

CASE STUDY

Applying value stream management to improve production processes in LED manufacturing industry - a case study

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The company under study is a company specializing in producing light-emitting diodes (LED). The revenue of the company has declined sharply in recent years. After analyzing, the root causes of the problem are high production lead time (LT) and high cycle time (CT) in the production process. The paper applied value stream management to improve the LED production process of the company. The primary objectives were to reduce the production LT and reduce the production CT to meet the takt time (TT) and therefore improve the revenue of the company. The results had shown that the LT had been reduced by 16.44%, from 235.5 minutes to 197 minutes, and the CT reduced by 36.68%, from 45.8 seconds to 29 seconds, meeting the TT.

Keywords: value stream management, SMED, job design, line balancing, work cells, Kanban, FIFO, LED manufacturing

Introduction

The company under study was founded in June 2018, producing LED lighting equipment in Vietnam. The production process of the company had so much waste, leading to the problems of increasing production lead time (LT) and cycle time (CT). The problems led to high production costs, low productivity, loss of contracts, and drop in sales, affecting the revenue of the company. The company wants to reduce waste, increase productivity, and reduce production LT in order to receive more contracts and then increase revenue.

Value Stream Management (VSM) is the appropriate methodology to solve the problem. The lean tools and techniques had been used with the objectives to reduce waste, reduce production LT, and reduce production CT to meet takt time (TT).

The current state value stream map (CSM) was constructed, and the current performance indexes were assessed. Lean tools, including Single-Minute Exchange of Dies (SMED), job design, line balancing, Kanban, First In First Out (FIFO), were used to construct the future state value stream map, and the future performance indexes were assessed. The results showed that the LT was reduced by 16.44%, from 235.5 minutes to 197 minutes, and the CT was reduced by 36.68%, from 45.8 seconds to 29 seconds, meeting the TT.

Literature review

VSM is an effective methodology for improving manufacturing processes with the goal of reducing manufacturing LTs and CTs using lean tools such as SMED, work design, line balancing, work cells, Kanban, FIFO, etc. (1)

William M. Goriwondo et al. (2) used VSM tools in reducing waste in bread manufacturing for a company in Zimbabwe. The case study showed how the VSM tool was used to identify and reduce defects by 20%, unnecessary inventory by 18%, and motion by 37% (2).

Anand Sasikumar and Kundan Kumar (3) mapped the current state for the product molded case circuit breaker, which is manufactured by one of the leading companies in India, to identify and reduce the Non-Value Added (NVA) activities and proposed a future state to reduce the production LT and improve the value-added time (3).

Rumbidzayi Muvunzi et al. (4) applied value stream mapping to reduce waste and improve productivity in a tile manufacturing company in Zimbabwe. A current state map (CSM) of the product family was created. The problems with the CSM were identified. Possible improvements were proposed, and a future state map (FSM), which has more efficient processes and optimum space and labor utilization, was created (4).

Dorota Stadnicka and Dario Antonelli (5) used Value Stream Mapping to map the current state map (CSM) and the FSM of the sleeve manufacturing process. The authors used Value Stream Analysis (VSA) to identify and eliminate wastes. The authors also used computer simulations to analyze the data concerning a manufacturing process of the sleeve in order to use the results of VSA (5).

Phong et al. used VSM for improving processes of manufacturing trolley bags (6) in 2015, of producing Printed Circuit Board (PCB) (7) in 2017, of producing packages in the cosmetics industry (8) in 2019, of producing lighting equipment (9) in 2019, and of warehouse operations (10) in 2023.

In using lean tools, Nystha Baishya and Sathish Rao U. (11) applied SMED/Quick Changeover (QCO) to improve the productivity at the screwing station of Hot Forged Rail (HFR) assembly at Robert Bosch. Ashwinkumar Arivoli and Vignesh Ravichandran (12) used line balancing to reduce manufacturing CT with a case study. Ahmad Naufal et al. (13) developed a Kanban system at a manufacturing company in Malaysia. Christoph Roser (14) determined the size of your FIFO lane based on the distributions of the CTs of front and back workstations and the station downtime of front workstations.

