INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VIII, August 2026

Capacity and UPH Improvement with Lean Tool: A Case Study of Electric Assembly Line

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DOI: https://doi.org/10.51583/IJLTEMAS.2026.150800111

Received: 03 September 2026; Accepted: 08 September 2026; Published: 19 September 2026

ABSTRACT

The economic environment is becoming more competitive as the modern world develops. For this reason, it is crucial for manufacturing companies to continuously improve, optimize processes, and reduce costs to outperform their rivals. Lean manufacturing is known as a good way for the great majority of companies. In this study, lean technology to enhance a production line for family products with rechargeable items would be mentioned. Lean tools and other suitable methods like line balancing, Maynard Operation Sequencing Technique (MOST), Define – Measure – Analyze – Improve – Control (DMAIC) cycle and work elements would be used to detect waste and non-value added, improving, and decreasing production time while ensuring product quality. As a good practical result, units per hour (UPH) factor increased from 48 to 90, units person per hour (UPPH) factor from 5.3 to 6.0, and saving the business $28,000 annually.

Keywords: Lean Manufacturing, Lean Line balancing, DMAIC, MOST, UPH, UPPH.

INTRODUCTION

Lean production stands out as a modern managerial approach aimed at elevating organizations and businesses through the efficient streamlining of manufacturing processes, waste reduction, and heightened overall productivity [1, 2].

An electronics manufacturing company identified a significant issue in its production line—the excessive presence of non-value-added (NVA) elements. This not only prolonged production times but also led to a wasteful utilization of resources. The impact is even more pronounced for production lines with a substantial percentage of NVA. Consequently, UPH and UPPH indexes were not good as expected. This study illustrates the application of lean tools to address the NVA challenge specifically within the family production line.

The objective is to eliminate non-value-added elements, thereby reducing production times without compromising the quality of the product. It could help enhance the capacity and improve the performance of the system.

Background

Lean manufacturing

Lean manufacturing, rooted in the Toyota Production System, has evolved into a pivotal management philosophy, garnering extensive attention in literature. The historical development of lean practices in post-World War II Japan, particularly through the seminal work at Toyota, serves as a foundational narrative. Core principles, such as just-in-time production and continuous flow, are widely acknowledged [1].

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Researchers emphasize the identification and elimination of the seven types of waste as fundamental [2].

Concepts like Kaizen, promoting continuous improvement, underscore the role of employee involvement [3]. Despite its recognized benefits, literature also addresses challenges in lean implementation, citing cultural resistance and leadership commitment as key obstacles [4]. Lean application beyond manufacturing is extensively explored, with adaptations in healthcare, services, and software development [5]. Measurement and evaluation, integral to lean success, are discussed through key performance indicators [6]. Supply chain integration and collaboration with suppliers are examined for their role in enhancing overall efficiency [7]. In essence, the literature on lean manufacturing provides a rich tapestry, weaving together historical insights, core principles, implementation challenges, diverse applications, and ongoing advancements.

Adhering to the principles mentioned earlier, lean manufacturing is centered on identifying and eliminating processes within an organization's supply chain for goods and services that contribute to increased costs without significantly adding value to customers. To fully harness the benefits of Lean, businesses must grasp and effectively apply the six core principles of lean manufacturing: waste identification, standardizing processes, maintaining continuous flow, implementing just-in-time practices, ensuring quality in the process, and fostering continuous improvement.

Lean Six sigma

Lean Six Sigma, a powerful amalgamation of Lean manufacturing and Six Sigma methodologies, has garnered substantial scholarly attention. The fusion of Lean waste reduction principles and Six Sigma focus on process variation has resulted in a comprehensive approach to organizational improvement. The literature highlights the complementary nature of these methodologies, emphasizing the synergies that arise from their integration [8]. Scholars often underscore the significance of Lean Six Sigma in achieving operational excellence and enhancing overall organizational performance [9]. The structured DMAIC (Define, Measure, Analyze, Improve, Control) methodology, a hallmark of Six Sigma, when coupled with Lean principles, forms a robust framework for problem-solving and continuous improvement [10]. Studies explore the application of Lean Six Sigma in various industries, demonstrating its versatility and effectiveness [11]. The literature also delves into challenges associated with implementation, citing factors such as organizational culture and leadership support [12]. Moreover, the integration of Lean Six Sigma with emerging technologies and Industry 4.0 is a topic of contemporary interest, reflecting the ongoing evolution of these methodologies in the digital era [13].

