Optimizing Sewing Line Changeovers Through Digital Process Standardization

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Abstract

Garment manufacturing suffers from significant productivity losses due to high changeover times in sewing lines, directly impacting line efficiency, delivery timelines, and cost competitiveness. This paper presents the design, development, and technical implementation of **StitchGrid**, an intelligent digital platform that optimizes changeover operations using Single-Minute Exchange of Dies (SMED) methodology adapted for sewing line complexities. The proposed system integrates real-time task allocation, pre-changeover readiness validation, predictive notifications, resource synchronization, and live visual dashboards to streamline style changeover processes. StitchGrid addresses multi-departmental coordination challenges by digitizing pre-changeover preparation across cutting, trimming, planning, and sewing departments. The platform offers flexibility, scalability, and lays the foundation for Industry 4.0 adoption through IoT integration and data-driven decision-making, enabling garment manufacturers to enhance operational agility and overall productivity.

Index Terms— SMED, Changeover Optimization, StitchGrid, Garment Manufacturing, Lean Manufacturing, Sewing Line Efficiency, Digital Manufacturing, Industry 4.0, Production Planning, Real-Time Monitoring.

1.Introduction

The global garment manufacturing industry operates under intense pressure to deliver high product variety at competitive costs while maintaining strict quality standards. One of the major operational challenges faced by garment factories is the significant loss of productive time during style changeovers in sewing lines. Each changeover requires the coordination of multiple departments, including planning, cutting, trimming, line balancing, machine settings, and operator allocation, often leading to extended idle times and production delays.

In conventional garment sewing operations, changeover processes are largely manual, heavily reliant on human coordination, and prone to communication gaps. These inefficiencies not only affect daily output but also disrupt overall production planning, inventory management, and on-time delivery performance. As fashion cycles shorten and customer demands become more dynamic, the need for faster, more flexible, and reliable changeover processes has become critical for garment manufacturers.

The Single-Minute Exchange of Dies (SMED) methodology, widely used in discrete manufacturing industries, offers a systematic approach to reducing changeover times by distinguishing between internal and external activities, standardizing operations, and promoting parallel task execution. However, applying SMED principles directly to sewing lines poses unique challenges due to high product variability, multi-skilled labor requirements, and dependency on material availability.

To address these challenges, this paper presents the design and implementation of **StitchGrid**, a digital changeover management platform specifically tailored for garment manufacturing environments. StitchGrid integrates SMED concepts with real-time task allocation, predictive readiness alerts, and live dashboards to optimize coordination across departments, minimize human-induced delays, and streamline changeover execution. This platform represents a step forward towards digitalization and Industry 4.0 adoption in the garment sector, enabling manufacturers to enhance operational flexibility, reduce downtime, and improve overall production efficiency.

2.Literature Review

2.1.1 Introduction to Changeover Challenges in Garment Manufacturing

Manufacturing agility is defined as the capability of a manufacturing system to adapt rapidly to market and environmental changes. Agile manufacturing integrates flexibility, responsiveness, and speed, enabling firms to maintain a competitive advantage by swiftly meeting fluctuating consumer demands (Womack & Jones, 2003). Digital transformation has become critical in achieving such agility, especially through the standardisation of processes to improve consistency, reliability, and efficiency (Dang-Pham et al., 2022).

In the dynamic landscape of garment manufacturing, the ability to swiftly transition production lines from one style to another—known as changeover—is crucial for maintaining efficiency and meeting market demands. Changeover time, defined as the interval between the last good piece of the outgoing style and the first good piece of the incoming style, directly impacts production throughput and operational costs .

2.2.2Key Challenges in Changeover Processes

High-Mix, Low-Volume Production Demands: The shift towards customized and fast fashion has led to increased frequency of style changes, making efficient changeovers more critical .

Lack of Standardized Procedures: Absence of standardized operating procedures can lead to inconsistencies and prolonged changeover times .

Equipment and Tooling Delays: Unavailability or delays in preparing necessary tools and equipment for the new style can cause significant downtime .

Inadequate Training and Skill Levels: Operators may lack the necessary training to perform quick and efficient changeovers, leading to errors and delays .

Poor Communication and Planning: Ineffective communication between departments and lack of pre-planning can result in misalignments and extended changeover durations .

2.1.3 Strategies for Mitigating Changeover Challenges

Implementing methodologies like Single-Minute Exchange of Dies (SMED) has proven effective in reducing changeover times. SMED focuses on converting internal setup activities (those that can only be performed when the machine is stopped) to external ones (those that can be performed while the machine is running), thereby minimizing downtime . A critical lean tool in reducing downtime and improving agility is the Single-Minute Exchange of Die (SMED) methodology, developed by Shingo (1985). SMED significantly reduces setup times by converting internal setup activities into external ones, thereby enabling faster changeovers and improved manufacturing efficiency (Helal et al., n.d.; Braglia et al., 2023).

Adopting digital tools for real-time monitoring and standardized checklists can enhance visibility and coordination during changeovers, leading to improved efficiency and reduced error.

In the context of lean manufacturing, prolonged changeover durations are identified as a major source of **non-productive time** and are often classified under "bucket loss" in garment production. This not only affects production targets but also impacts line balancing and workforce productivity. According to Online Clothing Study (2022), inefficiencies during style transition can cause a 10–20% dip in overall line efficiency, particularly when folder changes, machine tuning, or technical approvals are delayed. Moreover, the lack of integration between cutting, bundling, and sewing departments exacerbates the issue, as subsequent teams are often unaware of upstream readiness. These challenges underline the need for an integrated, real-time visibility system that connects all stages of style readiness, enabling coordinated actions and faster recoveries during every style shift.

2.3 Digital Transformation in Apparel Manufacturing

The apparel industry, traditionally characterized by labour-intensive operations and manual coordination, is undergoing a major shift through the adoption of **digital technologies**. Digital transformation in this sector involves integrating advanced tools such as cloud-based systems, mobile applications, IoT-enabled devices, artificial intelligence, and real-time dashboards to improve visibility, efficiency, and responsiveness across production lines.

According to **Sahoo & Mohapatra (2020)**, the apparel sector lags behind other manufacturing industries in terms of automation and digital maturity. However, the need for faster production cycles, shorter lead times, and the increasing popularity of fast fashion have accelerated the adoption of **Industry 4.0 principles**. Technologies like **cloud ERP**, **real-time data collection**, and **digitized quality and production tracking** are now being applied to replace manual reporting, reduce dependency on paper-based systems, and enable informed decision-making.

One of the key areas benefiting from digital transformation is **production planning and control**, especially during style changeovers. As highlighted by **Liu et al. (2019)**, integrating digital OBs (Operation Bulletins), mobile checklists, and live machine tracking significantly reduces communication gaps between departments and allows supervisors to anticipate and act on readiness requirements. Similarly, **Patel et al. (2022)** emphasize that data collected from floor-level operations in real time can be visualized using dashboards, enabling line-wise performance comparison and targeted interventions.

Furthermore, **digital lean tools**, such as mobile-based SMED checklists and Kaizen entry systems, are being used to drive continuous improvement and standardization. The ability to **capture operator-level data, monitor folder and machine readiness, and log delay reasons instantly** ensures that production managers are not just reacting to issues but proactively preventing them.

In practice, digital transformation also empowers factory leadership with **remote monitoring capabilities**, where dashboards reflect the real-time status of changeovers, delays, 5S compliance, and Kaizen participation across different departments or units. This transparency strengthens accountability and promotes a data-driven improvement culture throughout the organization.

2.4 Real-Time Production Monitoring and Dashboards

Real-time production monitoring has emerged as a critical element in modern garment manufacturing, enabling managers to make data-driven decisions on the go. Traditionally, factories relied on end-of-day reports, verbal updates, and manual checklists to track progress. These methods often led to information delays, reactive problem-solving, and a lack of line-wise transparency. The integration of **real-time dashboards** and **digital production tracking tools** addresses these gaps by providing continuous visibility into key performance indicators (KPIs), changeover status, delay causes, and line readiness.

According to **Patel et al. (2022)**, real-time dashboards help manufacturers monitor multiple production lines simultaneously, ensuring immediate response to bottlenecks and deviations from planned targets. In garment factories, such systems typically track operations like folder preparation, machine availability, delay entry, and style readiness — all of which are crucial for minimizing downtime and improving efficiency.