Research methodology

The research methodology in this paper includes the following steps:

1. Choose the value stream.
2. Map the current state.
3. Map the future state.

The step of choosing the value stream includes the following sub-steps:

1. Collect data on the number of products consumed.
2. Use Pareto chart to identify the product to be researched.
3. Use Suppliers Inputs Process Outputs Customers (SIPOC) to define the scope of the process to be researched.

The step for mapping the current state includes the following sub-steps:

1. Identify all workstations of the value stream.
2. Collect data on the workstation attributes.
3. Collect data on the available production time and customer daily demand (DD).
4. Collect data on the inventories of the value stream.
5. Calculate times in the process of the inventories.
6. Map the current state value stream.
7. Assess the current performance indexes.

The step for mapping the future state includes the following sub-steps:

1. Draw the current balanced chart
2. Use SMED to increase the workstation TTs
3. Use job design to reduce the workstation CTs
4. Use line balancing to balance the line and meet workstation TTs
5. Use work cells, Kanban, and FIFO to control inventories in the value stream
6. Map the future state value stream
7. Assess the future performance indexes
8. Assess the lean improvement

With review from (1), the SMED procedure used in this research includes the following steps:

1. Identify and classify internal and external activities.
2. Separate internal from external activities.
3. Convert internal activities to external activities.
4. Eliminate internal waste to minimize internal activities time.

The job design procedure (1) used in this research includes the following steps:

1. Identify and classify left-hand and right-hand operations.
2. Eliminate all waste in left-hand and right-hand operations.
3. Design physical tools to reduce operations time.
4. Allocating operations evenly to left and right hands.

Line balancing evenly distributes the work elements among workstations within the value stream to meet workstations TT by the following sub-steps:

1. Identify work elements and workers of the current workstations.
2. Rearrange work elements and workers to future workstations.

The work elements and workers are rearranged to balance the work between stations so that the new workstation CTs do not exceed workstation TTs.

After line balancing, workstations with approximately the same CT are grouped together to form work cells. The material flow in the work cell is continuous.

Kanban systems are constructed by the following sub-steps:

1. Define the positions of the Kanban systems.
2. Collect data and calculate the number of Kanban cards.

The Kanban system is placed between two workstations where the CT of the front station is smaller than that of the back workstation. The number of Kanban card N is calculated according to the following model.

$$N = \frac{D * L + SS}{Q}$$

Where D is the DD of the back workstation, L is the LT of the front workstations, SS is the safety stock, and Q is the container size.

FIFO systems are constructed by the following sub-steps:

1. Define the positions of the FIFO systems.
2. Collect data and calculate the sizes of the FIFO lanes.

The FIFO system is placed between two workstations that their CTs are stochastic. The size of the FIFO lane is calculated by the Christoph Roser model in (6) according to CT means and standard deviations of front and back workstations and station downtime of front workstations.

The methodology was presented for the case in the following sections.

Choosing the value stream

The company produced many products. The Pareto chart for products according to demands was shown in Figure 1.

From the Pareto chart, the value stream of Led Bulb 7W Daylight was selected for further research. The SIPOC diagram of the product was shown in Figure 2. In which the process included seven workstations.

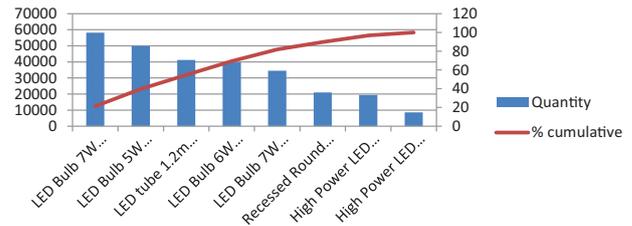


FIGURE 1 | The Pareto chart of products according to demands.