In summary, Lean Six Sigma provides a comprehensive understanding of its theoretical foundations, practical applications, and the evolving landscape of its implementation.

The DMAIC phases of Lean Six Sigma are Define, Measure, Analyze, Improve, and Control. They are used to identify and improve existing process problems with unknown root causes [14].

Define: Clearly articulate the problem from the perspectives of the company, stakeholders, and customers. Understand the quality expectations customers have and the extent of the issue.

Measure: Evaluate the current process and its contribution to the problem. Assess whether the process aligns with the previously established quality expectations of customers. Align each step of the process with predefined quality criteria, substantiating measurements with actual performance data.

Analyze: Examine all accumulated information to precisely determine the nature, scope, and root causes of the problem.

Improve: Develop and implement a solution, ensuring its effectiveness. Collaborate to design a resolution that addresses both the problem and its underlying cause. Validate the solution's appropriateness through data analysis. Test the solution and collect performance data to support its efficacy.

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Control: Monitor ongoing improvements and continue refining where possible. Establish definitive performance criteria. Formulate a plan capable of managing variations, sustaining improvements, and preventing a recurrence of the original problem.

Line balancing

Line balancing is a critical aspect of production and operations management. The optimization of workflow along assembly lines is at the core of line balancing, aiming to enhance efficiency and minimize idle time.

Key principles of line balancing involve the equitable distribution of tasks among workstations to eliminate bottlenecks and achieve a smooth production flow. *Takt time* is the rate at which parts or products must be produced to meet customer demand.

In the context of a specific production line, if the time taken for production precisely matches the *Takt time*, the line is in perfect balance. However, if there is a disparity, it is advisable to redistribute or reorganize resources to eliminate bottlenecks or excess capacity. Essentially, the allocation of workers and machines for each task in the line should be adjusted to achieve the optimal production rate [15].

MOST (Maynard Operation Sequencing Technique*)*

Maynard Operation Sequencing Technique (MOST) has been a subject of significant exploration in the realm of work measurement and process improvement [16]. Developed in the mid-20th century, MOST is a widely recognized and utilized methodology for analyzing and optimizing work processes. A task is dissected into separate motion components to calculate this. Each is given a numerical time value in time measurement units, or TMUs, where one hour is equal to 100,000 TMUs. The standard time is then calculated by adding all the motion element times together with any allowances. The original and more advanced Methods-Time Measurement technique, often known as MTM, is a global standard, whereas it is more prevalent in Asia.

Work elements

The specific actions are needed to finish a cycle at a workstation; the least amount of work that can be delegated to another operator.

Work that has been broken down into its component parts can help find and get rid of the waste that is buried within an operator's cycle. To achieve continuous flow, the elements might be spread in accordance to takt time. For instance, the small vertical boxes that indicate job items can be seen in the Operator Balance Chart figure. Time study with process steps split into elements which can be called *Yamayumi chart* [17].

Units Per Hour and Units Per Person Hour (UPH/UPPH)

The terms UPH (units per hour) and UPPH (units person per hour) are commonly used in manufacturing and production environments to measure productivity. UPH refers to the number of units produced per hour, while UPPH refers to the number of units produced per hour by a single person. Both metrics are important for assessing the efficiency of a production process and identifying areas for improvement [18].

UPH is a simple and direct measure of productivity. It is calculated by dividing the total number of units produced by the total number of hours worked. UPH is a simple and direct measure of productivity. It is calculated by dividing the total number of units produced by the total number of hours worked. UPH is a simple and direct measure of productivity. It is calculated by dividing the total number of units produced by the total number of hours worked.

UPH can be used to compare the productivity of different workers, machines, or production lines. It can also be used to track productivity over time and identify trends.

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METHODOLOGY

To optimize the production line for the assembly line of the electronics company, this study would use five processes that are based on the Lean six sigma theory: define, measure, analyze, improve, and control (DMAIC cycle) as on Figure 1 [19]. To determine production line capacity, utilization ratio would be measured and adjusted, which should be combined with Work elements and Line balancing tools.

