Research Article

Integration of digital lean principles and line balancing in apparel manufacturing

Abstract

Purpose: The integration of digitalization into the apparel manufacturing sector has become a strategic imperative, providing companies with a unique competitive edge. This study explores the application of ITEX PMD, an Internet of Things (IoT) data collection device, and evaluates the ITEX digital line balancing program within the context of digital lean management. By leveraging real-time data tracking, big data utilization, and advanced data analysis techniques, companies aim to enhance flexibility, agility, and operational efficiency in their manufacturing processes.

Design/methodology/approach: This research delves into operational definitions for men's hoody sweatshirts, detailing the types of machines used, specifying standard task times, and elucidating the precedence relations of operations. The study utilizes ITEX PMD as a real-time production data collection device, generating periodic line reports through the associated software program.

Findings: The ITEX digital line balancing program shows promise in assisting shop floor managers to optimize sewing lines with efficiency and seamlessness, contributing to overall operational excellence. The program provides another layer of visibility into the factory, reducing non-value-added activities, and improving efficiency. The ITEX Soft algorithm facilitates an ideal assembly line layout, ensuring a balanced workload among workstations, aligned with the continuous flow principle in the sewing line.

Originality/value: This shop floor and software solution not only enhance visibility but also offer a practical means to reduce non-value-added activities, thereby improving overall efficiency. The ITEX Soft algorithm emerges as a valuable tool, contributing to a more balanced workload among workstations and optimizing assembly line layout. This study sheds light on the potential of digital lean principles in reshaping manufacturing processes and fostering operational excellence in the apparel industry.

Keywords: apparel industry, lean management, digitalization, real time production monitoring, line balancing

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Introduction

The dynamic and rapidly evolving nature of the apparel industry, driven by changing customer demands, compels businesses to innovate and find solutions that maintain a competitive edge and improve operational efficiency. In this context, the strategic importance of sewing line balancing has become prominent, especially in the pursuit of operational excellence in apparel production. Sewing line balancing is a critical tool in lean manufacturing, with the aim of reducing bottlenecks, distributing work evenly among workstations, and optimizing resource utilization. Lean manufacturing principles emphasize waste reduction, eliminating imbalances between workstations, and a commitment to continuous improvement.[1]

Lean processes emerge as a practical solution, providing the ability to produce efficiently in smaller quantities across diverse production environments. Recognized as a methodology for maximizing customer value while minimizing waste, lean aims to enhance effectiveness, flexibility, and profitability.[2] This methodology is adaptable and applicable across various organizational structures and processes.

The Industry 4.0 initiative, originating from a 2011 German government strategy, envisions a high-tech future, integrating digitalization into production processes. This initiative leverages advancements in the Internet of Things (IoT) and information technology, emphasizing the fusion of physical systems with software.[3] Key technological trends underpinning Industry 4.0 include Big Data, IoT, Cloud Computing, Artificial Intelligence (AI), and more.

Continuous data collection through sensors on machines, GPS, or RFID is integral to Industry 4.0, but the significance goes beyond mere data accumulation. Comprehensive analysis and processing are imperative for informed decision-making at every stage of production. Recent advancements in lean management and digitization focus on leveraging digital tools to eliminate the seven types of waste and strengthen the implementation of lean methodologies. The synergy of digital trends presents significant potential for enhancing lean processes and tools, leading to the emergence of Digital Lean—an influential amalgamation that integrates Industrial IoT technology with manufacturing software.

Digital Lean provides real-time insights into operations, amplifying the effectiveness of fundamental lean tools such as kanban, heijunka, line balancing, and poke yoke.[4] The digitization of lean processes streamlines the tracing and measurement of production facilities. With real-time data tracking, big data, and advanced data analysis techniques, instantaneous monitoring of basic performance becomes possible.

The ITEX PMD, developed by ITM Tech Soft, is an IoT production tracking module that showcases the seamless fusion of digitization and lean processes. This module facilitates instantaneous measurement and transmission of operational data to the ITEX SOFT cloud network. Offering immediate visibility, it provides insights into the efficiency of each operation, operator performance, downtime, and defect quantities. The ITEX PMD empowers employees by delivering instant feedback, enabling operators to manage their pace, assess efficiency, and communicate alerts to supervisors or maintenance when necessary.

