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Improving the Efficiency and Warning the Blockage in the Surface Mount Technology Product Line by SQLite Methodology

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A B S T R A C T

The integration of advanced technology with effective management processes has become essential not only for the new growth potential but also for helping competitive advantages and sustain their positions in the industrial manufacturing field. In this research, we implemented lean six sigma methodologies and SQlite management system to improving the efficiency and warning the blockage in the surface mount technology product line. Additionally, we incorporated a smart management system to enable real-time, end-to-end monitoring of production line operations. This approach also addresses challenges related to PCB fixture management, streamlines workflows, minimizes waste, and boosts both operational speed and efficiency.

Keywords: SMT product line; Lean Six Sigma; Warning the blockage; SQlite management system

1. Introduction

The surface mount technology (SMT) production process is inherently complex and requires a high level of precision, carried out through a series of critical technical steps. While previous studies have primarily focused on optimizing individual stages of the production line [1], this research takes a simulation-based approach to analyze the entire process flow [2]. By doing so, it becomes possible to identify interactions between different stages and develop comprehensive improvement strategies for the whole system [3]. Through data collection, simulation input, and real-time trial runs, it became evident that enhancing the system is both necessary and essential [4]. The research team identified several operational issues in current factory lines, including inefficiencies related to waiting time, excessive movement during operations, and unnecessary transportation [5].

Applying smart management and Lean Six Sigma to the SMT production line represents a significant advancement in the modernization of the electronics manufacturing industry [6-7]. Centered around Lean Six Sigma principles [8-10], the research team conducted an in-depth analysis of the SMT process and identified that timely maintenance of SMT fixtures plays a crucial role in preventing unexpected line stoppages and minimizing unnecessary waste. Additionally, issues related to flipping and transferring semi-finished products between lines have emerged as critical operational concerns that require attention [11-14]. The implementation of an in-house manufacturing execution system (MES) has proven essential for enhancing automation and enabling real-time monitoring across the entire production line [15-16]. Operating on a local server (localhost), the internal MES not only ensures data security but also optimizes production efficiency by closely managing key stages such as solder paste printing, component placement, soldering, and inspection [17-18].

2. Methodology

2.1. The implementation of lean six sigma

The implementation of Lean Six Sigma through the DMAIC methodology, which consists of five sequential phases: Define, Measure, Analyze, Improve, and Control. This approach emphasizes a modern mindset: rather than correcting errors after they occur, it focuses on preventing mistakes from happening in the first place—aiming for perfection throughout the entire production and business process.

Application of the DMAIC Model:

Define (Problem Identification):

The customer requires a defect rate of $i\%$.

The currently measured defect rate is $n\%$, where $i \le n$.

Measure (Data Collection and Evaluation):

Data collected over a one-month period:

Total number of products is N

Number of defective products is D

Tỷ lệ lỗi ban đầu được tính (%):

$$\text{Defect Rate} = \frac{D}{N} \quad (1)$$

Xác định Defects Per Million Opportunities (DPMO):

$$\text{DPMO} = \frac{D \times 1{,}000{,}000}{N \times O} \quad (2)$$

2.2. Application of SQlite system in smart management

The production line management software (PLMS) features a user-friendly frontend developed in HTML, designed to intuitively display production information and machine status. It allows users to interact through functions such as charts, forms, and machine control panels.

On the backend, the system is powered by Node.js, which handles data collection and processing from equipment and monitoring systems on the production line. Node.js receives sensor data via APIs or industrial communication protocols then analyzes, stores the information, and sends results back to the HTML interface.

This setup enables real-time data to be continuously updated on the display, while user commands are quickly transmitted back to the production system. The combination of a clear, interactive HTML interface and the efficient data-handling capabilities of Node.js ensures that the SMT production management software runs smoothly, transparently, and efficiently.

2.3. Research model

The SMT production line modeled according to the process flow diagram is illustrates as the Figure 1.

Figure 1: SMT production line

The SMT line 1 begins with the preparation of printed circuit boards (PCBs), which are carefully inspected and cleaned before being loaded into the board feeder. From there, the boards are transferred to the solder paste printer, where solder paste is applied to designated component mounting areas through a stencil.

Next, the automated pick-and-place machine accurately positions electronic components onto the solder-pasted areas. The assembled boards are then inspected using an automated optical inspection (AOI) system and, if necessary, undergo rework. Afterward, the boards are sent through the reflow oven, where component leads are soldered to the PCB.

Post-reflow, the boards are inspected again to detect any soldering defects. The same process is then repeated on SMT Line 2 for the opposite side of the PCB. Finally, the assembled boards are cleaned to remove any remaining flux residues and subjected to functional testing to ensure proper operation.