A real-time dashboard aggregates data from floor-level inputs — such as digital delay forms submitted by mechanics or OB checklists completed by supervisors — and presents it in a visual, actionable format. These dashboards often include pie charts, bar graphs, and line-wise summaries to help managers identify top delay categories, check average changeover times, and compare performance across shifts or lines. **Liu et al. (2019)** highlight that such visibility helps bridge the communication gap between departments like cutting, sewing, and finishing, making it easier to coordinate actions before a problem escalates.

In the context of changeover optimization, dashboards can be linked directly to **machine tracking systems (** and **folder checklist modules**, allowing real-time updates on whether a line is ready to load a new style. This eliminates guesswork and supports **SMED implementation**, where readiness must be confirmed before actual loading begins.

3.Problem Statement

In garment manufacturing, sewing lines operate in highly dynamic environments where frequent product changes are necessary to meet diverse customer demands, fast fashion trends, and variable order sizes. Each changeover process involves multiple dependent activities such as preparing cutting markers, arranging trims and accessories, adjusting machine settings, assigning operators, and balancing workstations. The absence of a standardized and synchronized approach to manage these activities often leads to extended changeover durations, production idle time, and cascading delays in the overall production schedule.

Key challenges observed in conventional changeover processes include:

- Lack of real-time visibility into readiness status of required materials and trims.
- Delayed communication and coordination between planning, cutting, sewing, and quality departments.
- Human dependency for task initiation and completion tracking.
- Absence of structured task lists or accountability mechanisms.
- Inefficient parallel execution of preparatory activities.
- Limited data collection for root cause analysis of delays and performance deviations.

These inefficiencies not only contribute to reduced machine utilization and lower daily output but also negatively impact the factory's ability to meet delivery commitments, optimize resource allocation, and maintain profitability. There is a critical need for a systematic, digitized solution that can coordinate multiple departments in real-time, apply lean manufacturing principles such as SMED, and continuously monitor and optimize changeover performance.

4. System Design and Implementation

The proposed solution, StitchGrid**,** is a digital changeover management platform designed specifically for garment sewing lines to address the inefficiencies associated with conventional manual changeover processes. The system applies SMED principles by separating preparatory tasks, enabling parallel execution, and providing real-time coordination across multiple departments involved in the changeover process.

4.1 System Objectives

The primary objectives of StitchGrid are:

- Digitize and standardize all changeover activities.
- Enable early preparation through pre-changeover alerts.
- Allow parallel task execution across departments.
- Provide real-time visibility of changeover progress.
- Minimize human-induced delays and miscommunication.
- Collect operational data for continuous improvement.

4.2 System Architecture

The StitchGrid platform is designed using a modular, scalable, and cloud-based architecture to ensure flexibility, ease of deployment, and real-time responsiveness required for garment manufacturing environments. The core components of the system are outlined in Table 1.

Frontend Interface	ReactJS
Backend Server	Node.js and Express
Database Layer	Firebase Fire store (NoSQL)
Deployment Environment	Hosted on Google Firebase Cloud
IoT Integration	The system is designed to integrate with ESP32-based microcontrollers for live machine status monitoring and automated data collection.

Table 1: System Architecture Components

4.2.1 Data Flow and Operations

The StitchGrid system follows a real-time data flow model where all task updates, delay logs, and changeover progress are continuously synchronized between multiple users and departments. Supervisors and operators interact with the ReactJS frontend application, which communicates securely with the Node.js backend server. All data transactions are verified via Firebase Authentication and stored in Firebase

Firestore (NoSQL). Firebase Cloud Functions are triggered to process asynchronous tasks such as sending alerts, generating bottleneck warnings, and preparing reports for management.

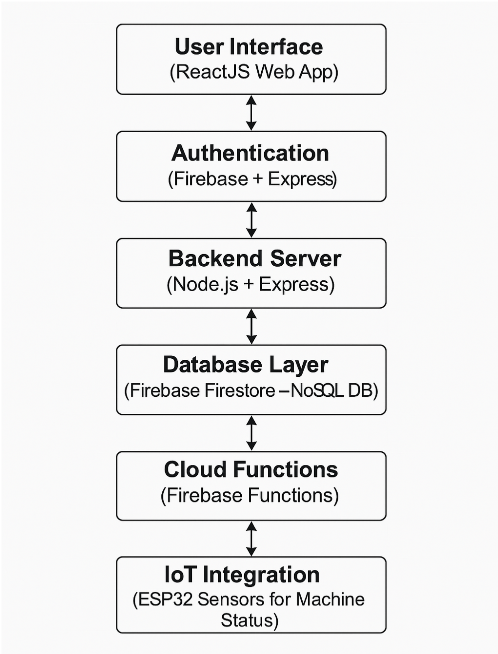

Figure 1: StitchGrid System Architecture

4.3 Functional Workflow

The StitchGrid workflow is divided into three key stages:

a) Pre-Changeover Preparation
- Generation of pre-defined task lists based on upcoming style.
- Automatic alerts sent to cutting, trimming, and planning departments several hours before the scheduled changeover.
- Readiness checks for markers, BOM availability, and trims inventory.
- Supervisor verification before changeover start.

b) Live Changeover Execution

- Changeover timer initiated by the line supervisor.
- Real-time task allocation and tracking across multiple users.
- Live status updates via handheld devices to ensure task completion visibility.
- Bottleneck alerts generated if task delays are detected.

c) Post-Changeover Analysis
- Automatic logging of total changeover duration.
- Recording of task-wise delay reasons for root cause analysis.
- Weekly and monthly performance reports generated for management review.

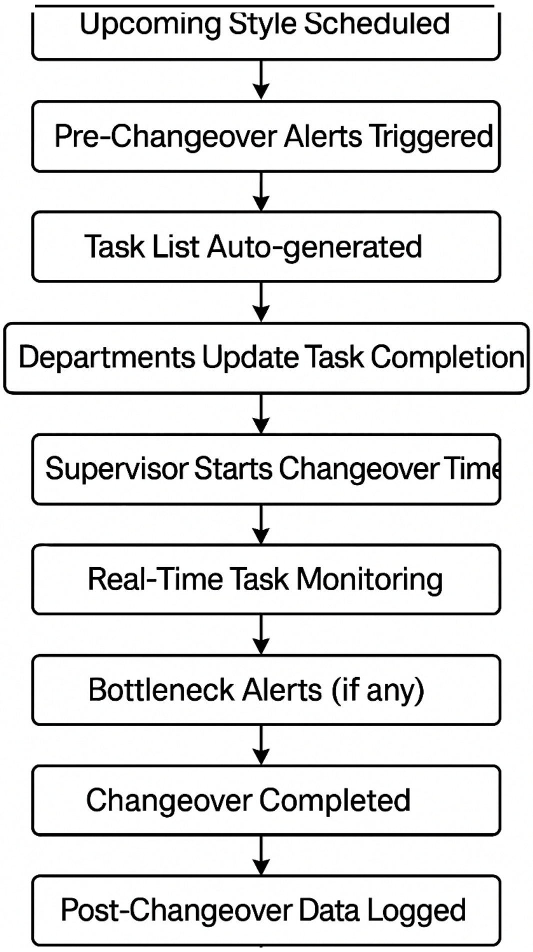

Figure 2: Workflow Diagram of StitchGrid

4.4 User Roles and Access

The system supports multiple user roles, each with specific permissions:

- **Planning Department:** Task generation, schedule creation.
- **Cutting and Trims Department:** Material readiness updates.
- **Line Supervisors:** Task execution tracking, timer control.
- **Quality Department:** Pre-production inspection readiness.

- **Management:** Performance monitoring and reporting.