Essentially, providing operators and teams with feedback (data) cultivates empowerment and motivation, aligning them with department and company goals. The ITEX Soft algorithm further contributes to an optimized machine layout and a more balanced workload among workstations, adhering to the continuous flow principle in the assembly line. This integration of digital lean processes represents a transformative approach to enhancing manufacturing operations in the apparel industry.

Research study

This study focuses on ABC Company, a prominent knitted garment manufacturer located in Bartin, Turkey. Established in 2005, the company specializes in the production of knitted garments, boasting an annual production capacity of 1,200,000 pieces. With 800 employees, ABC Company actively engages in manufacturing operations and exports finished garments to various European countries.

In pursuit of operational excellence, ABC Apparel has initiated a lean transformation, incorporating digital tools to streamline its processes. A shop floor control device, based on the Internet of Things (IoT), has been implemented within the factory premises to monitor sewing line processes comprehensively. This IoT device enables real-time tracking of workstations and measures key performance indicators (KPIs) for each production unit. The ITEX PMD device and ITEX Software program were specifically employed for data collection, as depicted in Figure 1 and Figure 2.

Figure 1 ITEX PMD shop floor device.

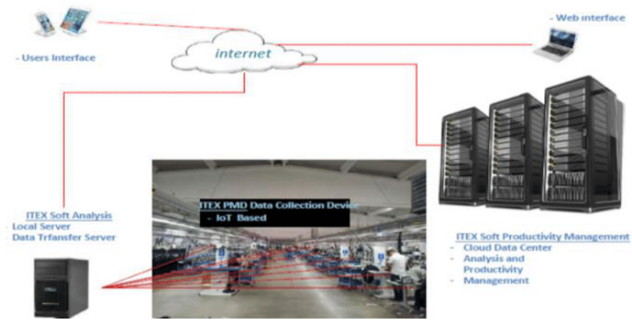

Figure 2 ITEX software management program.

Focus of the study

The primary focus of this investigation is the implementation of digital lean practices within ABC Apparel, with a specific emphasis on the stitching processes involved in the production of a knitted men's hoody sweatshirt. Illustrated in Figure 3, this case study serves as a practical demonstration of how digital lean methodologies enhance operational efficiency.

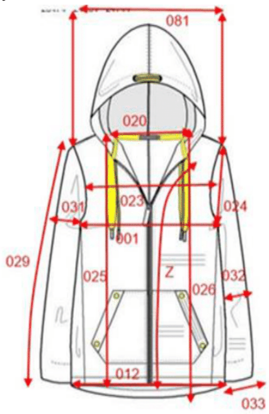

Figure 3 Hoody sweatshirt model.

Data collection and tools

For the study's purposes, the ITEX PMD device and ITEX Software program were utilized to capture necessary measurements and data. These tools facilitate a comprehensive understanding of the impact of digital lean implementation on ABC Company's sewing processes.

Case study overview

Table 1 provides detailed insights into the sewing operations for the knitted hoody sweatshirt. It outlines the types of machines utilized, standard task times, and the precedence relations between various operations. This detailed overview lays the foundation for a thorough exploration of how digital lean implementation influences the efficiency and productivity of ABC Company's sewing processes.

Table 1 Operation names, machine types, standard times of each task and precedence relations of operations for the sweatshirt style

Task number	Operation	Machine type	SMV	Precedence
1	Hood parts attachments	Overlock	0,267	0
2	Hood lock stitch	Lock stitch	0,275	1
3	Hood lining attachments	Overlock	0,283	2
4	Hood lining stitch	Overlock	0,296	3
5	Eyelet machine	Eyelet	0,256	4
6	Hood lock stitch	Lock stitch	0,833	5
7	Hood fixing	Lock stitch	0,550	6
8	Hood overlock	Overlock	0,303	7

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Table 1 Continued...