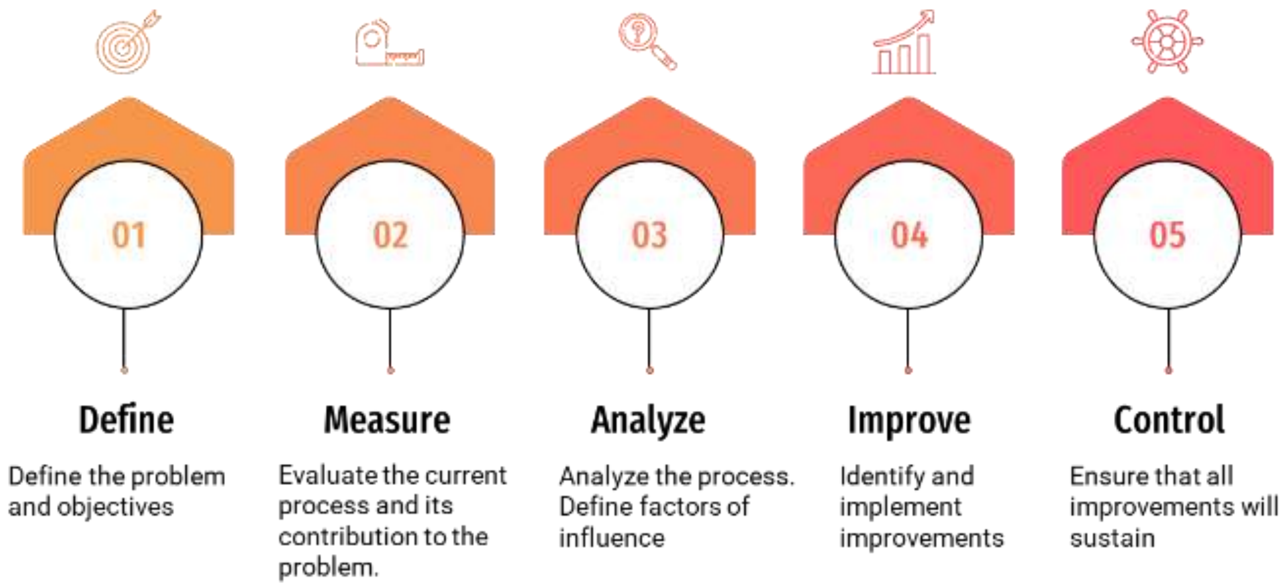

Figure 1: Lean Six Sigma roadmap

Step 1: Review the manufacturing process to find the problems that need to be solved and why the capacity cannot meet customer demand. Cycle times of all workstations of the production lines were measured. The time study method was applied. The number of measured samples (observations) depends on the variations of processing times; Normal time is estimated by multiply with performance rating of worker pace; Standard time includes allowance factor for personal time, fatigue, and delays. Line balancing chart was drawn to recognize the critical points should be improved.

Step 2: Determine the ratio of each type of tasks at each station in the manufacturing line. *Yamayumi chart* was developed. The business then chose the workstation with the highest utilization ratio as its improvement and research focal point.

Step 3: Use fishbone diagrams to determine the root cause of the problem so that you can take corrective and preventive action.

Step 4: Determine the defect rate, and then suggest an action plan to eliminate the station in the line with the highest utilization ratio. The standard time for each operation is then updated using the MOST technique. Additionally, rearranging the stations on the manufacturing line to reflect the modifications made in the preceding stage utilizing line balancing.

Step 5: Keep track of the post-improvement line's product quality. Observe outcomes for analysis.

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Case Study

This paper would focus on a case study involving an electric company that supplies most of its products to customers worldwide. The company operates as a unit within a multinational organization, providing services in product management, production, and design to global electronics manufacturers. The production process is customer-driven, with products being manufactured based on specific customer orders. The study specifically examines and analyzes an assembly line within this business.

The paper focuses on using lean manufacturing to examine, enhance, and improve utilization ratio, upgrade capacity in the management of engineering operations to meet the demand of customers.

