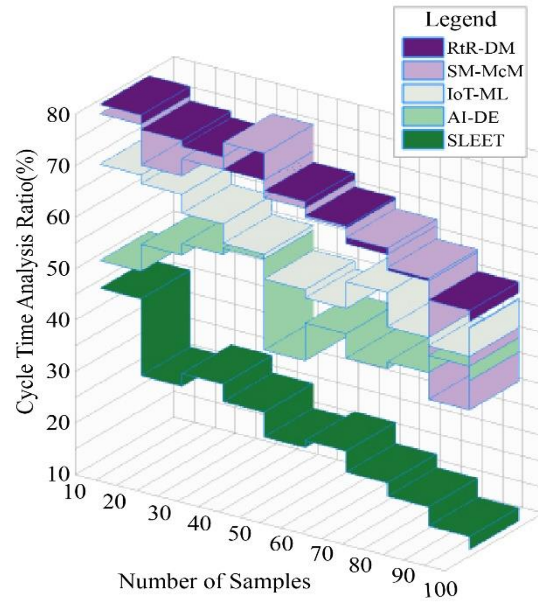

Fig. 7 Cycle time analysis

4.3. Analysis of Productivity

Lean integration under SLEET clearly affects productivity, which has grown by 4.84%. The rise is attributed to the coordinated implementation of layout enhancements, together with real-time monitoring and waste reduction in Figure 8. Due to this improvement, the system has shown that it can independently maximize resource use. Lean implementation allows one to realize performance gains for all kinds of activities. The increase in productivity indicates that strategic capacity planning has been effective. The aim is constant and scalable improvement in the textile units.

$$t\{rm.fpr''\} = ro'' < li - wero'' >* \{rm(rd - wt')\} \quad (18)$$

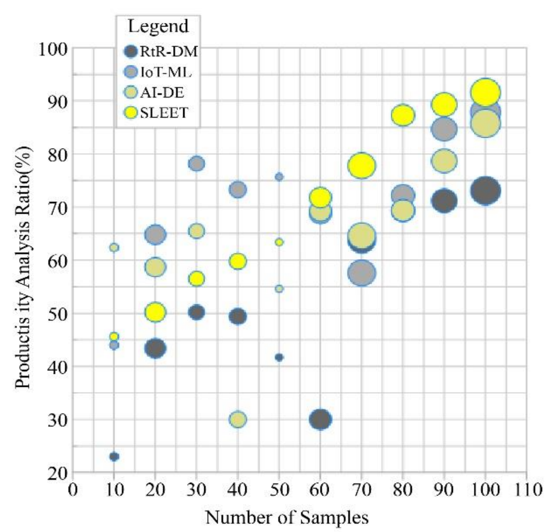

Fig. 8 Productivity analysis

This fundamental Equation (18) establishes the transition of raw materials into a finished product's rate of efficiency $\{rm.fpr''\}$. SLEET helps to increase this ratio ro'', by lowering input waste and either maintaining or raising output. Changes in layout, monitoring, and workflow directly affect productivity $li - wero''$. Analyzing lean performance mostly depends on the equation. Using this approach results in reduced waste, thereby increasing output $li - wero''$. Lean integration in the textile sector is financially advantageous.

4.4. Analysis of Real-Time Waste Monitoring

Real-time waste monitoring with SLEET helps to promptly find and fix process inefficiencies. The automated tracking features of the system guarantee a small lag time between detection and response, as shown in Figure 9. By reducing waste as it occurs, this function supports ongoing lean execution. Two advantages are improved quality control and higher response all across the production floor. Constant monitoring of activities generates transparency. In line to eradicate non-value-added activities in real-time, this improves decision-making.

$$[pp' - diw].mt(if - ar') + \iint rd_i ai \tag{19}$$

This formula allows us to determine the proportion of dynamically identified waste concerning total usage $[pp' - diw]$. Using monitoring tools lets SLEET catch inefficiencies as they arise $mt(if - ar')$. Real-time detection rd_i allows individuals to act quickly to address issues ai, therefore lowering waste. This might be constantly observing lean performance by applying Equation (19). Lower ratios suggest better control and stability of processes. Its use of quantifiable measures promotes operational discipline.