Task number	Operation	Machine type	SMV	Precedence
9	Front ironing	Iron	0,367	0
10	Pocket fusing	Iron	0,678	0
11	Pocket overlock	Overlock	0,330	10
12	Pocket lock stitch	Lock stitch	0,290	11
13	Pocket preparation	Iron	0,599	12
14	Pocket upper lock stitch	Lock stitch	0,460	13
15	Locker preparation ironing	Iron	0,432	14
16	Pocket part control	Manuel	0,207	15
17	Pocket join to front	Lock stitch	0,950	9,16
18	Shoulder stitch	Overlock	0,279	17
19	Sleeve joining	Overlock	0,450	18
20	Side joining	Overlock	0,900	19
21	Sleeve cover stitch	Cover stitch	0,633	20
22	Hem lock stitch	Lock stitch	0,252	21
23	Hem cover stitch	Cover stitch	0,317	22
24	Hood join to body	Overlock	0,366	8,23
25	Zipper piping	Cover stitch	0,275	24
26	Zipper edge fixing	Lock stitch	0,288	25
27	Front zipper baby to overlock	Overlock	0,550	26
28	First zipper join	Lock stitch	0,496	27
29	Second zipper join	Lock stitch	0,825	28
30	Front souffle stitch	Overlock	0,314	29
31	Zipper covering lock stitch	Lock stitch	0,667	30
32	Neck piping	Cover stitch	0,463	31
33	Neck piping stitch	Lock stitch	0,331	32
34	Label join	Lock stitch	0,553	33
35	Second zipper stitch	Lock stitch	0,369	34
36	First zipper stitch	Lock stitch	0,367	35
37	Zipper lock stitch	Lock stitch	0,579	36
38	Rivet machine	Rivet	0,311	37
39	Care label join	Lock stitch	0,317	38
40	In line ironing	Iron	0,366	39
41	Ironing	Iron	0,1000	40
42	Final control	Manuel	0,366	41
			19010	

Methodology and procedures

ITEX PMD: A catalyst for digital lean practices in garment manufacturing

ITEX PMD, serving as an integral Internet of Things (IoT) data collection device, seamlessly integrates into the fabric of garment manufacturing processes. Its user-friendly setup allows for efficient installation on each machinery unit within the factory, with operators being assigned through RFID cards, thereby establishing an organized and streamlined workflow. Functioning as a shop floor control device, it captures real-time data from machines and operations through IoT technology. The collected data is then securely stored in the cloud, creating a robust data pool that can be seamlessly integrated into the appropriate software program. In essence, the ITEX PMD stands as a pivotal initial step in the digitalization journey of garment manufacturing processes.

The ITEX PMD data collection device is equipped with performance-led lights at the top and quality-led lights at the bottom. LED color and behavior settings customization occurs through an intuitive interface on the device's screen. The device accommodates the configuration of minimum and maximum range values for "Performance" and "Repair" metrics, with three LED light modes: fixed, flashing, and off. This dynamic functionality transforms the ITEX PMD into a personalized andon system, actively alerting operators and line supervisors to pertinent performance and quality concerns, fostering an environment conducive to effective line balancing.

Within the broader spectrum of manufacturing Key Performance Indicators (KPIs), the Overall Equipment Efficiency (OEE) stands as an unparalleled metric for assessing production process efficiency. Recognizing that productivity gains stem from OEE loss reduction, the ITEX PMD facilitates direct measurements of availability, performance, and quality rates. As delineated in Table 2, these precise measurements provide invaluable insights into monitoring and enhancing the overall efficiency of garment manufacturing processes.

Availability: The availability of production equipment is critical to the success of a manufacturing operation. Thus, availability refers to the percentage of scheduled time that a machine is available to handle its task. This metric deals with losses related to downtime caused by malfunctioning equipment, shortages of materials, employees changing shifts, or any other disruptive events. To calculate an availability percentage, divide the amount of operating time by the planned production time during a given period.

$$Availability = \frac{Operating\ time}{Net\ available\ time} \quad (1)$$

"Operating time" is the net available time minus all other downtime (i.e., breakdowns, setup time and maintenance). "Net available time" is the total scheduled time minus contractually required downtime (i.e., paid lunches and breaks).