Define

In the service and manufacturing industries, companies are supposed to maximize customer satisfaction by ensuring quality, and prompt delivery, at the lowest price.

The Define phase involves clearly defining the problem that needs to be solved. In this case, the problem is that the Argo production line is overloaded and cannot meet customer demand.

The problem statement at the top of the dashboard indicates that the line is currently overloaded, with a capacity utilization of 170%. This is due to a large backlog of orders from customers in Q2 and Q3 of FY23 as shown on Figure 2.

No.	#Bay	Family	Model	Shift	Hourly /shift	Working hour	OBC		Standard shift daily cap	%Eff	% FPY		Line Required									Avg	Available Line	% Utilize	#line
							HC/line	UPH					Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	######	Dec-23				
1	Bay 22	Argo	DS930	2	10.3	20.5	9	48	984	90%	98%		5.86	1.42	1.42	1.54	1.43	1.43	1.73	1.42	1.42	1.84	1	184%	2

Figure 2: Required production line capacity to meet customer demand

The goal statement is to improve the UPPH (units per hour) of the line and resolve the overutilization of capacity by Q3 FY23. To achieve this, the plan is to increase the UPH from 48 to 90 units per hour.

The risks associated with the project include:

- Increasing the number of DLHC (direct labor headcount) from 9 to 15
- Increasing the UPPH from 5.3 to 6.0LBR (labor cost per unit) not decreasing after re-balancing

The overall goal of the project is to increase the capacity of the Argo production line by 200% to meet the growing customer demand.

Measure

Base on the definition of UPH and UPPH, the ratio of each station and the bottleneck were calculated and showed in the Figure 3 below:

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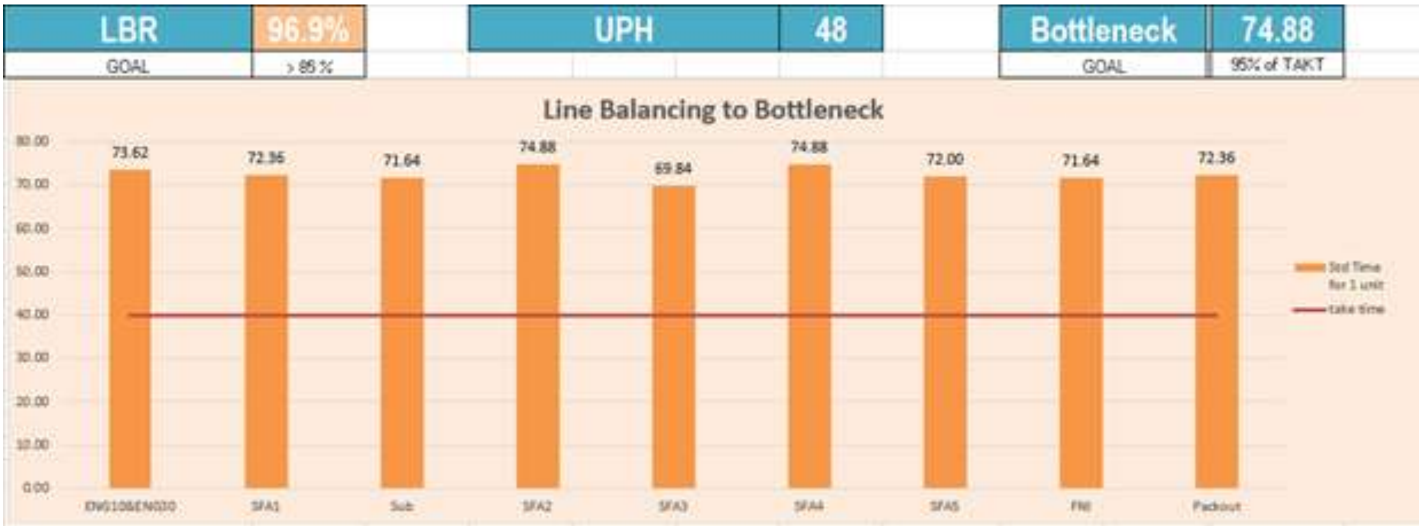

Figure 3: Line Balancing to bottleneck

According to the calculation, the utilization ratio with highest value is the 4th and 6th workstation, next is station 1, station 2. Workstation 5 and 8 have the lowest utilization ratio.