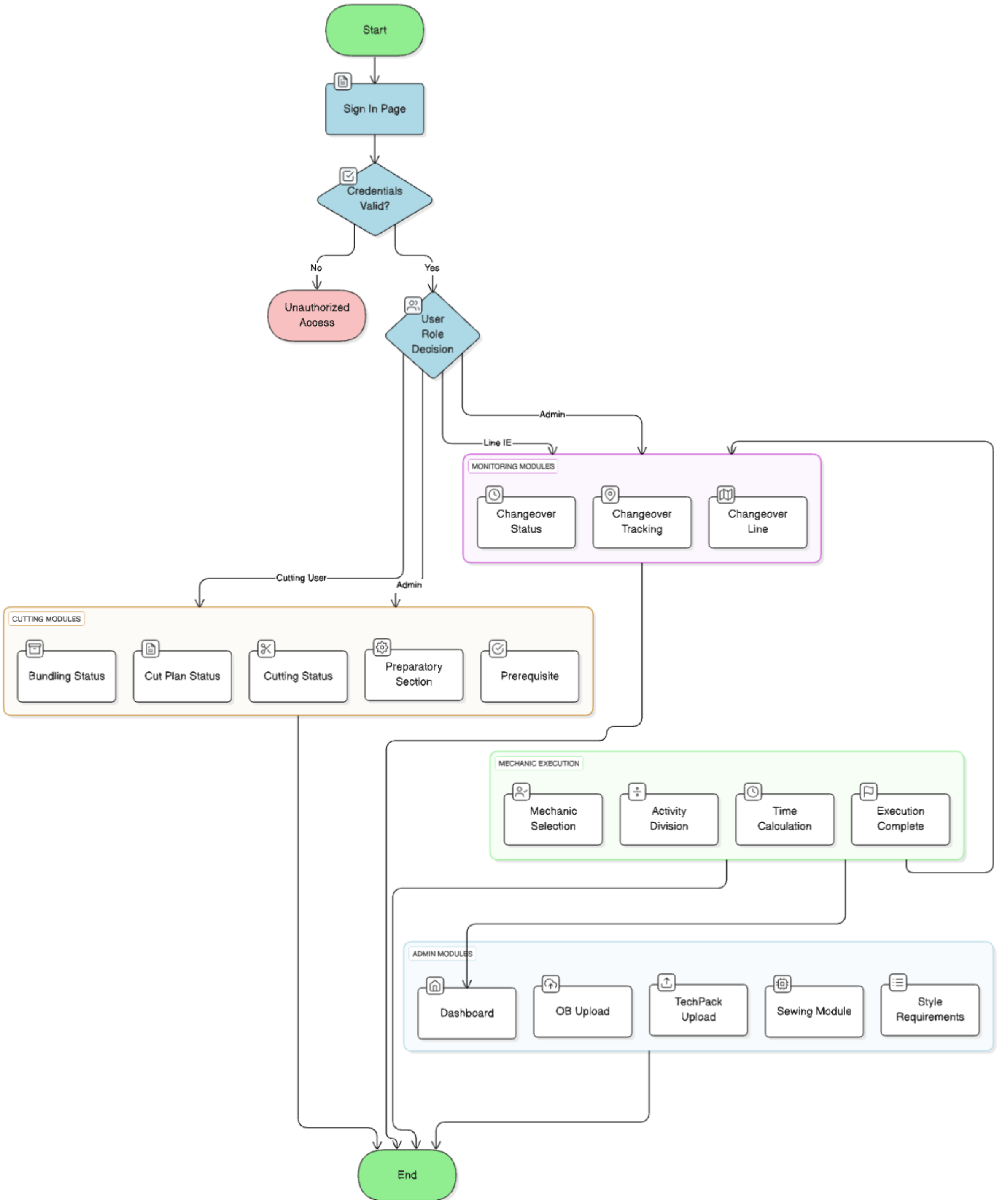

Figure 3: StitchGrid User Modules

4.5 User Interface Demonstration

The StitchGrid platform offers a simple and intuitive interface designed for factory supervisors and department users to track and update changeover progress in real-time.

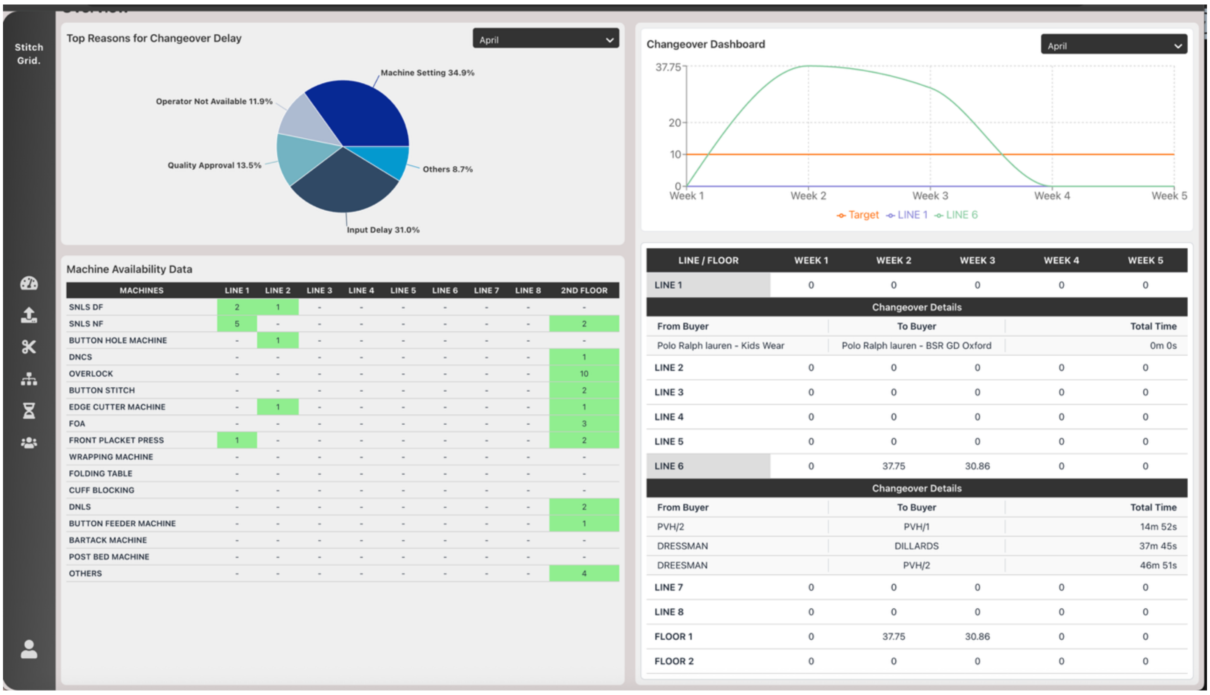

Figure 4: StitchGrid Real-Time Dashboard View

5. Discussion and Analysis

The implementation of StitchGrid introduces a structured and digitized approach to optimize sewing line changeovers in garment manufacturing using SMED principles. Unlike conventional manual coordination, which heavily relies on inter-departmental communication and experience-based decisions, StitchGrid standardizes the changeover process by converting it into a sequence of well-defined, pre-planned tasks that are tracked in real-time.

5.1 Improvement over Conventional Methods

In traditional garment manufacturing environments:

- Changeover processes are mostly reactive and start only after the preceding style is completed.
- Operators and supervisors often wait for trims, markers, or BOM confirmation.
- Responsibility gaps lead to communication delays and uncoordinated task execution.
- Supervisors manually track readiness, often leading to incomplete visibility.

StitchGrid addresses these inefficiencies by:

- Initiating pre-changeover preparation through automated alerts.
- Digitizing task allocation, removing dependency on verbal communication.
- Allowing multiple departments to update readiness status in real-time.
- Providing supervisors with a live dashboard to monitor task progress and identify bottlenecks immediately.

5.2 Flexibility and Adaptability

StitchGrid is designed to handle different garment manufacturing environments, including:

- High product variability with frequent style changes.
- Multiple sewing lines operating simultaneously.
- Varying batch sizes and order quantities.
- Integration possibilities with ERP and MES platforms for full production synchronization.

5.3 Contribution to Lean and Industry 4.0

By automating and optimizing the changeover process, StitchGrid directly supports:

- Reduction of non-value-adding activities.
- Improved equipment utilization and manpower productivity.
- Enhanced data collection for performance analysis and continuous improvement.
- Building the foundation for Industry 4.0 adoption through IoT integration and predictive analytics.

5.4 Analysis of Delay Data

The delay data collected during pilot deployments revealed that Machine Setup Delay, Folder Unavailability, and Operator Readiness collectively contributed to more than 50% of the total changeover delay time. This validates the importance of early material preparation and proactive operator allocation which StitchGrid directly addresses. The Pareto analysis further confirmed that addressing these top contributors results in maximum impact on overall changeover time reduction.