Performance: The performance metric measures losses related to the speed of the production line. It may vary widely over time depending on the types of products you produce. Generally speaking, however, poor performance outcomes are often related to operator inefficiencies, old or inadequate machines, and the use of low-quality raw materials. On the other hand, performance considers the speed at which a manufacturing process is being run. When applied to machines, it considers the speed at which a machine works compared to the optimal speed the machine was designed to achieve. A 100% performance score means the manufacturing process or machine is working at its optimal running capacity.

$$Performance\ Rate = \frac{Ideal\ cycle\ time \times total\ pieces\ run}{Operating\ time} \quad (2)$$

Quality: The final metric in the calculation is the quality score. Quality deals with losses incurred due to goods not passing quality checks. This includes goods that are downgraded or reworked. A quality percentage can be determined by dividing the number of quality-approved units produced by the total number of units produced during a set period.

$$Quality\ Rate = \frac{Total\ pieces\ run - defects\ number}{Total\ pieces\ run} \quad (3)$$

Defects number is the total number of pieces scrapped, reworked, repaired, returned or downgraded.

To calculate OEE, we use formula (4).

$$OEE = Availability \times Performance \times Quality\ Rate \quad (4)$$

In summation, the ITEX PMD emerges as a sophisticated and multifaceted tool that not only captures real-time data for analysis but also serves as an alert system, contributing to the evolution of digital lean practices within the garment manufacturing landscape. Its capacity to seamlessly integrate into existing processes while providing rich and actionable data exemplifies its transformative potential within the broader framework of Industry 4.0 and lean manufacturing methodologies.

Indeed, from the data presented in Table 2, we can derive the key performance indicators (OEE) for the garment manufacturing process at ABC Company.

Availability: 84.90%

Line Performance: 65%

Quality Rate: 94%

To calculate the Overall Equipment Efficiency (OEE), we can use the formula (4):

OEE=84.90%×65%×94%

OEE=84.90%×65%×94%=51.87%

Table 2 Periodic line report for the mens' hoody sweatshirt

ABC APPAREL

Periodic Line Report

Üretim Hattı	Hat Üretim Verimliliği	Hat Verimliliği	Line Performance	Availibility	Üretim Adet	Maliyet (TL)	Ciro (TL)	Kar / Zarar	Fabrika K.K.Z	Fabrika Kaynaklı K.Z. %	Kişi K.K.Z	Kişi Kaynaklı K.Z. (%)
BANT 07	82%	56%	65%	84,90%	5.300	0	0	0	16.619	10,81%	5.613	3,65%

Sipariş No	Model Adı	STD	Kesim Adet	Toplam Üretim Miktarı	Sipariş Tamamlanma Oranı (%)	Üretim Adet	Kalite Adet	1. Kalite	First Quality	2.Kalite	2. Kalite (%)	Tamir	Tamir Oranı(%)	Günlük Ciro
319396 KOLL-3 / 3119557	319396 KOLL-3	23,725	13.642	6.201	45%	5.280	5.280	5.278	94%	2	0%	347	6%	0
319396-222703 / 3119557	319396-222703	23,939	539	400	72%	20	20	20	94%	0	0%	0	0%	0
						5.300	5.300	5.298	94%	2	0%	347	6%	0

Defect Report

Sipariş No	Model	Üretim Adet	2. Kalite	2.Kalite (%)	Adet	Oran %	Baskı Defo Adet	Baskı Defo Oran %	Dikim Defo Adet	Dikim Defo Oran %	Kumaş Defo Adet	Kumaş Defo Oran %	Nakış Hata Adet	Nakış Hata Oran %	Toplam
319396 KOLL-3 / 3119557	319396 KOLL-3	5280	2	0 %			0	0 %	0	0 %	2	100 %	0	0 %	2
319396-222703 / 3119557	319396-222703	20	0	0 %	0										0
Toplam					0		0	0 %	0	0 %	2	100 %	0	0 %	2

Repair Report

Sipariş No	Model	Üretim Adet	Tamir Adet	Tamir (%)	El Tamiri Adet	El Tamiri Oran %	Jut Adet	Jut Oran %	Leke Adet	Leke Oran %	Overlok Tamiri Adet	Overlok Tamiri Oran %	Reçme Tamiri Adet	Reçme Tamiri Oran %	Renk Farkı Adet	Renk Farkı Oran %	Singer Tamiri Adet	Singer Tamiri Oran %	Ütü Hatası Adet	Ütü Hatası Oran %	Toplam
319396 KOLL-3 / 3119557	319396 KOLL-3	5280	347	6 %	10	3 %	19	5 %	23	7 %	23	7 %	49	14 %	2	1 %	212	61 %	9	3 %	347
Toplam					10	3 %	19	5 %	23	7 %	23	7 %	49	14 %	2	1 %	212	61 %	9	3 %	347