3. Results and Discussion

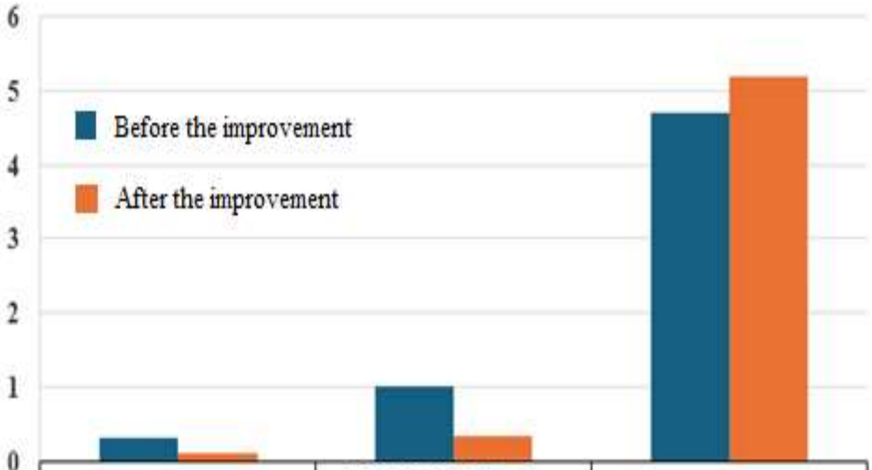
3.1. Replacing manual labor with a PCB flipping machine and a robot for semi-finished product

After the Top side of the PCB is processed on SMT Line 1, it must be transferred to SMT Line 2 for Bottom side processing. This transition requires an intermediate transfer station [13].

Surveys have shown that many factories currently rely on manual labor for flipping PCBs, changing fixtures, and transporting semi-finished products. However, several studies have indicated that manual handling can introduce defects such as PCB warping, broken or bent component leads, and other mechanical issues [14-15].

To address these challenges, the research team proposes replacing manual labor with a PCB flipping machine and an Autonomous Guided Vehicle (AGV) for semi-finished product transport [16].

Based on a surveyed average monthly wage of 8 million VND per worker, and considering that two workers are required to handle this task across two shifts per day, a cost-benefit analysis has been conducted. The comparison between manual labor and automation is evaluated using the benefit-cost (B/C) ratio and payback period method.



	PCB (%)	DPMO (Defects Per Million Opportunities)/1000	Sigma
Before	0.3	1	4.7
After	0.1	0.333	5.2

Figure 2: Applying lean six sigma to the production line

Figure 2 shows that the improvements led to a decrease in defect rate and DPMO, and a rise in sigma level, reflecting enhanced process quality, reliability, and efficiency. These metrics demonstrate the successful application of quality improvement methods, likely involving Lean or Six Sigma principles.

The Sigma level has increased from 4.7 to 5.2. This is a significant improvement, indicating that the process is approaching world-class quality levels, with minimal variation and high defect prevention capability.

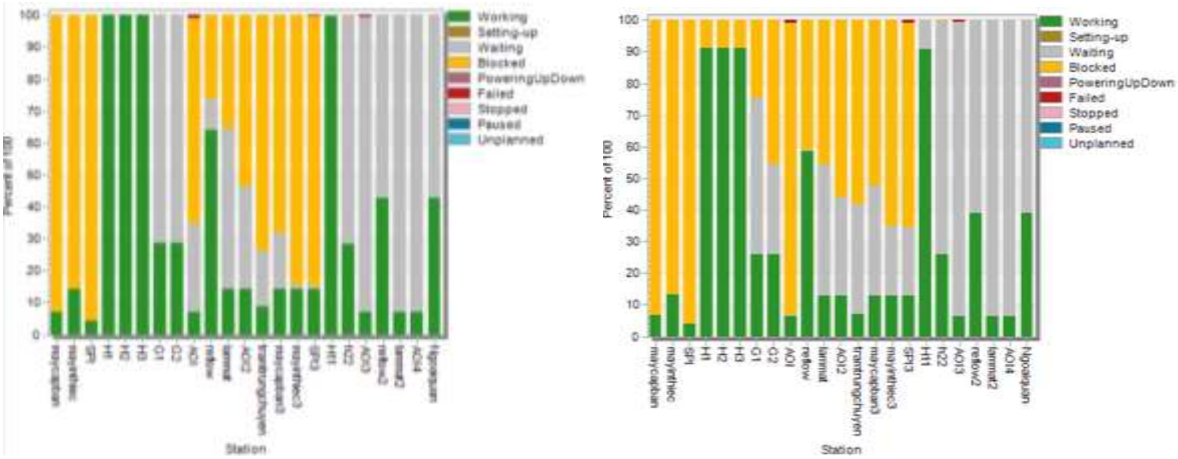


Figure 3: Results of before and after improvement by the quipment replacement and process innovations

This chart in Figure 3 (a) illustrates the percentage breakdown of different activities across various stations in a production line. Each bar represents a station, and the colors within the bars indicate how time is distributed among various statuses such as working, waiting, setting-up, blocked. This is a valuable tool for identifying bottlenecks, inefficiencies, and potential improvements in the production workflow.

The chart in Figure 3 (b) provides a visual breakdown of how each station in the production line allocates its operational time across different activity states. Each column illustrates the proportion of time spent in states such as working, waiting, setting-up, and others.

The chart highlights imbalances in station performance across the line. While some stations operate with high productivity, others face delays and underutilization. Targeted actions to minimize waiting and setup time, and better align station roles, could lead to improved overall efficiency.