Analyze

By applying Fish-bone chart (Ishikawa Diagram), the root cause has identified:

- IFC Machine test is overloading to adapt demand
- Material supplies demand up trend risk for capacity
- Cycle time is under takt time, output does not achieve capacity
- Work element was not standardized
- Many new operators

The root causes have been defined through Fish-bone chart shown in Figure 4 below:

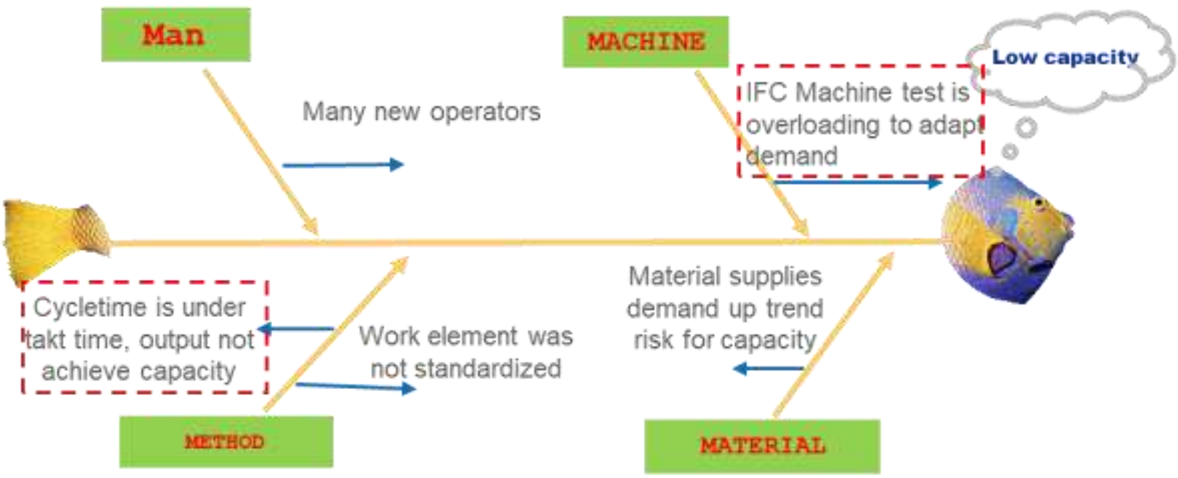

Figure 4: Fish bone diagram

Cycle time is higher than Takt time customers require. The current equipment/station is overloaded for all products. The loading for all products is greater than 100%, which means that the machines are working at a higher rate than they are capable of. The UPH and capacity of this line are showed in Figure 5 below

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Product model (SKU)	CT/IPK	Process										
		1	2	3	4	5	6	7	8	9	10	11
		ENG10&ENG30	IFC	SFA1	SUB	SFA2	SFA3	SFA4	SFA5	FAT	FNI	Packing
D59308 (All Generic SKUs)	Monthly demand	47364	47364	47364	47364	47364	47364	47364	47364	47364	47364	47364
	Cycle time	73.62	189	72.36	71.64	74.88	69.84	74.88	72	115	71.64	72.36
	Takt time	46.17	46.17	46.17	46.17	46.17	46.17	46.17	46.17	46.17	46.17	46.17
	Current equipment/station	1	3	1	1	1	1	1	1	3	1	1
	UPH	48.90	53.47	49.75	50.25	48.08	51.55	48.08	50.00	87.88	50.25	49.75
	Toal resource required	1.67	4.30	1.65	1.63	1.70	1.59	1.70	1.64	2.62	1.63	1.65
	%Loading	167%	143%	165%	163%	170%	159%	170%	164%	87%	163%	165%
	#Required equipment/station	**0.67**	**1.30**	**0.65**	**0.63**	**0.70**	**0.59**	**0.70**	**0.64**	**0.00**	**0.63**	**0.65**

Figure 5: Demand & current capacity

With the results of analysis steps, requiring resource need for improve Hourly throughput equip has been proposed.