Loss Time Report

Kayıp Zaman Adı	Fabrika K.K.Z	Fabrika Kaynaklı K.Z. %	Kişi K.K.Z	Kişi Kaynaklı K.Z. (%)
Doktor	0	0,00%	47	0%
Hat Kurulumu	44	0,20%	0	0%
Belirsiz İzin	0	0,00%	2690	12%
Operasyon Değişikliği	4643	20,88%	0	0%
Ek İş	10771	48,45%	0	0%
Kırık İğne Arıza	0	0,00%	8	0%
Makine Arıza	36	0,16%	0	0%
İş Bekleme	7	0,03%	0	0%
Tamir(Fabrika Kaynaklı)	1118	5,03%	0	0%
Erken Çıkış	0	0,00%	1731	8%
Kişisel İzin	0	0,00%	1137	5%
	16.619	75%	5.613	25%

Therefore, the calculated OEE for ABC Company's garment manufacturing process is approximately 51.87%. This metric offers a comprehensive assessment of the overall efficiency, taking into account availability, line performance, and quality rate. Continuous monitoring and improvement in these areas can further enhance the OEE, contributing to increased productivity and operational excellence.

Digital line balancing program

The visual representation in Figure 4 distinctly illustrates the task duration of each operator in comparison to the cycle takt time. A noticeable incongruity is evident, with certain operators managing heavier workloads while others handle lighter tasks. This observed disparity underscores the critical necessity for a comprehensive line balancing initiative aimed at equitably distributing the workload among operators.

Line balancing, integral to lean manufacturing, focuses on optimizing task allocation throughout the production line. By ensuring a more balanced distribution of workload, line balancing improves efficiency, minimizes idle time, and mitigates the risk of bottlenecks. In the context of Figure 4, the objective is to synchronize the task times of operators with the cycle takt time, fostering a smoother and more harmonized workflow.

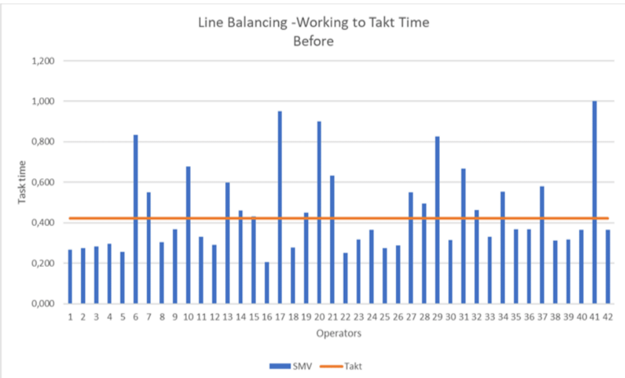

Figure 4 Operator's task time to cycle takt time (Before line balancing).

Strategic adjustments in task assignments, coupled with potential process optimizations, can be explored to achieve an optimal line balance. This not only maximizes the utilization of available resources but also contributes to the overall effectiveness of the production line. A balanced line not only enhances productivity but also aligns with the principles of lean manufacturing, promoting a more responsive and agile operational framework.

In essence, the insights derived from Figure 4 serve as a catalyst for proactive measures, instigating a deliberate line balancing strategy. Consequently, the garment manufacturing process at ABC Company can strive to achieve a more synchronized and efficient operational flow, ultimately fostering heightened productivity and competitiveness in the industry.

The enhancement of sewing line efficiency, conceptualized with "stations" representing employees and assuming no machine restrictions, is systematically achieved through dedicated software. The step-by-step process for minimizing cycle time and optimizing the production line is outlined below:

1) **Setting optimization ınterval:** The user inputs either the "Daily Customer Demand" or the "Total Number of Operators" as the optimization interval. This crucial parameter allows the program to calculate the most effective cycle time for the optimization process.
2) **Defining operation sequences:** Operations are sequenced according to the workflow, emphasizing the constraint that one operation cannot commence until the completion of its predecessor. Accurate definition of dependent operations is imperative for the correctness of the optimization calculation.
3) **Initiating calculation:** Once the parameters are established and operation sequences defined, the user triggers the calculation process by clicking the designated button within the software interface. At this stage, the program conducts intricate calculations to determine tasks assigned to stations, total working time for these tasks, hourly production capacity of the line, and the overall efficiency achieved through optimization.