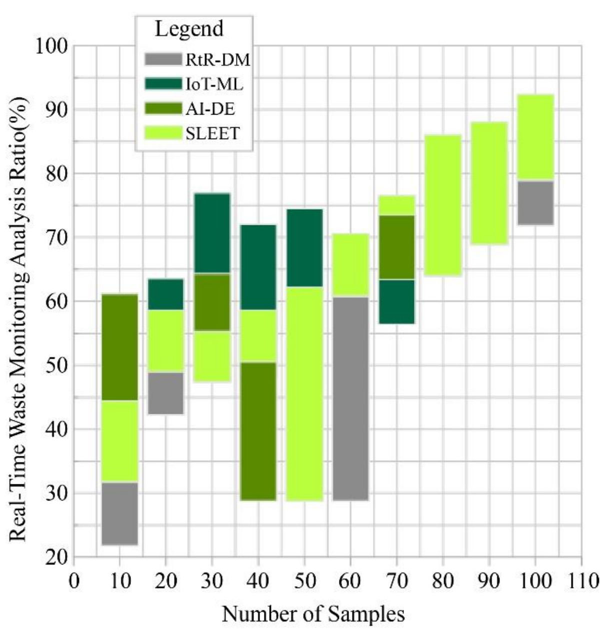

Fig. 9 Real-time waste monitoring analysis

4.5. Analysis of Dynamic Feedback Loops

SLEET uses feedback loops to enable processes to improve with time. These loops constantly record, examine, and react to the operational irregularities. Real-time input makes system agility better and enables quick adaptation to local issues, as shown in Figure 10. This helps facilitate interactions among management, operators, and machinery. This correspondence fixes mistakes fast and minimises them. The feedback system drives constant development since it keeps lean discipline throughout the production process. This opens the path for real-time reactions supported by data to match performance fluctuations.

$$sy\{md: \rightarrow qm' = I(fb - xe'')\}: \rightarrow s\{qt - ame''\} \tag{20}$$

This Equation (20) measures the real-time responsiveness of the system ai for modifications md. The feedback systems of SLEET determine whether one can quickly modify qm and correct inefficiencies $I(fb - xe'')$. Improved feedback efficiency s points to a quick-thinking, adaptable manufacturing environment $\{qt - ame''\}$. With this ratio, monitor the condition of your system for constant improvement. Adaptive decision-making leveraging real-time data is feasible with this equation. Good feedback loops help to protect process quality and problem frequency.