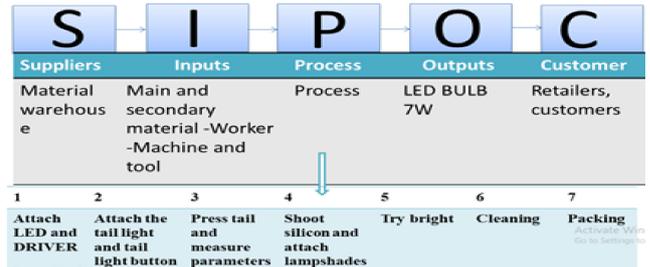


FIGURE 2 | SIPOC diagram of Led Bulb 7W Daylight.

TABLE 1 | Stations in the process.

Station	Name
W1	Attach chip LED and driver
W2	Attach the tail light and tail light button
W3	Press and measure
W4	Shot silicon and attach lampshades
W5	Try bright
W6	Cleaning
W7	Packing

TABLE 2 | The work stations attributes.

	W1	W2	W3	W4	W5	W6	W7
CT(s)	45.8	14.2	17.2	19.8	31.8	13.2	15.2
LT(s)	45.8	14.2	17.2	28.6	38.2	13.2	15.2
COT(s)	2840	0	2310	0	2110	0	0

Current state mapping

The workstations in the process were shown in Table 1.

The workstation attributes, including CT, LT, and change over time (COT) were collected and shown in Table 2.

The company worked one shift per day, 9 hours per shift. The total break time per day was 60 minutes. The available production time was calculated as follows:

$$APT = (9 - 1) * 3600 = 28800 \text{ (s)}$$

The maximum DD was 960 products; the process TT PTT was calculated as follows:

$$PTT = APT/DD = 28800/960 = 30 \text{ (s)}$$

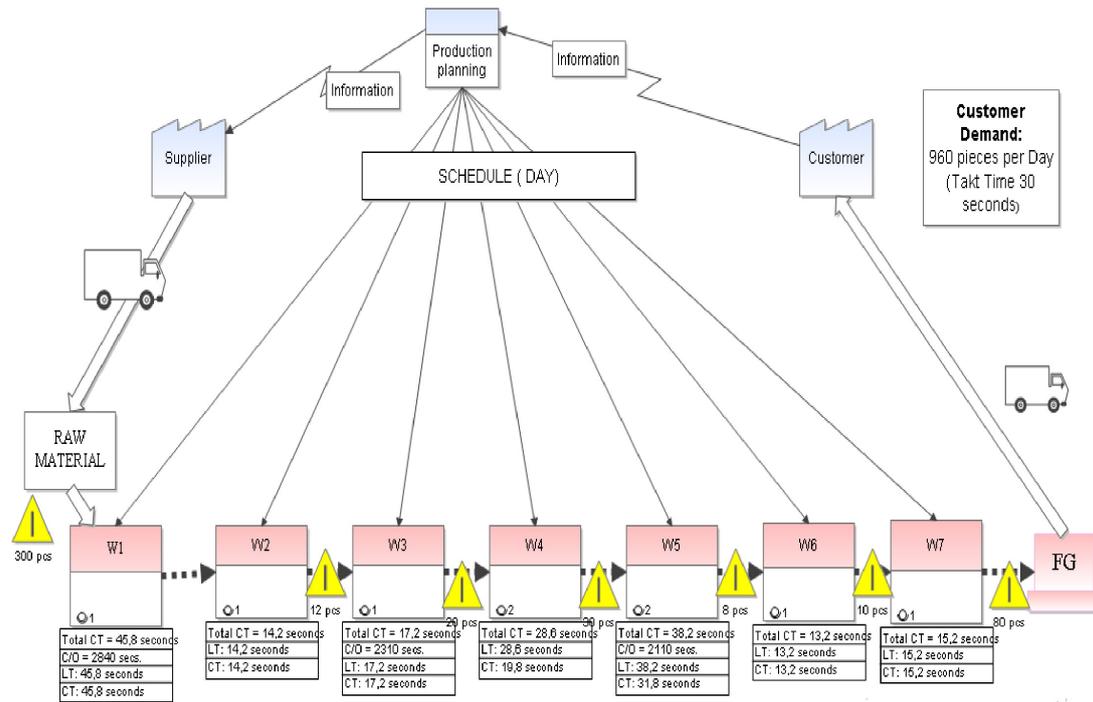


FIGURE 3 | The current value stream map CSM.