This systematic approach, facilitated by dedicated software, ensures a methodical optimization of the sewing line, leading to minimized cycle times and heightened production line efficiency.

This optimization is based on the following line balancing calculations given below:

$$Cycle\,Takt\,Time = \frac{Daily\ working\ hours\left(min\right)}{Daily\ Production\,Target} \tag{5}$$

$$Number\ of\ Operator\ \ for\ operation = \frac{Operation\ standard\ time}{Cycle\,Time} \tag{6}$$

$$Daily\,Production\,of\ operation = Number\ of\ operator * \left(\frac{Daily\ working\ hour}{Standard\ time\,of\ operation}\right) \tag{7}$$

$$Line\ Efficiency = \frac{Sum\ of\ SMV}{Actual\ Number\ of\ work\ stations \times Cycle\,time} \tag{8}$$

The utilization of a Digital Line Balancing Program proves instrumental in achieving efficiency and productivity in the sewing line, specifically for the sweatshirt style. Let's recap and elaborate on the key parameters and outcomes:

I. **Daily Working Time:** A total of 570 minutes is allocated for daily operations, representing the available time for the manufacturing process.

II. **Daily Customer Demand:** The daily production target or customer demand is set at 1350 pieces, reflecting the quantity sought to meet market requirements.

III. **Cycle Takt Time:** Calculated using Formula (5), where the Cycle Takt Time is derived by dividing the daily working time by the daily customer demand:

$$Cycle\,Takt\ Time = \frac{570\,min}{1350\ pcs} = 0.422\,min\ /\ \ pcs$$

This Cycle Takt Time serves as a benchmark, representing the targeted time frame for the production of each sweatshirt style unit.

IV. **Average Operators' Performance Rate:** Acknowledged at a commendable 75% for the sewing line, this metric underscores the anticipated proficiency of the workforce in completing assigned tasks. It is a key determinant in assessing the overall efficiency of the sewing line.

Table 3 furnishes a comprehensive overview of the optimized sewing line subsequent to the implementation of the digital line balancing algorithm. In this post-optimization context, 65 operators actively participate, and the algorithm is purposively structured to achieve the minimum cycle time, thereby amplifying the overall operational efficiency within the garment manufacturing process.

Citation: Bülent KOC, Selin HE. Integration of digital lean principles and line balancing in apparel manufacturing. *J Textile Eng Fashion Technol.* 2024;10(1):1‒9.
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Table 3 Digital line balancing report