STYLE NAME: PURE PRESS		HANGER LOADING START TIME :10:30 am		Con. No: 12669.1		
SL. NO.	DELAY DESCRIPTION	TIME TAKEN(IN MINS)	REMARKS	INTERNAL	EXTERNAL	WASTE
1	AIR BLOCKING IN ARMHOLE PRESSING M/C	10	it's an unintended issue that causes unnecessary downtime. Ideally, this should be eliminated by identifying and fixing the root cause.			
2	MACHINE SETUP FOR SLEEVE ATTACH	25	Machine setup for sleeve attach (tape style) delay falls under internal activities because it requires stopping the machine for adjustments.			
3	LONGER M/C MOVEMENT FROM SECOND FLOOR TO FIRST	20	This delay falls under waste because the lack of an ideal machine space leads to unnecessary movement, increasing changeover time.			
4	THREAD CHANGE DELAY	12	Operator causality			
5	FF1 MACHINE SETUP DELAY	40	This is typically an internal activity because it involves adjusting machine settings, changing attachments, aligning guides, and testing			

			stitches while the machine is stopped.			
6	FF2 MACHINE SETUP AND TESTING	10	The same machine was previously utilized for similar styles, indicating that the machine settings and adjustments were already optimized. Any delays observed should be minimal and promptly addressed.			
7	QUALITY DELAY	16	Training and communication issue, Lack of clear instructions on wash care label placement.			
8	CHANGEOVER LAYOUT NOT PLANNED	6	Lack of planning before switching production batches			
9	CUFF ATTACH M/C NOT PRE SET	12	Lack of pre-shift machine checks – The cuff attachment machine was not set up before production started.			
10	SIDE SEAM PRESSING NOT READY AND CLEANED	7	Machine not cleaned in advance			
11	SIDE SEAM PRESSING MACHINE	20	Not Preheating the Pressing Machine Beforehand			
12	GUSSET M/C NOT PRE SET	34	Poor planning or lack of responsibility for machine settings			
TOTAL TIME		212 MINS				

Table 2: Changeover Delay during assembly Changeover

DELAY DESCRIPTION	TIME TAKEN (MINS)	CUMULATIVE TIME (MINS)	CUMULATIVE %
Ff1 machine setup delay	**40**	**40**	**18.87%**
Gusset m/c not pre set	**34**	**74**	**34.91%**
Machine setup for sleeve attach	**25**	**99**	**46.70%**
Longer m/c movement (second floor)	**20**	**119**	**56.13%**
Side seam pressing machine not preheated	**20**	**139**	**65.57%**
Quality delay	**16**	**155**	**73.11%**
Thread change delay	**12**	**167**	**78.77%**
Cuff attach m/c not pre set	**12**	**179**	**84.43%**
Air blocking in armhole pressing m/c	**10**	**189**	**89.15%**
Ff2 machine setup and testing	**10**	**199**	**93.87%**
Changeover layout not planned	**6**	**205**	**96.70%**
Side seam pressing not ready & cleaned	**7**	**212**	**100.00%**

Table 3: Pareto analysis of Changeover Delay during assembly Changeover

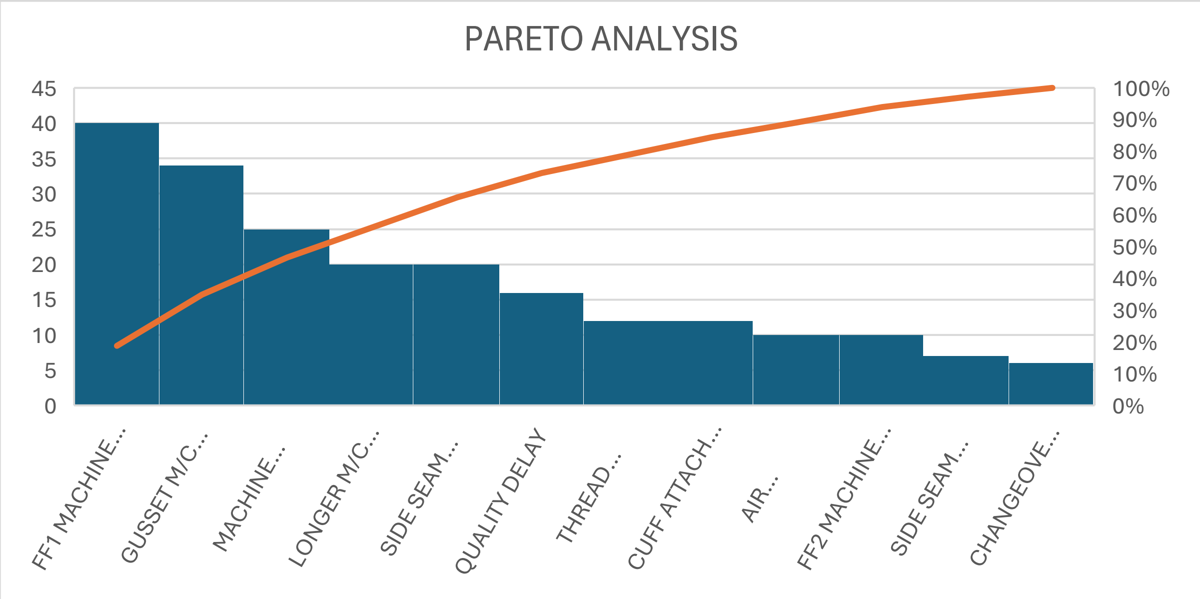

Figure 5: Pareto analysis of Changeover Delay during assembly Changeover

5.5 Why-Why Analysis for Root Cause Identification

Problem	Why? (1st Level)	Why? (2nd Level)	Why? (3rd Level)	Why? (4th Level)	Why? (5th Level - Root Cause)
French Fell 1 Machine Setup delay	Operators are not aware of the required machine settings in advance	There is no pre-setup checklist or digital tracking system.	Machine settings are not standardized or digitally stored.	Different operators use different methods for setup	Lack of formal training and process standardization
Gusset machine not pre-set	Machine not prepared in advance	No clear responsibility	No communication system	No scheduling tool	Lack of planning
Machine setup for sleeve attach	Setup takes too long	Machine adjustments not recorded	No past reference for setup	No digital database	No system for machine history tracking
Longer machine movement (second floor)	Machines placed on a different floor	Poor layout planning	Space constraints	No fixed machine allocation	Inefficient layout
Side seam pressing machine not preheated	Operators start work without preheating	No preheat reminder	No digital alert system	No standard operating procedure (SOP)	Lack of process discipline
Quality delay	Defects found late	No inline inspection	Operators unaware of defects	No real-time defect tracking	Lack of inline quality control

Table 4: WHY-WHY analysis of Changeover Delay during assembly Changeover

5.6 Hypothesis Testing for Change-over Loss

Symbol	Meaning	Value
n	sample size (change-overs analysed)	7
$\bar{x}$	sample mean of change-over loss	**69.7 min**
S	sample standard deviation	**43.8 min**
μ0	target / allowable change-over loss	**10 min**
α	significance level	0.05 (two-tailed)

Table 7: *Hypothesis Testing for Change-over Loss*

5.6.1 Hypotheses

Null (H_0) There is *no* significant change-over loss between styles:

$$\mu=\mu_0=10 \text{ min}$$

Alternative (H_1) There *is* significant change-over loss between styles:

$$\mu\neq 10 \text{ min}$$

5.6.2 Test Selection

Because the population standard deviation is unknown and n<30n<30n<30, a **one-sample t-test** is appropriate.

5.6.3 Assumptions

Change-over loss observations are independent.
Loss times are approximately normally distributed (checked via normal-probability plot; no strong departures observed).
Scale of measurement is continuous (minutes).

Sample Data

FROM	**T0**	**WEEK**	CHANGEOVER LOSS
Style A	Style B	WEEK 5	160 MINS
Style B	Style C	WEEK 6	66 MINS
Style C	Style D	WEEK 8	90 MINS
Style D	Style E	WEEK 10	48 MINS
Style E	Style F	WEEK 12	37 MINS
Style F	Style G	WEEK 15	40 MINS
Style G	Style H	WEEK 15	47 MINS

Table 8: *Sample Data of 2 months changeover analysis*

5.6.4 Test Statistic

$t = (\bar{x} - \mu_0) / (s / \sqrt{n})$
$t = (69.71 - 10) / (43.83 / \sqrt{7})$ $t = 59.71 / 16.57$
$t = 3.60$
Degrees of freedom: $df = n - 1 = 6$

5.6.5 Decision Rule

Critical $t_{0.025,6} = \pm 2.447$
Since $|t| = 3.60 > 2.447$, **reject H_0**.
(Two-tailed p-value ≈ 0.024.)