TABLE 3 | Inventories and TIP.

	I	TIP (minutes)
RM	300	150
W1-W2	0	0
W2-W3	12	6
W3-W4	20	10
W4-W5	30	15
W5-W6	8	4
W6-W7	10	5
FG	80	40

The inventories I of raw materials RM, WIP between workstations, and finish good (FG) were collected and shown in Table 3. In addition, the corresponding times in process (TIP), with the above DD were also calculated and shown in the same table.

$$TIP = \frac{I}{DD}$$

From all the above data, Igrafx had been used to draw the current state value stream map, as shown in Figure 3.

From the map, the current value stream performance indexes were shown in Figure 4.

Looking at the table, the production LT of 235.5 minutes was very long due to a long time in process, which showed high non-value-added time; the CT, 45.8 seconds, did not meet the TT of 30 seconds; the value stream was unbalanced. Lean tools needed to be applied to solve all the above problems.

Lead Time = 235,5 minutes
VA / T = 172 seconds
RM = 150 minutes
WIP = 2730 seconds
FG = 40 minutes
C/T = 45,8 seconds
C/O = 121 mins.

FIGURE 4 | The current indexes.

Future state mapping

In order to improve the current state map, some lean tools had been used. With the available production time APT of 28,800 seconds, the DD of 960 products, workstation TTs were calculated and shown in Table 4.

$$TT = \frac{APT - COT}{DD}$$

The balance chart with workstation CT and workstation TT was shown in Figure 5.

SMED

Some workstation CTs exceeded the corresponding workstation TT. SMED should be used to reduce workstation changeover times to lift up workstation

TABLE 4 | The work stations TTs.

	W1	W2	W3	W4	W5	W6	W7
CT(s)	45.8	14.2	17.2	19.8	31.8	13.2	15.2
COT(s)	2840	0	2310	0	2110	0	0
TT(s)	27	30	27.9	30	27.8	30	30

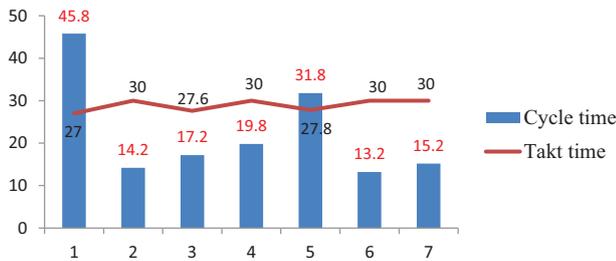


FIGURE 5 | The balance chart of the current value stream.

TABLE 5 | The work station TTs after SMED.

	W1	W2	W3	W4	W5	W6	W7
CT(s)	45.8	14.2	17.2	19.8	31.8	13.2	15.2
COT(s)	240	0	70	0	330	0	0
TT(s)	29.8	30	30	30	29.7	30	30

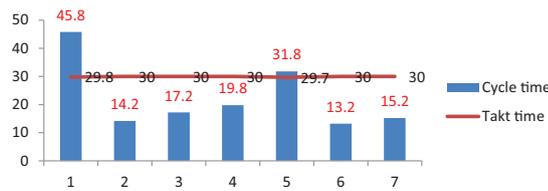


FIGURE 6 | The balance chart after SMED.

TT. After using SMED, the workstation COTs were reduced, then workstation TT were changed as in **Table 5**.

The balance chart after using SMED was shown in **Figure 6**.