Number of operators	Machine	Operation	Optimization time	Optimization percentage
1-2	Lock stitch	Hood edge stitch	9.500	%100
3	Lock stitch	Hood fixing stitch	9.500	%100
4	Iron	Front ironing	9.500	%100
5-6	Lock stitch	Pocket fusing	9.500	%100
7	Overlock	Pocket parts attached	9.500	%100
8-9	Iron	Pocket prep. Ironing	9.500	%100
10	Lock stitch	Pocket upper stitch	9.500	%100
11-12	Lock stitch	Pocket joining	9.500	%100
13	Overlock	Sleeve joining	9.500	%100
14-15	Overlock	Side joining	9.500	%100
16	Cover stitch	Sleeve cover stitch	9.500	%100
17	Overlock	Hood joining	9.500	%100
18	Overlock	Front zipper baby overlock	9.500	%100
19	Lock stitch	First zipper joining (70cm)	9.500	%100
20-21	Lock stitch	Second zipper joining (70cm)	9.500	%100
22-23	Lock stitch	Zipper covering stitch	9.500	%100
24	Cover stitch	Neck piping join	9.500	%100
25	Lock stitch	Neck piping stitch	9.500	%100
26	Lock stitch	Label join	9.500	%100
27	Lock stitch	Right zipper stitch	9.500	%100
28	Lock stitch	Left zipper stitch	9.500	%100
29	Lock stitch	Zipper lock stitch	9.500	%100
30	Iron	In-line iron	9.500	%100
31-33	Iron	Ironing	9.500	%100
34	Manuel	Final control	9.500	%100
35	Overlock	Hood attached	7.872	%82
	Iron	Front ironing	1.320	%13
35 Total			9.192	%95
36	Lock stitch	Pocket stitch	0.990	%10
		Hood lock stitch	8.108	%85
	Lock stitch total		9.098	%95
	Overlock	Pocket part attached	0.229	%2
36 Total			9.327	%97
37	Lock stitch	Pocket part stitch	8.550	%90
38	Overlock	Hood lining stitch	8.344	%87
39	Overlock	Hood lining attached	8.727	%91
40	Iron	Pocket prep. Ironing	8.161	%85
41	Eyelet	Eyelet	7.548	%79
42	Lock stitch	Hood stitch	5.560	%58
43	Lock stitch	Hood fixing stitch	6.716	%70
44	Overlock	Hood stitch	8.933	%94
45	Lock stitch	Pocket upper stitch	4.062	%42
	Iron	Pocket ironing	3.237	%34
45 Total			7.299	%76
46	Overlock	Pocket part preparation	6.103	%64
47	Lock stitch	Pocket joining	9.010	%94
48	Overlock	Shoulder join	8.226	%86
49	Overlock	Sleeve join	3.768	%39
50	Overlock	Side joining	7.536	%79
51	Cover stitch	Sleeve cover stitch	9.163	%96
52	Lock stitch	Hem edge stitching	7.430	%78
53	Cover stitch	Hem stitch	9.346	%98
54	Overlock	Hood joining	1.291	%13
	Cover stitch	Zipper piping	8.108	%85
54 Total			9.399	%98

Table 3 Continued...

Number of operators	Machine	Operation	Optimization time	Optimization percentage
55	Lock stitch	Zipper edge stitch	8.491	%89
56	Overlock	Front zipper overlock	6.716	%70
57	Lock stitch	First zipper joining (70cm)	5.124	%53
58	Lock stitch	Second zipper joining (70cm)	5.324	%56
59	Overlock	Front souffle stitch	9.258	%97
60	Lock stitch	Neck piping stitch	0.259	%2
		Front zipper stitch	0.666	%7
	Lock stitch total		0.925	%9
	Cover stitch	Neck piping	4.151	%43
60 Total			5.076	%52
61	Lock stitch	Label join	6.804	%71
		Right zipper stitch	1.379	%14
	Lock stitch total		8.183	%85
62	Lock stitch	Front zipper stitch	7.571	%79
		Left zipper stitch	1.320	%13
	Lock stitch total		8.891	%92
63	Rivet	Rivet	9.169	%96
64	Lock stitch	Label join	9.346	%98
65	Manuel	Final control	1.291	%13
	Iron	In-line iron	1.291	%13
		Ironing	0.984	%10
	Ironing total		2.275	%23
65 Total			3.566	%36

The Digital Line Balancing Program, by optimizing work stations and rates, ensures tasks are allocated judiciously, minimizing idle time and maximizing overall productivity. This strategic approach, supported by advanced algorithms and digital tools, fosters continuous improvement and efficiency enhancement in garment manufacturing processes. The comprehensive overview provided by Table 3 serves as a roadmap for achieving a synchronized, streamlined, and productive sewing line, aligning ABC Company with industry best practices and fostering competitiveness in the dynamic apparel landscape.

Figure 5 provides a visual representation of the time optimization percentage for each operator. A comparative analysis with the data presented in Figure 4 reveals an improved distribution of workload among operators following the implementation of digital line balancing. However, discernible unevenness still persists within the sewing line, suggesting the need for further enhancements through kaizen initiatives.

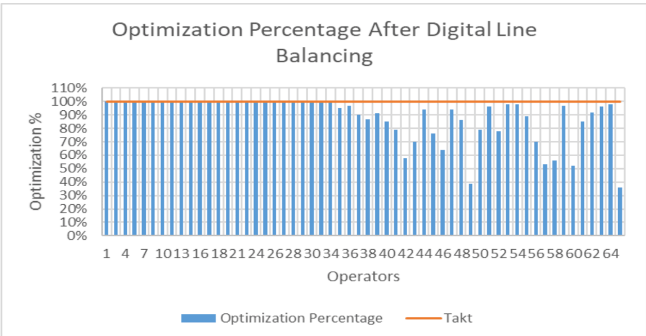

Figure 5 Line balancing chart based on digital line balancing results.