5.6.6 Interpretation

The analysis shows the **actual average change-over loss (70.83 min) is statistically greater than the 10-minute target** at the 95 % confidence level. Losses are not confined to a single transition (range 14–160 min) and therefore represent a systemic issue across multiple style changes

Converting to Pieces

Line speed = 189 pcs / h = 3.15 pcs / min

$69.7\ \text{min} \times 3.15\ \text{pcs min} \approx 220\ \text{pcs}$
Impact: each style change on Line 6 wipes out **≈ 220 pieces (12 % of a 1 800-pc day)**.

5.7 Corrective Actions and Improvement Strategies

Based on the Pareto analysis and Why-Why root cause analysis, the following corrective actions were identified and implemented to minimize changeover delays:

Standardized Machine Setup Procedures:
Machine setup checklists were created and integrated into StitchGrid's pre-changeover task lists, reducing variability in machine adjustments.

Digital Pre-setup Alerts:
StitchGrid generated advance notifications to supervisors and maintenance teams for preparing machines, attachments, and folders before changeover start time.

Operator Skill Training:
Targeted operator cross-training programs were conducted to reduce dependency on specific individuals and improve task flexibility.

Layout Optimization:
Machines frequently used for multiple styles were permanently relocated closer to sewing lines to eliminate unnecessary machine movement.

Inline Quality Checks:
Inline defect tracking was introduced to reduce quality delays during changeover execution.

Preheating Automation:
Preheating reminders for pressing machines were incorporated into StitchGrid's digital task system to ensure readiness before production resumes.

The implementation of these corrective actions, supported by StitchGrid's real-time monitoring system, resulted in substantial reductions in changeover delays and improved production line stability.

6. Methodology

This project adopted a mixed-method research approach, combining both **quantitative** and **qualitative methodologies** to ensure comprehensive understanding and solution development.

On the **quantitative** side, changeover time was analysed before and after implementation to assess impact. Production loss due to delays in machine setup was estimated by calculating time lost against line output targets. Real-time machine utilization was tracked via digital dashboards, and a cost-benefit analysis was conducted to evaluate the efficiency of digital Kaizen implementation.

In parallel, **qualitative analysis** was carried out through on-ground observations of mechanic behaviour, highlighting their reliance on experience-based setups rather than standardized processes. Feedback from production and IE teams was collected to evaluate the adoption and effectiveness of SMED principles and digital changeover readiness systems. Challenges in knowledge transfer, folder preparation discipline, and machine setup standardization were identified and documented as key areas for process improvement.

6.1 Primary Data Study.

To understand the on-ground challenges related to style readiness and operational delays, a detailed primary data study was conducted at well-known factory. The objective was to capture real-time insights from the sewing floor and identify patterns in inefficiencies that occur during style transitions.

Manual data was collected from mechanics, supervisors, and IE teams through informal interviews and floor interactions. Specific attention was given to how machine setups were done, how folder arrangements were communicated, and whether SMED principles were being followed. The findings revealed that while checklists existed, they were rarely implemented; and preparation activities that could have been done in advance were usually handled reactively.

Also, a **manual mapping of folder usage operation-wise** was carried out for multiple OBs to understand repetitive setup requirements. This exercise highlighted a clear need for a digital system to streamline folder planning, machine readiness, and delay tracking.

The primary data collected formed the foundation for problem analysis, system design, and app feature planning in this project.

6.2 Secondary Research

To complement the primary observations on the production floor, extensive secondary research was conducted to explore industry best practices, existing literature, and relevant tools used for minimizing style changeover time in garment manufacturing.

6.2.1 Bottleneck Identification

During the course of the project, multiple bottlenecks were identified that significantly impacted the efficiency of style readiness and contributed to unnecessary delays on the production floor.

1. Last-Minute Folder Arrangement

One of the most critical bottlenecks observed was the unplanned and last-minute preparation of folders. Despite folder requirements being listed in the OB, they were not proactively communicated or arranged in advance. This led to stalled setups and idle machines during changeovers.

2. Lack of OB Visibility

OBs were often circulated through informal means such as WhatsApp or paper printouts. This caused confusion among mechanics and supervisors, who frequently had to verify information manually. The absence of centralized OB access delayed preparation activities.

3. Machine Setup Based on Verbal Instructions

Machine readiness was dependent on verbal communication from line supervisors or mechanics' experience. There was no structured system to track idle machines or pre-assign them for upcoming styles, resulting in miscommunication and delay.

4. No Delay Logging or Visibility

There was no formal system to capture reasons for delay. Without logging, recurring problems went unnoticed by management, making it difficult to take preventive actions or hold ownership for process failures.

5. SMED Checklist Not Followed

Although a structured SMED checklist existed in the factory, it was not actively used or enforced. Mechanics often completed internal activities after line loading had already begun, violating lean principles and increasing downtime.

6. No Line-Wise Performance Tracking

There was no dashboard or tracking mechanism to compare how different lines were performing during style transitions. This made it hard to identify weak-performing areas and improvement opportunities.

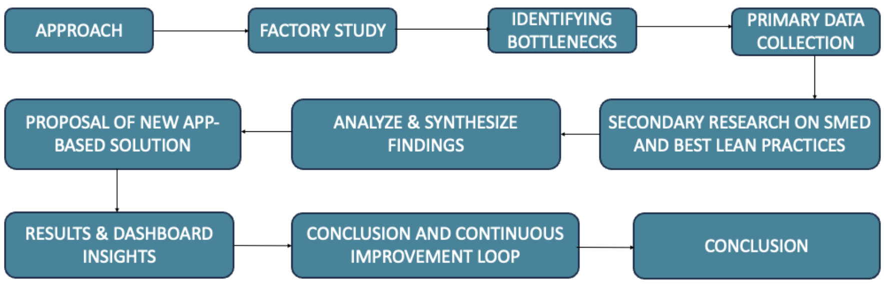

Figure 6: Approach of the Project

6.3 Existing Changeover Process at the Factory

At Laguna Clothing, style changeovers are frequent due to varied buyer requirements, seasonal collections, and short-run styles. However, the changeover process on the sewing floor has traditionally been reactive, with limited planning, inconsistent execution, and high dependency on individual experience.

6.3.1 Current Practice Before Implementation

1. OB Distribution:
OBs (Operation Bulletins) were shared via WhatsApp or physical printouts. There was no centralized system for teams to access the OB, resulting in confusion and miscommunication.

2. Folder & Trim Preparation:
Folders were arranged post style loading or just moments before. Mechanics would often wait until the line was loaded before asking for folder details, leading to downtime.

3. Machine Setup:
Machine readiness was decided through verbal communication. There was no structured process to pre-assign idle machines or prepare attachments in advance.

4. Delay Reason Capture:
No formal delay logging system existed. Reasons for delay were neither documented nor reviewed, making it difficult for the IE team to identify repetitive issues.
5. Checklist Usage:
While a SMED checklist existed, it was rarely followed. Internal activities (which should have been done beforehand) were completed after line loading, increasing non-productive time.

6.Monitoring &Analysis:
Changeover performance was not tracked line-wise. There were no dashboards or reports to compare lines or measure efficiency improvement.

Area	Before	After
OB Access	WhatsApp/Paper	Uploaded to App, auto-parsed
Folder Prep	Last-minute	Checklist visible in app before loading
Machine Planning	Verbal	Idle machine tracker used
Delay Reasons	Not captured	Entered by mechanic in real time
SMED Checklist	Not followed	Digitally integrated into process
Performance Tracking	Manual / None	Weekly dashboard auto-generated

Table 5: Before & After Changeover process

6.3.2 OB Access & Format Update

Initially, OBs (Operation Bulletins) at Laguna were shared with mechanics and production teams through informal channels such as WhatsApp messages or printed sheets. These OBs followed a basic format which often lacked structured columns for key planning aspects like folder requirement, machine type, and guide information. As a result, mechanics had to rely on verbal instructions or personal experience to set up machines and prepare folders, leading to frequent confusion and inconsistent setups.

As part of the project intervention, the OB format was revised to support **digital parsing and structured checklist generation**. This updated OB format was designed to be uploaded directly into the app. The system automatically parses these columns and displays a structured, operation-wise checklist — making it easier for mechanics to plan setups in advance and for supervisors to track readiness accurately.

This change ensured better planning, reduced miscommunication, and allowed the OB to act as a live input into the digital readiness flow.

6.3.3 Folder Preparation Process

Folder preparation plays a critical role in ensuring a smooth and efficient style transition on the sewing floor. However, during the initial study, it was observed that folder arrangements were typically done **at the last minute**, often after the new style had already been loaded on the line.