Job design

After using SMED, CTs still exceeded TT in some workstations. With review from (1), job design had been used to reduce workstation CTs by eliminating redundant operations and allocating operations evenly to left and right hands. The two-hands method was used to remove non-operations and arrange value-added operations properly. In addition, some tools were designed to reduce operation times. After using job design, CTs of workstations W1 and W2 were reduced as in **Table 6**.

The balance chart after applying *job design* was shown in **Figure 7**.

TABLE 6 | Workstation CTs after *job design*.

	W1	W2	W3	W4	W5	W6	W7
CT(s)	38	12	17.2	19.8	31.8	13.2	15.2
TT(s)	29.8	30	30	30	29.7	30	30

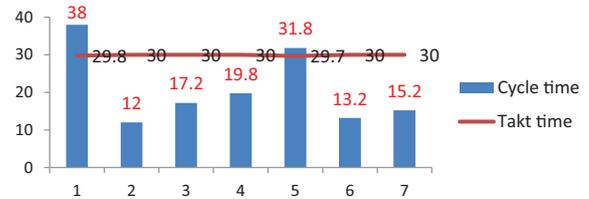


FIGURE 7 | The balance chart after using *job design*.

TABLE 7 | Workstation CTs after *Line Balancing*.

	W1	W2	W3	W4	W5
CT(s)	29	19	19.8	25	26
TT(s)	29.8	30	30	30	29.7

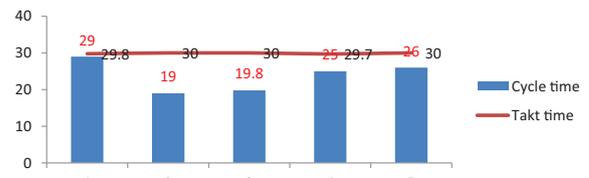


FIGURE 8 | The balance chart after *line balancing*.

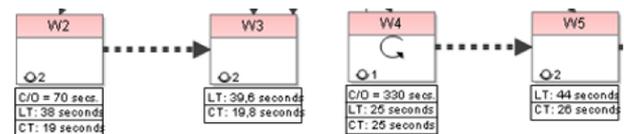


FIGURE 9 | Work cells W2-W3, and W4-W5.

Line balancing

Looking at **Figure 7**, the value stream was still unbalanced, and some workstation CTs still exceeded TTs. With review from (1), line balancing needs to be applied to solve the problems. The work elements and workers of old stations were rearranged to new workstations to balance the work between stations so that the new CTs did not exceed TTs. After using line balancing, there were five news stations in the value stream, with CTs shown in **Table 7**.

The balance chart after applying *line balancing* was shown in **Figure 8**.