Improve

Derived from the root causes identified during the Analyze Phase, the elimination of end line inspection marked a significant change. The output from the sub-assembly line was redirected directly to the main assembly line, bypassing the inspection phase. This breakthrough solution is deemed crucial for the enterprise's efficiency. However, ensuring alignment among departments such as production, Industrial Engineering, and planning is imperative, with a particular emphasis on the quality department, serving as the factory's representative for the customer.

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There were five phases of improvement as shown in Figure 6.

	Root Cause	Selected Countermeasure	Owner	Target	Finish
Throughput Improvement Activities	IFC Tester capacity can't meet the UPH 90	Add IFC machine	Team - Zebra customer	20-Feb-23	Done
	Assembly station can't achieve the UPH 90	Break down the process assembly, use OBC analysis for motion study and line balance	IE Team	24-Feb-23	Done
		Finalize Layout and approval Raise PCN	IE Team	24-Feb-23	Done
		Adding station and modify line	IE Team	25-Feb-23	Done
		Training and buyoff Line	Trainer team	25-Feb-23	Done
	Training	Guide for Operators running with new method	IE team	24-Feb-23	Done
	Run trial	Implement trial run for 1 shift and monitor out put each hour	IE Team	28-Feb-23	Done
	Monitor performance	Tracking hourly output/issue each line and each shift and implement quick action	IE Team	1-Mar-23	Done

Figure 6: Improvement Phase

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After the implementation of the trial run, the result showed that there was no case of nonconformity products in actual production. Therefore, the solution had been sustained. Before and after implement line balancing the UPH and capacity meet the demand of customers. The bottleneck also has been solved. The results have been shown in Figure 7 and 8.