6.3.4 Layout Optimisation: Introduction of Modular Line

A **modular line** was introduced as part of the layout optimisation strategy to perform **preliminary operations before parts are fed into the main production line**. The objective was to isolate operations that could be done externally — such as collar assembly, pocket attaching, or label fixing — so that the main line is loaded only when all necessary components are ready.
This change supports the **SMED principle of external activity management**, allowing multiple operations to be executed in paralle

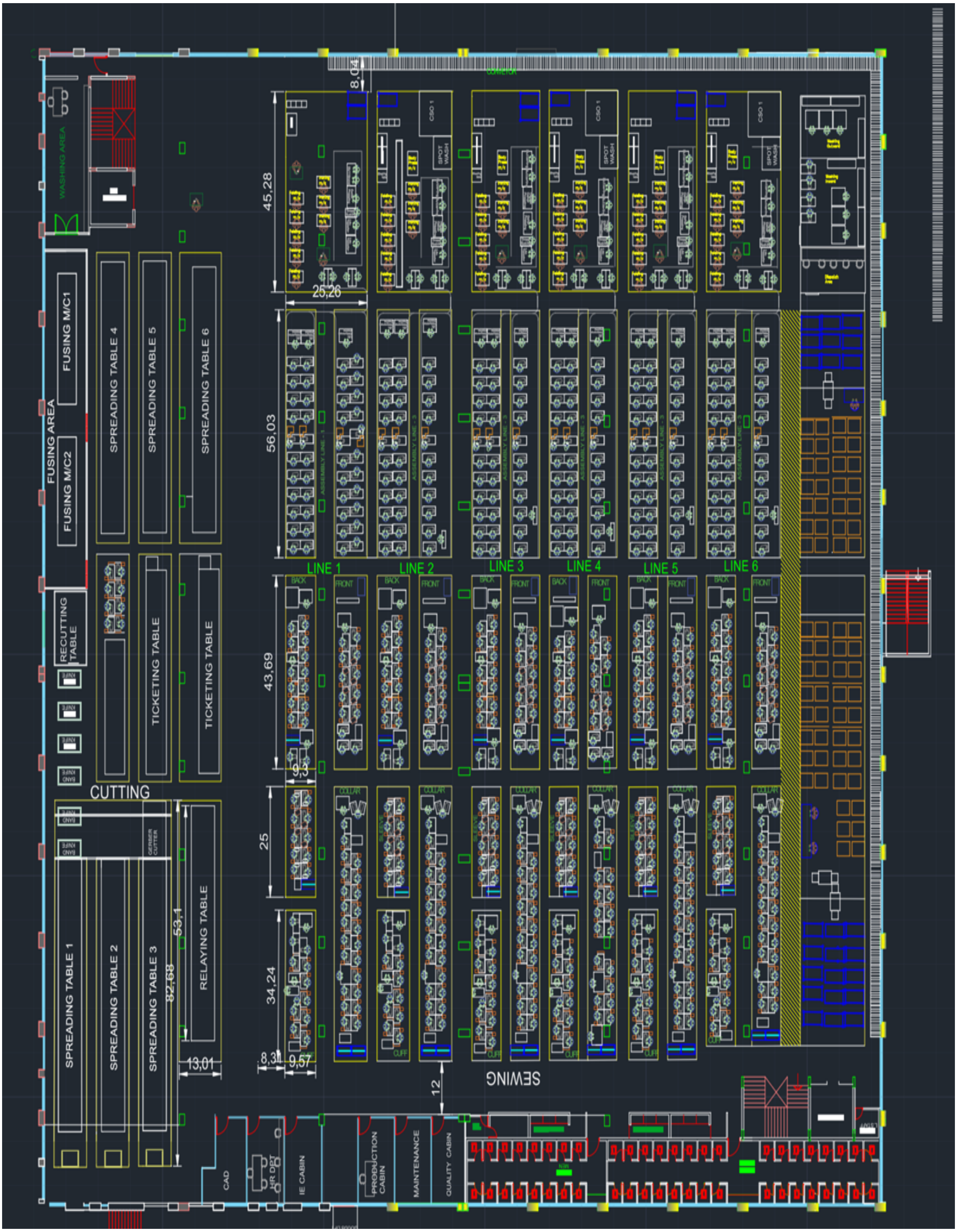

Figure 7: Previous Layout of the Floor

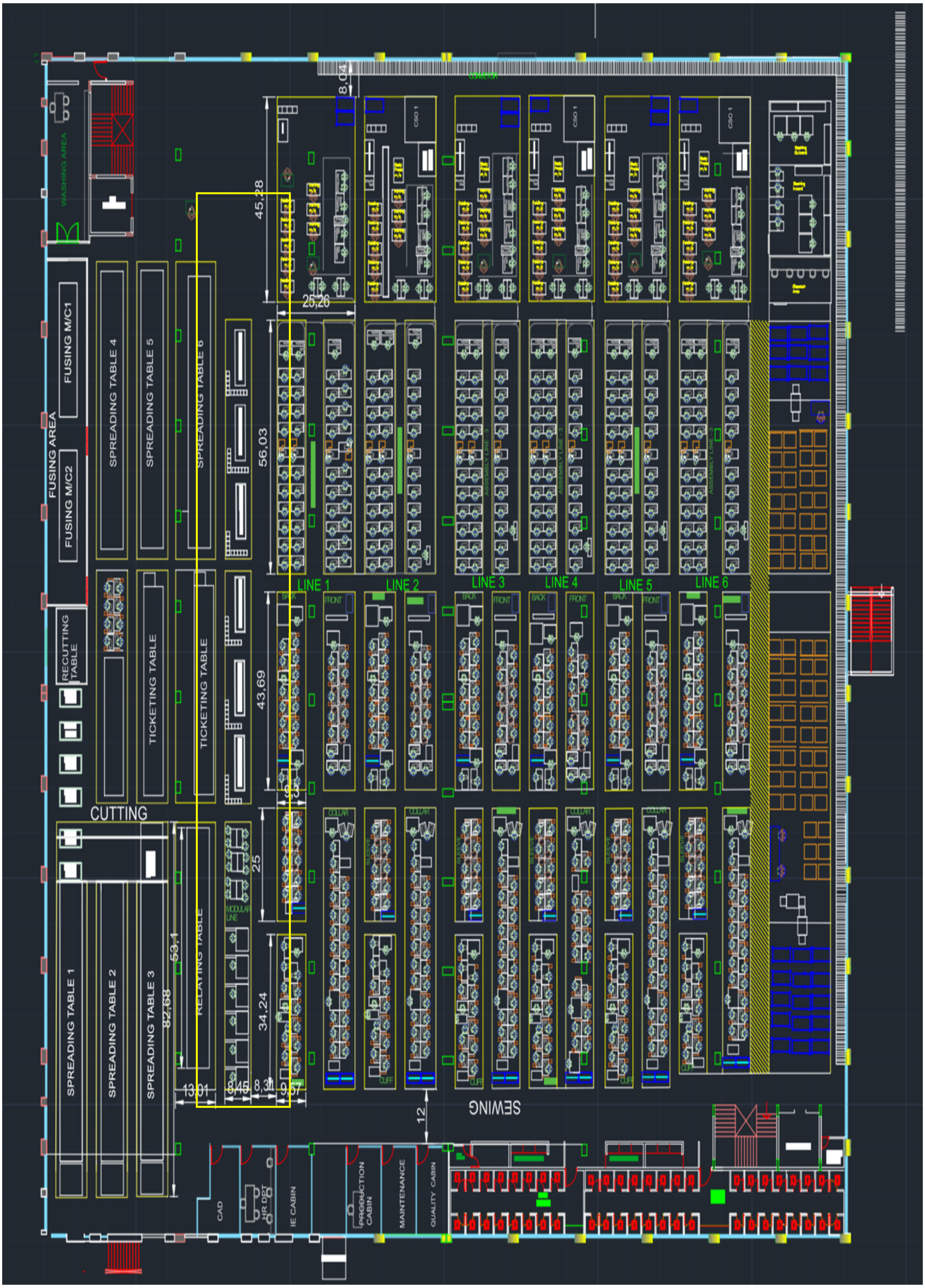

Figure 8: Layout after Pre-paratory line

Purpose:

To enable **preparation of semi-finished components** (like collar set, cuff attach) before loading to main line.
To reduce loading-time delays by ensuring parts are fully ready.
To minimize interruptions in the main sewing line during changeovers.
This change supports the **SMED principle of external activity management**, allowing multiple operations to be executed in parallel without disturbing the existing flow of production.