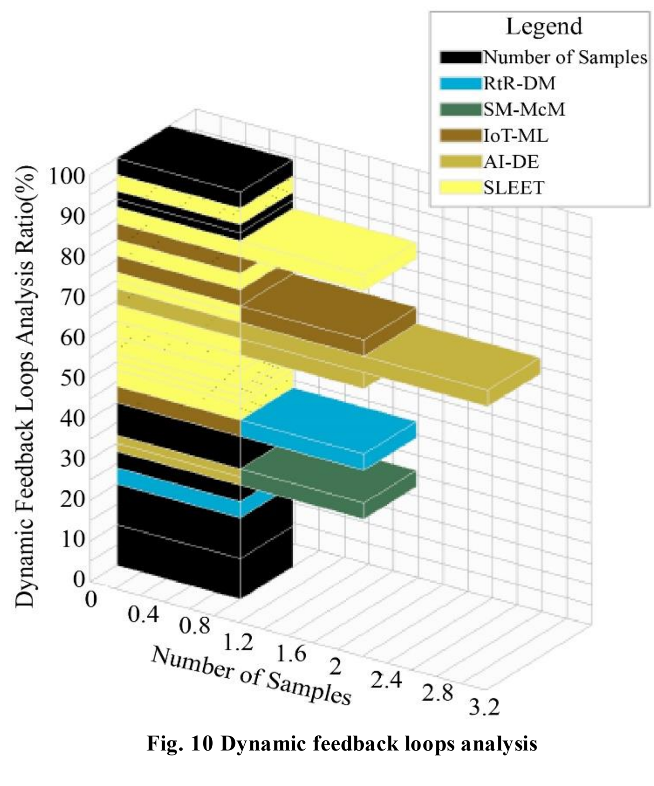

Fig. 10 Dynamic feedback loops analysis

4.6. Analysis of Dynamic Demand Satisfaction

By applying modular lean implementation and flexible planning, SLEET efficiently manages changing needs in textile manufacturing. Its scalable character makes reallocation of resources and processes simple, as shown in Figure 11. Due to this flexible nature, orders are guaranteed promptly and without surplus or stockpiling. This approach will help to meet the demands of your consumers and the ever-shifting market. Meeting production goals under several circumstances becomes more dependable. SLEET's adaptive design shows its value in highly varied industrial environments where order criteria are subject to regular fluctuations.

$$\lim_{d\to\infty} msr\langle F_{Re}(r_n) - F_{Re}(F), F_n - u\rangle \leq 0 \quad (21)$$

Equation (21) helps one determine how closely the manufacturing system responds $\lim_{d\to\infty} msr$ to changing demand. SLEET's modular and flexible architecture lets it reorganize $F_{Re}(r_n)$ its activities to satisfy evolving needs. A high flexibility index indicates that the system can react effectively without F_n compromising quality or delay. The equation helps one evaluate demand responsiveness. The capacity of the system to meet dynamic needs confirms its adaptability.

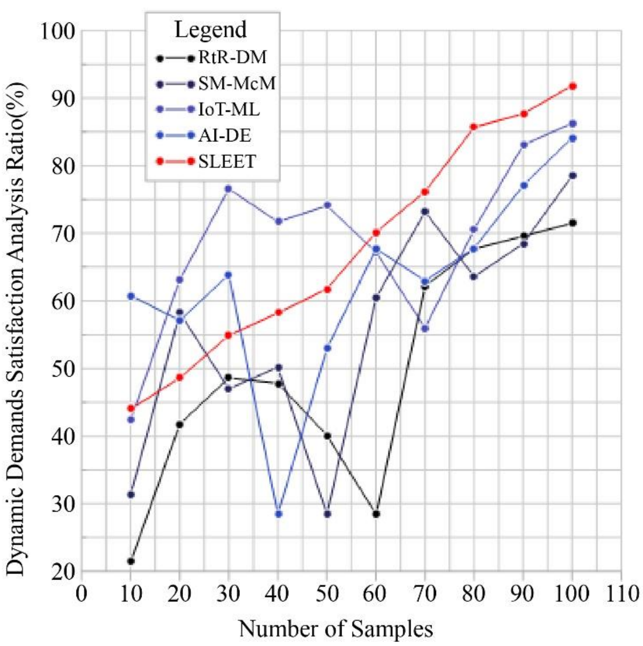

Fig. 11 Dynamic demands satisfaction analysis

4.7. Analysis of Operational Efficiency

The three elements upon which SLEET's productivity rests are waste reduction, process optimization, and procedural standardizing. Lean tools are tightly linked to optimize productivity and reduce downtime in Figure 12. This increases throughput while inputs either stay identical or are lowered. Perfect integration of design, inspection, and continuous feedback yields maximum efficiency. The improvements in motion, time, and arrangement of tasks help to make every element of textile production more operationally healthy and dependable.

$$I(C) = \frac{s_2 \cos(lwt+mn) + s_1 \sin(lwt+mn)}{b_2 b_3 - b_1 b_4} \quad (22)$$

Equation (22) offers important information by allowing one to compare the actual output of the system with its ideal output under ideal circumstances $I(C)$. SLEET s improves this by lowering wait, motion, and downtime inefficiencies s.

Higher efficiency figures suggest more consistent workflow and intelligent utilization of resources $lwt + mn$. This equation forms the backbone $b_2 b_3$ of lean system efficiency measurement. Lean restructuring's effectiveness has been validated by operational efficiency gains$b_2 b_3$. It makes benchmarking across departments and changes possible.