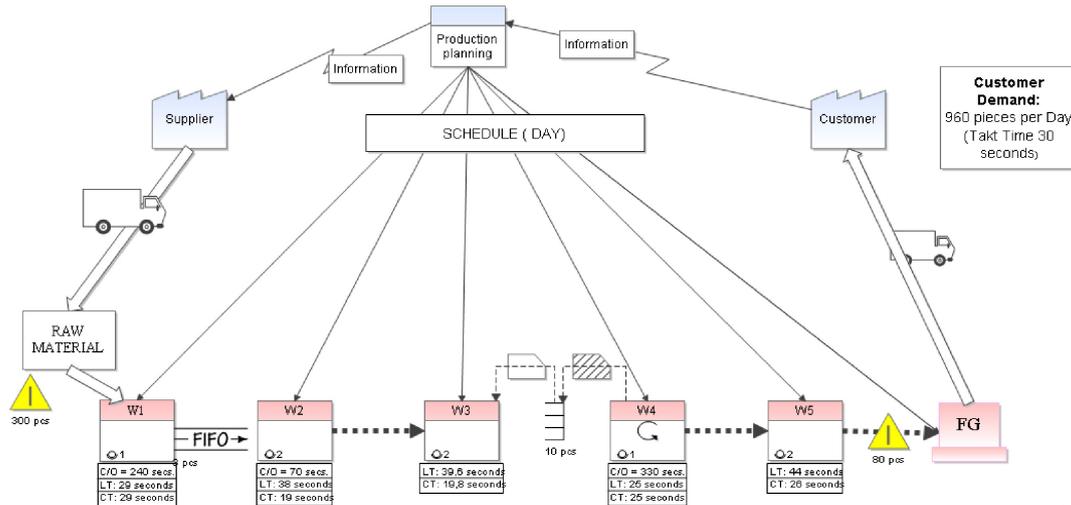


FIGURE 10 | Future value stream map FSM.

TABLE 8 | The number of Kanban card between stations.

n	Supermarket	Stations	D	L	SS	Q	N	N
1	S1	W3-W4	960	0.021	100	10	2.213	3

TABLE 9 | The calculation of FIFO lane size.

FIFO		M(s)	SD(s)	DT(s)	S
W1-W2	W1	29.1	1.51	300	11
	W2	19.9	1.14		

Work cells

Looking at Figure 8, the CTs of stations W2 and W3 were nearly the same; these stations would be grouped to be a work cell. Similarly, stations W4 and W5 would be grouped to be a work cell. The materials flow in these work cells is nearly continuous, as shown in Figure 9.

The work stations in the value stream were now still unbalanced. Kanban & FIFO systems needed to be installed to control WIP. To control WIP, a Kanban system would be placed between stations W3 and W4, and a FIFO lane would be placed between stations W1 and W2.

Kanban systems

With review from (1), the dual Kanban system was used; the numbers of Kanban cards in the supermarket were calculated from the following model, with parameters of DD (D), LT (L) (day), safety stock (SS), and container size (Q).

$$N = \frac{D * L + SS}{Q}$$

Data had been collected to estimate the parameters; then the number of Kanban cards was calculated as in Table 8.

FIFO lanes

The size of the FIFO lane between stations 1 and 2 was calculated based on the supporting software provided by

Lead Time = 197 minute
VA / T = 119 seconds
RM = 150 minutes
WIP = 6,98 minutes
FG = 40 minutes
C/O = 10,7 mins.
CT = 29 seconds

FIGURE 11 | The future indexes.

TABLE 10 | The results of the implementation.

	CSM	FSM
LT (minute)	235.5	197
CT (seconds)	45.8	29

Christoph Roser, with parameters of station CT mean (M), standard deviation (SD), and station down time (DT). Data had been collected to estimate the parameters; then the size S of the FIFO lane was calculated as in Table 9.

From all the above data and the Igrafx support, the future state value stream map was drawn as in Figure 10.

From the future map, the future value stream performance indexes were shown in Figure 11.

In order to assess the lean improvement, the critical performance indexes of the maps CSM and FSM are shown in Table 10.

From the table, we see that the LT reduced by 16.44%, from 235.5 minutes to 197 minutes, and the CT reduced by 36.68%, from 45.8 seconds to 29 seconds, meeting the process TT.

Conclusion

This article discusses the application of the VSM methodology to improve the production process Led Bulb 7W Daylight with the objective to reduce process of the LT and to reduce process CT to meet TT. The current state map (CSM) was constructed, and the current performance indexes were assessed. The FSM was constructed using lean tools of SMED, job design, line balancing, work cells, Kanban, and FIFO systems. From the map, the future performance indexes were assessed.

The results had shown that the objectives had been achieved. The LT had been reduced by 16.44%, from 235.5 minutes to 197 minutes, and the CT had been reduced by 36.68%, from 45.8 seconds to 29 seconds, meeting the process TT. All of these would improve the company's sales performance and then increase revenue.

However, the method discussed in the article had also some restrictions. The data had been collected in a short time duration, not enough for better parameter estimations to make better results. The future state map had not been experimented to assess the real improvement. These restrictions help determine the direction of future research.

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