Benefits:

- Faster style transitions
- Improved line balancing and flow
- Reduced bottlenecks caused by incomplete part preparation
- Mechanic and operator time better utilized in advance

This modular preparatory line serves as a **buffer and readiness stage**, improving both efficiency and quality during style changeovers and day-to-day operations.

To further support efficient style readiness and reduce on-line disruptions, **factory-wise ideal areas** were introduced specifically for conducting **external activities** such as machine setup, folder attachment, and guide preparation. These designated zones allow mechanics to prepare idle machines and components in advance, without obstructing the ongoing operations of the main sewing lines.Previously, such setups were done on live lines or in ad-hoc locations, often causing **congestion, safety risks, and confusion**. By introducing clearly defined prep zones, machines required for upcoming styles could be shifted and set up in these areas, following proper SMED guideline

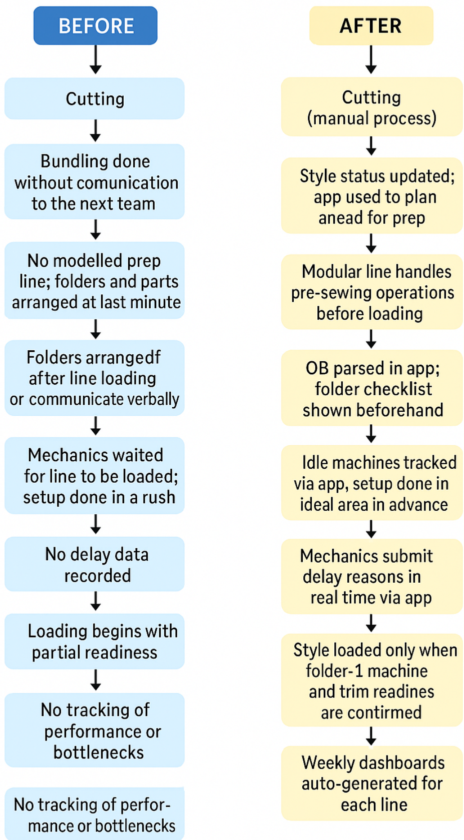

Figure 9: Before & After process change

7. Experimental Results

To evaluate the practical applicability and performance of the StitchGrid system, a pilot implementation was conducted in a controlled production environment simulating typical garment manufacturing conditions. The evaluation focused on assessing the platform's ability to optimize changeover operations in sewing lines by improving coordination, visibility, and task execution.

After implementing the proposed solution, measurable improvements were observed across multiple stages of the style readiness and changeover process. The results validated that digitization, lean planning, and real-time tracking significantly improved process efficiency and team coordination.

Before (Style A to Style B)

OPERATION	TIME TAKEN	REMARKS
Attach bone	5m 49s	MACHINE SETTING
Run Collar	6m 14s	QUALITY APPROVAL
Collar pointing	15m 48s	IERS - MACHINE TAKES TIME TO COOL DC
Top stitch collar	2m 5s	MACHINE SETTING
Collar bottom cutting	1m 8s	
Hem band	2m 11s	OPERATOR NOT AVAILABLE
Insert collar	6m 26s	MACHINE SETTING
Pick turn	4m 45s	IERS - SPARE PARTS NOT READILY AVAILA
Top stitch band	6m 39s	MACHINE SETTING
Trim base	0m 34s	
Notch & mark collar	2m 19s	INPUT DELAY
Pick iron	0m 31s	
Button hole on neck band	9m 21s	INPUT DELAY
Button stitch on neck band	14m 8s	MACHINE SETTING
Left Placket Iron	0m 12s	
Left Placket tack	1m 53s	
Right Placket Iron	3m 24s	INPUT DELAY
Right Placket tack	2m 21s	OPERATOR NOT AVAILABLE
Iron placket	0m 36s	
Pocket attach	6m 45s	QUALITY APPROVAL
Label Attach	4m 36s	
Button hole front X 6	21m 6s	MACHINE SETTING
Button sew front X 6	10m 12s	INPUT DELAY
Extra button sew X2	9m 9s	MACHINE SETTING
Tack Size Label	0m 7s	

Sew Main Label +Secondary label	23m 22s	MACHINE SETTING
Yoke Attach with tape	2m 6s	OPERATOR NOT AVAILABLE
Sew Rolling placket with tape	7m 19s	MACHINE SETTING
Sew pleats on Sleeve	4m 59s	QUALITY APPROVAL
Sleeve placket trim	0m 41s	
Big sleeve Placket Press	0m 41s	
Make sleeve box	5m 43s	MACHINE SETTING
Button hole X1	10m 14s	MACHINE SETTING
Button X1	7m 16s	MACHINE SETTING
Cuff hem	0m 7s	
Run cuff	3m 26s	MACHINE SETTING
Cuff raw edge trimming	0m 20s	
Cuff turning	32m 46s	HERS - MACHINE IS ARRANGED FROM SP NE,MECHANIC SHOW NO URGENCY FOR WORK, OPERATOR WAS NOT AVAILABLE
Iron cuff	0m 2s	
Topstitch cuff fused	7m 34s	QUALITY APPROVAL
Button hole X1	10m 14s	MACHINE SETTING
Button X2	8m 24s	QUALITY APPROVAL
Shoulder pressing	9m 30s	OTHERS - HEATING THE MACHINE
Set collar	5m 5s	MACHINE SETTING
Finish collar	8m 20s	INPUT DELAY
Set Sleeve with tape	6m 19s	MACHINE SETTING
Sleeve Top with tape	10m 13s	QUALITY APPROVAL
Press sleeve	14m 5s	OPERATOR NOT AVAILABLE
Side Seam with tape	13m 43s	QUALITY APPROVAL
Press side seam	11m 15s	OTHERS - MACHINE HEAT
Cuff attach	6m 52s	OPERATOR NOT AVAILABLE
Serge bottom	0m 46s	
Finish collar	8m 20s	INPUT DELAY

CHANGEOVER TIME: 46 m 51 s

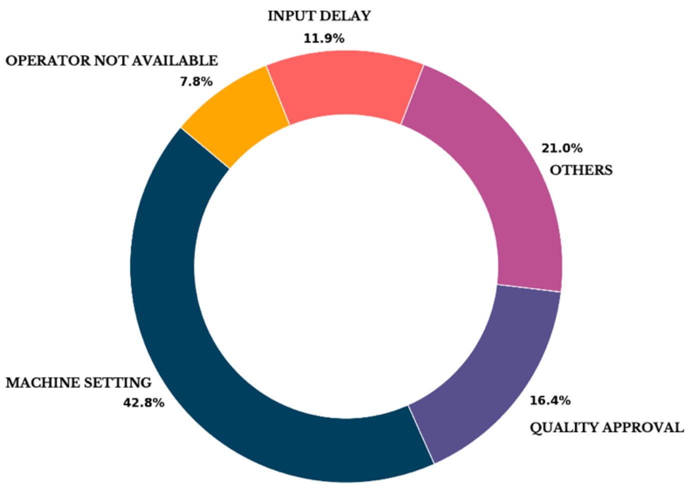

Figure 5.18: Changeover time delay reasons from Dressman to Aldeno

This chart shows that **machine setting delays alone account for over 42%** of total production delay time.
This was the **biggest bottleneck** in the pre-implementation phase.

Why machine setup time was too high:

1. Folder and Attachment Confusion
2. Manual communication
3. No tracking or accountability

After Implementation (Aldeno to PVH Van Heusen)

Following the successful pilot setup and digitization rollout, the **style changeover from Aldeno to PVH Van Heusen** was tracked using the new system. This transition marked the first full implementation of the app, including OB upload, checklist readiness, delay logging, and idle machine planning.