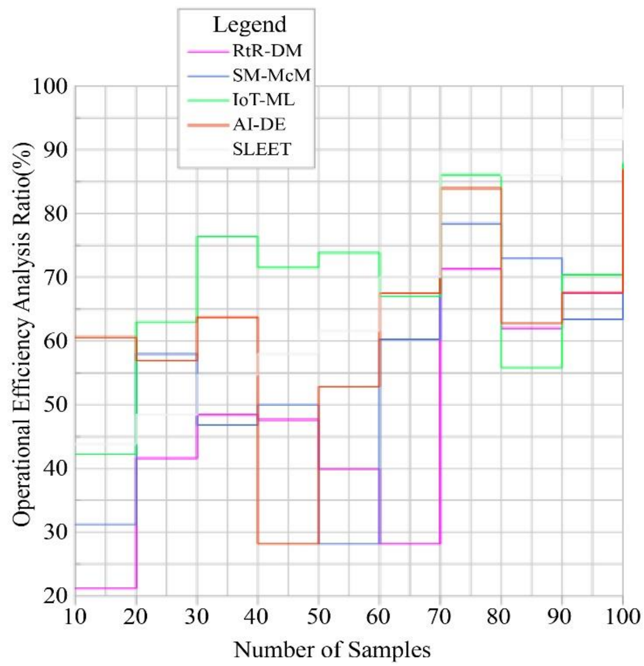

Fig. 12 Operational efficiency analysis

4.8. Analysis of Layout Reconfiguration

Under SLEET, the position of the workstation is precisely matched with the process sequence through design change. It minimizes operator travel, better uses space, and reduces material handling, as illustrated in Figure 13. By eliminating pointless movements and waiting time, this physical restructuring helps apply lean ideas.

Apart from enhancing line balancing, it aids in cellular production. The redesigned layout produces shortened cycle times, more worker comfort, and simplified processes. This makes it abundantly evident that maximizing performance mostly depends on spatial design.

$$W - 1(0)\,\alpha_{EXA} = W - 1(0)\,\omega s W_0 = W - 1(0) \cup \cap_0 \quad (23)$$

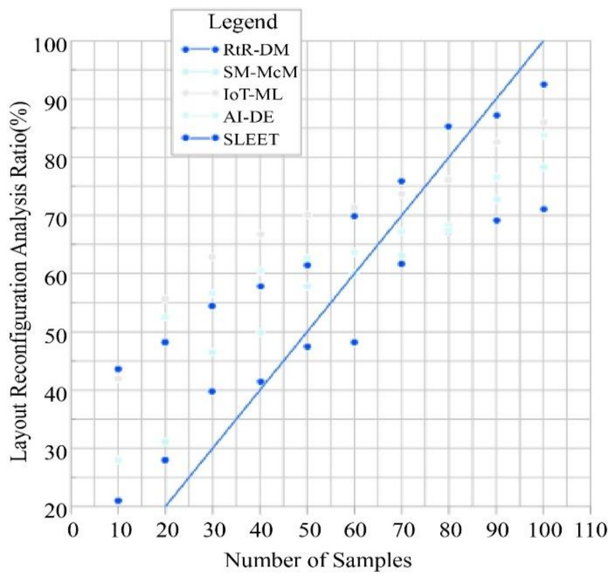

Fig. 13 Layout reconfiguration analysis

This Equation (23) will help one determine the proportion of the work W area directly employed for value-added tasks $\alpha_{E X A}$. SLEET optimizes layouts by reorganizing desks and reducing wasted space $1(0)\omega s W_0$. A better layout will help with the clutter, operator coordination, movement flow, and operator clutter. This formula supports the concept of spatial optimization in lean manufacturing. This helps us to be certain that the physical layout facilitates our lean objectives. Well-designed layouts help to increase safety and cycle times. The main operational improvement was cutting down cycle time from 472 to 438 seconds and operator trip distance from 153 to 117 feet using the SLEET framework. These changes show how effectively combined lean concepts with continuous layout changes are performing. Verifying the effectiveness of SLEET's phased, feedback-driven approach, production increased 4.84 percent. Combining lean software with other approaches reveals that SLEET and other unified adaptive architectures can greatly improve textile manufacturing performance.