3.2. Result of smart management application in SMT production line operation

The table presents performance data for various machines or processes involved in a production line, including metrics such as processing time, number of processed units, failure count, and efficiency.

NameVNM	IncludeProcTime	ProcTime	IncludeNumberProcessed	NumberProcessed	IncludeFailed	Failed	id	Simtime	Efficiency ⌄ 1
Board Loader	1	10	1	0	1	0	1	0	0
Solder Paste Printer	1	20	1	0	1	0	2	0	0
SPI	1	6	1	0	1	0	3	0	0
Board Loader2	1	10	1	0	1	0	4	0	0
Solder Paste Printer2	1	20	1	0	1	0	5	0	0
SPI2	1	6	1	0	1	0	6	0	0

Figure 4: Parameters in the SMT production line management

Figure 4 shows across all listed stages-including Loader, Solder Paste Printer, SPI, board loader, and SPC the number of processed units is consistently one, while the processing time varies from 5 to 20 units of time, depending on the station.

Notably, each process recorded zero successful outputs, while the failure count is consistently one, indicating that every processed item failed at each stage. This results in an efficiency score of zero across the board.

The data strongly suggests a systemic issue, as every stage fails to produce a successful unit. This could point to incorrect input materials, a configuration error across multiple machines, or a testing phase that captures only failed trial runs.

S/N	Machine Name	Processing time	Processed tray count	NG product	Status	NG Rate	Efficiency
1	Board Loader	10	0	0	Normal	0%	0%
2	Solder Paste Printer	20	0	0	Normal	0%	0%
3	SPI	6	0	0	Normal	0%	0%
4	Board Loader2	10	0	0	Normal	0%	0%
5	Solder Paste Printer2	20	0	0	Normal	0%	0%
6	SPI2	6	0	0	Normal	0%	0%
7	H1	140	0	0	Normal	0%	0%
8	H2	140	0	0	Normal	0%	0%
9	H3	140	0	0	Normal	0%	0%
10	G1	40	0	0	Normal	0%	0%
11	G2	40	0	0	Normal	0%	0%
12	AOI	5	0	0	Normal	0%	0%
13	Reflow	45	0	0	Normal	0%	0%
14	AOI2	5	0	0	Normal	0%	0%
15	Board Loader3	10	0	0	Normal	0%	0%
16	Solder Paste Printer3	20	0	0	Normal	0%	0%
17	SPI3	6	0	0	Normal	0%	0%
18	H11	140	0	0	Normal	0%	0%
19	G21	40	0	0	Normal	0%	0%
20	AOI3	5	0	0	Normal	0%	0%
21	Reflow2	45	0	0	Normal	0%	0%
22	AOI4	5	0	0	Normal	0%	0%
23	Visual Check Station	60	0	0	Normal	0%	0%
Total processed trays:			0				
Total NG products:			0				
Process defect rate:			0%				

Figure 5: Real-Time operating parameters of the SMT production line

One of the key features in Figure 5 that should be integrated into the production line management software (PLMS) is the capability to detect and alert for production line overload. This mechanism operates by monitoring operational indicators such as the number of PCBs, machine cycle times, and equipment load ratios.

The table provides a detailed overview of multiple machines along a production line, listing their processing time, number of trays processed, defective (NG) products, and efficiency.

Despite the varied processing times across equipment from 5 to 140 units every machine reports a processed tray count of zero. Consequently, all values for NG product count, NG rate, and efficiency remain at 0%. Each machine is marked with a "Normal" operational status, indicating that no errors or malfunctions were recorded at the equipment level.

However, the absence of processed trays and NG products across all 23 machines suggests that production has not yet started, or the system is in an idle or setup phase. It may also imply that data collection is occurring before actual operation or that there is a delay in system feedback.

Board Loader3	10	948	0	Blockage	0%	7.07%
Solder Paste Printer3	20	948	0	Blockage	0%	14.15%
SPI3	6	949	0	Blockage	0%	4.24%
H11	140	474	0	Normal	0%	49.52%
G21	40	474	0	Normal	0%	14.15%
AOI3	5	474	0	Normal	0%	1.77%

Figure 6: Overload warning feature in the production line monitoring

While the lower line shows promising operational stability, the upper segment is hindered by blockages, significantly affecting productivity. Immediate attention is required to address these blockages and restore overall process efficiency as shown in Figure 6.

4. Conclusion

The improvement of the SMT production line using the Lean Six Sigma methodology has enabled the clear identification of bottlenecks within the manufacturing process particularly those caused by manual operations, unnecessary waiting times, and inconsistencies in product quality.

By applying the lean sig sixma and Sqlite management system, the enterprise was able to identify root causes of waste and implement optimal solutions, including the deployment of intelligent alert systems via MES and the replacement of manual tasks with automated machinery.

These improvements have not only reduced the average PCB defect rate from 0.3% to 0.1%, but also enhanced productivity and output quality, contributing to the development of a more modern, stable, and sustainable production line an essential factor in the increasingly competitive electronics industry.

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