OPEARATION	TIME TAKEN	REMARKS
Attach bone	0m 27s	
Run Collar	1m 2s	
Collar pointing	2m 43s	QUALITY APPROVAL
Top stitch collar	0m 11s	
Collar bottom cutting	0m 41s	
Hem band	1m 41s	
Insert collar	2m 13s	QUALITY APPROVAL
Pick turn	0m 38s	INPUT DELAY
Top stitch band	1m 32s	OTHERS - OPERATOR CASUALITY
Trim base	0m 37s	
Notch & mark collar	4m 17s	QUALITY APPROVAL

Pick iron	1m 5s	
Button hole on neck band	10m 24s	INPUT DELAY
Button stitch on neck band	4m 0s	INPUT DELAY
Left Placket Iron	1m 46s	
Left Placket tack	2m 5s	
Right Placket Iron	2m 23s	INPUT DELAY
Right Placket tack	2m 3s	MACHINE SETTING
Iron placket	1m 36s	
Stitch tape to pocket	2m 54s	MACHINE SETTING
Pocket iron with fusing	2m 17s	QUALITY APPROVAL
Pocket hem	1m 44s	
Pocket attach	2m 7s	
Press pocket	4m 52s	INPUT DELAY
Washcare label Attach	2m 46s	MACHINE SETTING
Button hole front X 6	6m 18s	MACHINE SETTING
Button sew front X 6	1m 24s	
Tack Size Label	2m 34s	
Sew Main Label +Secondary label	7m 22s	INPUT DELAY
Yoke Attach with tape	1m 6s	
Sew Rolling placket with tape	1m 40s	
Sew pleats on Sleeve	7m 25s	QUALITY APPROVAL
Sleeve placket trim	0m 49s	
Big sleeve Placket Press	2m 3s	QUALITY APPROVAL
Make sleeve box	4m 38s	QUALITY APPROVAL
Button hole X1	2m 49s	INPUT DELAY
Button X1	4m 51s	INPUT DELAY
Cuff hem	0m 26s	
Run cuff	0m 42s	
Cuff raw edge trimming	0m 41s	
Cuff turning	0m 51s	
Iron cuff	1m 40s	

CHANGEOVER TIME: 14 m 52 s

Table 5.6: Changeover time from Aldeno to PVH NA

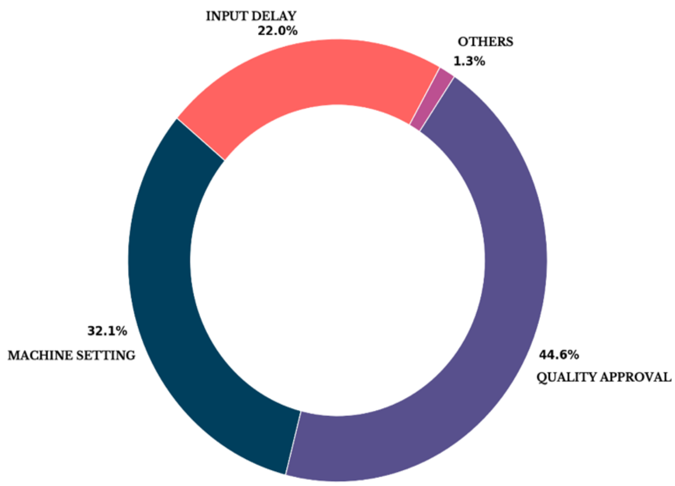

Figure 5.19: Changeover time delay reasons from Aldeno to PVH NA

What Went Right – Why Machine Setup Improved:
Digital OB access
Standardized folder requirements
Status & notifications
Better visibility = less confusion

Production Loss

Transition	Changeover Time	Target Time	Loss (Minutes)	Line Rate (Pieces/Hour)	Production Loss (in pieces)
DRESSMAN-ALDENO	47	10	37 min	189 pcs/hr	116 pcs
ALDENO-PVH VAN HUESAN	15	10	5 min	189 pcs/hr	15 pcs

Table 5.7: Production loss comparison

After implementing the digital changeover app, the production loss during changeover was reduced from **116 pcs** to just **15 pcs**, highlighting the drastic improvement in planning, machine readiness, and style preparation.

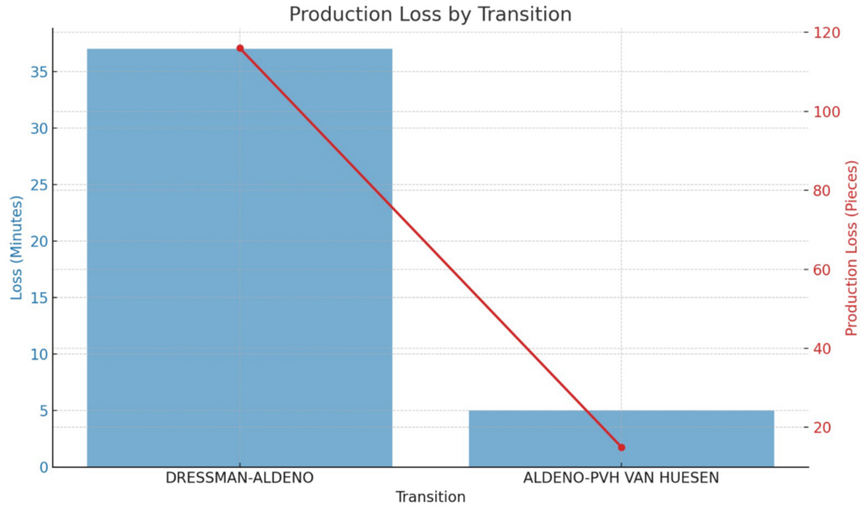

Figure 5.20: Production loss comparison bar chart

5.9 Cost Analysis

Metric	Dressman → Aldeno	ldeno → PVH Van Heus	Notes
Garment loss (pcs)	**116**	**15**	Unproduced pieces during. change-over delay
Standard minute value (SMV)	25 min/pc	30 min/pc	IE rating sheets
Total labour minutes lost	116 × 25 = **2900 min**	15 × 30 = **450 min**	pcs × SMV
Line cost per minute (₹)	3.13	3.13	see cost model below
Cost of loss (₹)	2 900 × 3.13 = **9 078**	450 × 3.13 = **1 409**	Idle labour + factory OH
Incremental saving		**₹ 7 669 per change-over**	9 078 – 1 409
Average change-overs / month		4	Historical planning
Monthly saving potential		**₹ 30 676**	7 669 × 4

Table 5.8: Cost Analysis Table

Line-cost model (basis for ₹ 3.13 per minute)

Input	Value	Derivation
Manpower on line	120 heads	machinists + 35 helpers/(
Average wage	₹ 15000 / month	HR payroll
Total wage bill	₹ 15000 × 120 = ₹ 1800000 / month	
Working days / month	25	factory calendar
Wage per day	₹ 1 800 000 / 25 = ₹ 72 000	
Available minutes / day	540	9-h shift (including breaks
Observed line efficiency	50 %	IE tracker
ost per productive minu	72 000 / (540 × 0.50) ≈ **₹ 3.13**	

Table 5.9: Line Cost per minute Table

5.10. Summary of Key Results

Changeover Time Reduction:
Across multiple style transitions in Lines 7 and 8, the average changeover time decreased by around **40–50%** after implementing Stitch Grid.

Targeted Delay Minimization:
Delays due to machine setup, material readiness, and operator availability—identified through Pareto and root-cause analysis—were significantly reduced, demonstrating the effectiveness of focused interventions.

Statistical Validation:
A one-sample t-test confirmed that the observed mean changeover loss (~70 minutes) was statistically greater than the 10-minute SMED target at a 95% confidence level, thereby validating the need for systemic optimization.

Positive User Feedback:
Supervisors and operators reported improved task visibility, better coordination across departments, and increased confidence in changeover planning—all of which align with the quantitative improvements.

Altogether, the results demonstrate that StitchGrid not only delivers measurable reduction in changeover time and delays, but also enhances workforce coordination and process accountability—key steps toward leaner, Industry 4.0–aligned garment manufacturing.

6.Conclusion

The implementation of StitchGrid led to a substantial 40–50% reduction in changeover durations across both Line 7 and Line 8, demonstrating its effectiveness in streamlining operations. By specifically targeting the most significant delay factors—machine setup, material readiness, and operator availability—identified through Pareto and root-cause analyses, StitchGrid directly addressed the core inefficiencies in the changeover process. The significance of these improvements was statistically validated through a one-sample t-test ($t = 3.60$, $df = 6$, $p \approx 0.024$), confirming that average changeover losses (~70 minutes) were definitively higher than the SMED benchmark of 10 minutes. Additionally, feedback from supervisors and operators highlighted improved task visibility, smoother coordination, and greater confidence during changeovers, further reinforcing the quantitative outcomes. Altogether, these results confirm that StitchGrid not only delivers measurable operational gains but also enhances cross-functional collaboration and accountability—creating a solid foundation for evaluating its economic feasibility.

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