5. Conclusion and Future Work

The SLEET framework has proven to be a scalable and efficient means of raising output per unit of effort in the textile sector. The main objectives of SLEET were shortened operator trip distances and increased general productivity by 4.84% with more lean tools such as cellular manufacturing, VMS, and workstation redesign. Real-time waste monitoring and dynamic feedback loops helped to further assist immediate remedial actions by enhancing operational responsiveness and adaptability to shifting production demand. The results reveal that since SLEET is organized and executed in different stages, it is an effective lean implementation technique.

5.1. Future Work

Future research combining with Industry 4.0 technology will help SLEET to improve its decision-making capacity. Among these technologies are real-time data visualization, AI predictive analytics, and IoT sensor tracking. It should be evaluated across several sectors within the textile industry and customized for Small and Medium-Sized Enterprises (SMEs) to increase the applicability of the model and find more chances for ongoing process improvement.

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References

[1] Pramod Kumar et al., “Integration between Lean, Six Sigma and Industry 4.0 Technologies,” *International Journal of Six Sigma and Competitive Advantage*, vol. 13, no. 1-3, pp. 19-37, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[2] Luana Sposito Valamede, and Alessandra Cristina Santos Akkari, “Lean 4.0: A New Holistic Approach for the Integration of Lean Manufacturing Tools and Digital Technologies,” *International Journal of Mathematical, Engineering and Management Sciences*, vol. 5, no. 5, pp. 851-868, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[3] Gautam Dutta et al., “Overcoming the Barriers of Effective Implementation of Manufacturing Execution System in Pursuit of Smart Manufacturing in SMEs,” *Procedia Computer Science*, vol. 200, pp. 820-832, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[4] Hardik Majiwala, Suresh Sharma, and Pankaj Gandhi, “Lean and Industry 4.0 Strive to Create Smart Factory through Integration of Systems: An Exploratory Review,” *4th International Conference on Internet of Things and Connected Technologies (ICIoTCT)*, pp. 184-195, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[5] Jos A.C. Bokhorst et al., “Assessing to What Extent Smart Manufacturing Builds on Lean Principles,” *International Journal of Production Economics*, vol. 253, pp. 1-12, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[6] Benedictus Rahardjo et al., “Lean Manufacturing in Industry 4.0: A Smart and Sustainable Manufacturing System,” *Machines*, vol. 11, no. 1, pp. 1-17, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[7] Varun Tripathi et al., “Development of a Data-Driven Decision-Making System Using Lean and Smart Manufacturing Concept in Industry 4.0: A Case Study,” *Mathematical Problems in Engineering*, vol. 2022, no. 1, pp. 1-20, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[8] G. Citybabu, and S. Yamini, “Lean Six Sigma 4.0 - A Framework and Review for Lean Six Sigma Practices in the Digital Era,” *Benchmarking: An International Journal*, vol. 31, no. 9, pp. 3288-3326, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[9] Paulo Peças et al., "Lean Methods Digitization towards Lean 4.0: A Case Study of e-VMB and e-SMED," *International Journal on Interactive Design and Manufacturing*, vol. 16, no. 4, pp. 1397-1415, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[10] Varun Tripathi et al., "Lean, Green, and Smart Manufacturing: An Ingenious Framework for Enhancing the Sustainability of Operations Management on the Shop Floor in Industry 4.0," *Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering*, vol. 238, no. 4, pp. 1976-1990, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[11] Ahmad Abdullah, Shantanu Saraswat, and Faisal Talib, "Impact of Smart, Green, Resilient, and Lean Manufacturing System on SMEs' Performance: A Data Envelopment Analysis (DEA) Approach," *Sustainability*, vol. 15, no. 2, pp. 1-26, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[12] Hung-Wen Tsai et al., "Use of the Smart Lean Method to Conduct High-Quality Integrated Perioperative Management before Hospitalization," *International Journal of Environmental Research and Public Health*, vol. 18, no. 24, pp. 1-16, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[13] Varun Tripathi et al., "A Sustainable Productive Method for Enhancing Operational Excellence in Shop Floor Management for Industry 4.0 using Hybrid Integration of Lean and Smart Manufacturing: An Ingenious Case Study," *Sustainability*, vol. 14, no. 12, pp. 1-21, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[14] Venkata Saiteja Kalluri et al., "Enhancing Manufacturing Efficiency: Leveraging CRM data with Lean-based DL Approach for Early Failure Detection," *Bulletin of Electrical Engineering and Informatics*, vol. 14, no. 3, pp. 2319-2329, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[15] Mohammad Shahin et al., "Integration of Lean Practices and Industry 4.0 Technologies: Smart Manufacturing for Next-Generation Enterprises," *The International Journal of Advanced Manufacturing Technology*, vol. 107, no. 5-6, pp. 2927-2936, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[16] Attia Hussien Gomaa, "LSS 4.0: A Conceptual Framework for Integrating Lean Six Sigma and Industry 4.0 for Smart Manufacturing Excellence," *Indian Journal of Management and Language (IJML)*, vol. 5, no. 1, pp. 8-29, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[17] Michele Fiorello et al., "Towards A Smart Lean Green Production Paradigm to Improve Operational Performance," *Journal of Cleaner Production*, vol. 413, pp. 1-18, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[18] Attia Hussien Gomaa, "Lean 4.0: A Strategic Roadmap for Operational Excellence and Innovation in Smart Manufacturing," *International Journal of Emerging Science and Engineering*, vol. 13, no. 5, pp. 1-20, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[19] D. Sobya, and S. Jeyabalan, "Enhancement of Production Rate and Flexibility in an Assembly Line by Execution of Various Lean Techniques - A Case Study," *International Journal of Engineering Research in Africa,* vol. 51, pp. 15-27, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[20] Sarah Lonsdale, *Wildly Different: How Five Women Reclaimed Nature in a Man's World*, Manchester University Press, 2025. [Google Scholar] [Publisher Link]