It is evident that achieving a high optimization rate necessitates ongoing improvement efforts. Kaizen, as a continuous improvement philosophy, becomes instrumental in addressing the remaining disparities in the sewing line. Implementation of kaizen methodologies involves training operators in new processes, identifying high-performing individuals, and strategically assigning them to roles that align with their strengths. Such interventions are pivotal in achieving optimal efficiency in the line balancing process.

The Digital Line Balancing (DLB) algorithm plays a pivotal role in the optimization of workstations within a production line. This process involves the strategic redesign of workstations, utilizing task times for individual operations and considering the cycle takt time within a cell layout design. The core principles guiding cell layout design in both DLB algorithms include:

a) **Undisturbed work flow sequential:** Ensuring a smooth and uninterrupted flow of work sequences.

b) **Counterclockwise flow:** Structuring the workflow to follow a counterclockwise direction.

c) **Proximity of sewing machines:** Placing sewing machines in close proximity to enhance operational efficiency.

d) **Placement of last operation:** Positioning the last operation in close proximity to the first operation, often adopting a U or C shaped cell configuration for optimal flow.

e) **Strategic placement of best operators:** Assigning the most skilled operators to the initial and final operations of the line.

f) **Utilization of multi-skilled operators:** Incorporating multi-skilled operators to balance the cell and enhance flexibility.

The successful integration of these principles into the cell layout design ensures the development of a cohesive and optimized sewing line. ABC Company, by implementing the DLB technique, aims to achieve a line configuration aligned with industry best practices. This strategic approach not only promotes efficient workflows but also maximizes the utilization of human resources. The iterative nature of these approaches highlights ABC Company's commitment to continuous improvement and operational excellence within the garment manufacturing process.

Conclusion

Implementing ITEX PMD as a shop floor control technology represents a valuable step in enhancing manufacturing processes; however, a holistic approach is essential for satisfactory results. Focusing solely on technology neglects the integral role of efficient processes, a prerequisite for successful digital implementations. The coexistence of Industry 4.0 and Lean principles is crucial, emphasizing the need to combine Lean and 4.0 technology in garment production to achieve an efficient and optimized production process.[5]

Real-time shop floor control, facilitated by technologies like ITEX PMD, empowers management with data for real-time risk assessment. Through full interaction with the software program, management gains the ability to monitor the factory floor, enabling quicker and better decision-making at the right time.[6] Implementing digital lean management, considering the aforementioned improvements, can result in a substantial 10-30% improvement in productivity and cost efficiency.

Digital Line Balancing (DLB) plays a pivotal role in helping shop floor management achieve higher productivity and reduce lead times by eliminating wasted time in the production line. Digital algorithms enable line managers or supervisors to optimize sewing lines more quickly and effectively, requiring less setup time and facilitating the assignment of the most efficient operators based on work content. Allocating skill or semi-skilled workers to the right positions contributes to higher productivity. Digital lean apparel companies are encouraged to implement cross-training programs for line operators, fostering adaptability to changes in customer demand, with standardized work practices ensuring efficient performance.[8–26]

ITEX SOFT plays a crucial role in assisting supervisors in optimizing assembly lines for high productivity in a short time frame. It is strongly recommended to include criteria such as skill levels of operators, performance rates, and machine types in this program. Developing algorithms that automatically assign the right operators to specific tasks and provide optimal proposals for sewing lines represents a key area for improvement.

Achieving line balancing is envisioned at a cycle takt time between the lowest and highest task times. The development of a new algorithm is proposed to determine the best takt time, achieving the highest line efficiency within the specified range of the number of workers. Following digital takt time calculation, operations are assigned to newly designed workstations based on the positional weight of operations, machine types, and operators' performance.[7] The main idea is to ensure that algorithms are supported by user-friendly software for the garment industry, seamlessly integrated into companies' ERP programs, facilitating efficient workflow management and adherence to industry standards.

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Conflicts of interest

Authors declare that there is no conflict of interest.

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