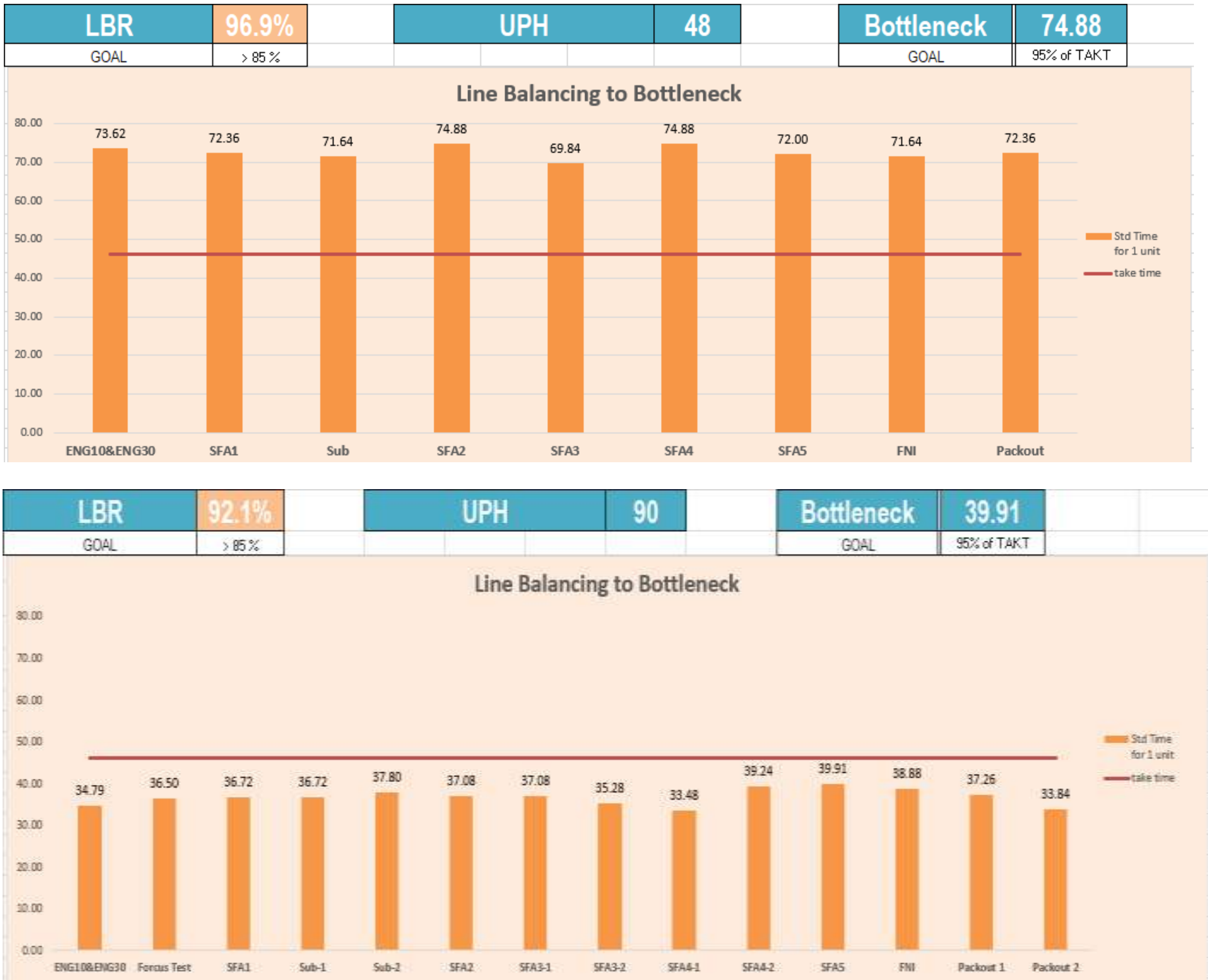

Figure 7: Before & After LB implementation

Summary	Before	After
Total CT	653	549
Bottle neck CT (s)	74.88	39.91
Takt time (s)	46.17	46.17
UPH	48	90
UPPH	5.3	6.0
LBR	96.9%	91.8%
%Improvement UPH	47%	
%Improvement UPPH	13%	

Figure 8: Final results

The cost saving of the project was calculated to show the effectiveness of the solutions. It includes many relative elements of costs, which is summarized as in Figure 9.

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Working days	30								
%Efficiency	95%								
%FPY	98%								
UPH Before	48								
UPH After	90								
Sum of Quantity	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22
EVM Argo DS9308 FC	131,268	31,063	31,200	31,200	32,253	31,200	39,000	31,200	33,200
#Line needed before	4.45	1.05	1.06	1.06	1.09	1.06	1.32	1.06	1.12
#Line needed after	2.37	0.56	0.56	0.56	0.58	0.56	0.70	0.56	0.60
#HC/line before	9	9	9	9	9	9	9	9	9
#HC/line after	15	15	15	15	15	15	15	15	15
HC needed before	123.0	30.0	30.0	30.0	30.0	30.0	36.0	30.0	33.0
HC needed after	108.0	27.0	27.0	27.0	27.0	27.0	33.0	27.0	27.0
#HC Reduced	15.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	6.0
Monthly hard saving	$ 2,333.33								
Annual hard saving	$ 28,000.00								

Figure 9: Total annual hard cost saving from the project

Control

The process owner is responsible for controlling the process and making sure that it is always achieving the target. The implementation plan is responsible for tracking the progress of the process and making sure that it is always achieving the target. Industrial Engineering Department (IE) keeps monitoring, getting high performance, looking for opportunities for continuous improvement. IE has been documented the process by uploading standardize process into system.

CONCLUSION

This study shown how the application of lean principles, tools, and techniques was applied in an electronics assembly line. It has enhanced the operational effectiveness of the production process by significantly improving UPH and UPPH, solving bottlenecks, reducing cycle time to meet Takt time and raising production efficiency.

Results significantly UPH increased from 48 to 90, UPPH from 5.3 to 6.0 and bottleneck decrease from 74.88 to 39.91. They contribute much on company operations capacity. In addition, these results bring huge saving of $28,000 yearly. IE should split and balance the process into more to divide the workload and balance the process flow to improve the capacity/ output to meet customer demand. IE should continuously look for future opportunities for improve non-value-added effects, take the chance for head count improvement, increase UPPH, and improve more line balancing ratio.

Similar applications for other manufacturing lines were under consideration, which would bring much more benefits for the organization. A post-improvement standard process reduces variety in work methods and, consequently, in the output of results.

ACKNOWLEDGEMENTS

We acknowledge Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for supporting this study.

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