[21] Stephen Tyler Urchick, "*Realism by Rail: Art and Mobilities in Late Imperial Russia*," Ph.D. Dissertation, Yale University, pp. 1-24, 2023. [Google Scholar] [Publisher Link]

[22] Joseph M. Henning, *Interpreting the Mikado's Empire: The Writings of William Elliot Griffis*, 1st ed., Bloomsbury Academic, pp. 1-230, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[23] Kathleen Griffith, *Build Like a Woman: The Blueprint for Creating a Business and Life You Love*, St. Martin's Essentials, pp. 1-288, 2024. [Google Scholar] [Publisher Link]

[24] Andrew Lock, "'*They Learn Best by Teaching and Making their Own Mistakes, not by Lectures from Superiors.' An Assessment of the British Expeditionary Force's Infantry Tactical Progress on the Somme Front, September 1916 - April 1917*," Doctoral Thesis, University of East Anglia, pp. 1-273, 2023. [Google Scholar] [Publisher Link]

[25] Michael Crawley, *To the Limit: The Meaning of Endurance from Mexico to the Himalayas*, 1st ed., Bloomsbury Publishing, pp. 1-272, 2024. [Google Scholar] [Publisher Link]

[26] Marco Iansiti, and Karim R. Lakhani, *Competing in the Age of AI: Strategy and Leadership When Algorithms and Networks Run the World*, Harvard Business Review Press, 2020. [Google Scholar] [Publisher Link]

[27] M. Mohan Prasad et al., "A Framework for Lean Manufacturing Implementation in Indian Textile Industry," *Materials Today: Proceedings*, vol. 33, pp. 2986-2995, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[28] Hanifah Hatif, Khai Loon Lee, and Gusman Nawanir, "Improving Employee and Workplace Performance via Lean Manufacturing Practices: A Case Study in a Textile Company," *International Journal of Industrial Management*, vol. 18, no. 1, pp. 43-59, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[29] Ahmad Ali Yame, "*System Throughput Optimization and its Interaction with Waste under Lean Manufacturing Considerations*," Lawrence Technological University, pp. 1-24, 2021. [Google Scholar] [Publisher Link]

[30] Arash Solgi, Productivity Prediction of Garment Employees, 2021. [Online]. Available: https://www.kaggle.com/code/arashsolgi/productivity-prediction-of-garment-employees