International Journal of Quality Engineering and Technology

ISSN online: 1757-2185 - ISSN print: 1757-2177
https://www.inderscience.com/ijqet

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DOI: 10.1504/IJQET.2023.10047087

Article History:

Received:	19 August 2021
Accepted:	02 March 2022
Published online:	21 February 2023

A Lean Six Sigma case study to improve the manufacturing process affected during COVID-19

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Abstract: The key manufacturing industry was badly affected by the COVID-19 in India. In this study, we found that the product demand is dynamic during COVID-19. We selected one of the electrical OEMs in India to execute the value added-Flow analysis and VSM study which showed 96% and 85% of total delivery lead time is contributed by NVA activities at the manufacturing process respectively. We also plotted the spaghetti diagram and analysed that total product movement is 287 metres in the current state with the complex flow. We did total of six main Kaizens after Ishikawa and FMEA. We constructed single-piece flow with saving of the half shop floor space and total product movement was reduced from 287 to 96 metres, while total delivery lead time was reduced from 14.6 to 7.72 days. We concluded that lean Six Sigma deployment in the manufacturing industry solved the problems of demand fluctuations.

Keywords: lean manufacturing; VSM; FMEA; spaghetti; value-added flow.

Reference to this paper should be made as follows: Kenge, R. and Khan, Z. (2023) 'A Lean Six Sigma case study to improve the manufacturing process affected during COVID-19', *Int. J. Quality Engineering and Technology*, Vol. 9, No. 1, pp.20–33.

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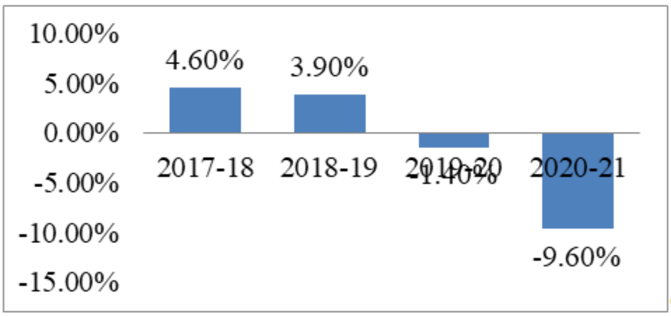
1 Introduction

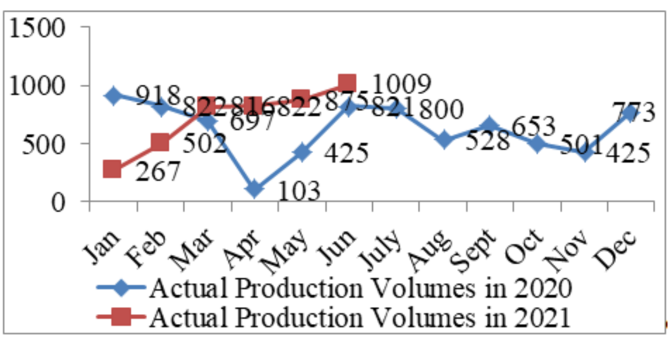
COVID-19 bring an instant abrupt stop to a large number of business ventures over the world, as many nations had closed their sea, air, and local logistic movements while striking country-wide lockdowns, resulting in a disruption in overall life. The manufacturing industry lockdown in India strongly affected the global business. The manufacturing industry comes up with roughly 20% jobs to India's working populations and GDP's 15–16%. It was influenced badly in many ways due to the COVID-19 such as a negative effect on manufacturing numbers. In long run, this badly impacted the total sales and money generation. The Index of Industrial Production that is IIP shown –9.6% turnovers as shown in Figure 1 specify that the main manufacturing industry was badly affected from the 1st and the 2nd COVID-19 wave (Economic Times, 2021).

Figure 1 Year on year IIP that is % growth index for industrial production in India (see online version for colours)



In this case study, we are trying to analyse the impact of COVID-19 on one of the electrical OEM manufacturing industries in India and the actual deployment of lean tools to overcome it. Figure 2 shows the actual production volumes of one of the electrical OEMs in India in 2020–2021 during the COVID-19.

Figure 2 The actual production volumes of one of the electrical OEM in India (see online version for colours)



2 Literature review

2.1 Lean manufacturing process

The lean manufacturing process is a concept of minimising the losses or waste at the production process and maximising efficiency or productivity. The lean defines waste as a non-value adding items or part of any process where the customers are not paying for.

2.2 Importance of the lean manufacturing process during COVID-19

COVID-19 impacted the manufacturing industry adversely in a way of no work for workers; underuse of machinery's causing less productivity. Lean manufacturing process tries to prevent or remove above-mentioned issues in the production process. We listed the main benefits of the lean manufacturing process as below (Twi-Global, 2021),

- Waste removal: Waste removal helps in improved workshop space.
- Quality improvement: Lean manufacturing process deployment improves product quality. It helps the manufacturing industry to save the cost of repair and rework.
- Cost-saving: Lean saves the cost of production by improving the overhead on operations like high raw material, WIP and Finish good inventories.
- Delivery lead time improvement: Lean improves the manufacturing process and builds shorter lead times for faster delivery to the end customers.

2.3 Concept of the waste in the manufacturing process

Waste is anything that does not give value to the end customer. Following are the main wastes

- Excess transportation
- High inventory
- Excess movement of man, tools, or machinery
- Wait during the production process
- Excess-production
- Excess processing to a product
- Quality issues that needs rework.

Above waste can be mainly broken into three types where first is Mura that is a waste due to product demand variation, second is Muri that is waste due to overloaded workers at a given workstation resulting in the loss of motivation in an organisation, and third is Muda that is waste due to non-value-added activities.

2.4 The lean manufacturing process step by step deployment guide

Lean manufacturing process deployment is divided into five main steps that are customer requirement or value, mapping of the value stream, the flow of the value through the stream, the principle of the pull by a customer, and Kaizen. These steps are briefed as below

1 Value: Value is defined as the customer product or services required for which they are paying. This product or services requirement is manufactured by the manufacturer who also eliminates the waste to deliver the requirements at the optimal cost and maximum profits for the customer.

2 Mapping of the value stream: In this step, we map the detailed manufacturing process from customer demand to the final product or services delivered to the customer. In this mapping, we are analysing the resources with the target of waste identification and elimination. Today's manufacturing process mapping is complex and needs joint efforts from cross-functional teams.

3 Defining and creating the flow: Defining and creating flow is removing departmental restrictions to improve delivery lead times of products or services. It also helps to improve the utilisation of the available layout of the workshop.

4 Construct a pull by customer: A pull is the start of production when a customer places a demand. Earlier push method of MRP system predefine the raw material inventories based on the sales forecast. However, forecasts inaccuracy may result in a high or shortage of raw material inventories. This may lead to high overhead costs, uneven production plans, or no customer delight.

5 Kaizen: Kaizen that is continuous improvement try for consistent waste elimination to build the perfect value stream. Kaizen is a culture and it comes through all hierarchy levels of a business for value creation for the end customer (Twi-Global, 2021).

3 Research methodology

3.1 Value-added flow analysis

The value-added flow analysis measures the time required for each workstation step. This measured time can be further divided into value-adding (VA), non-value-adding but required (NVA-r), and total non-value adding (NVA) process at a given workstation. We carried out the value-added flow analysis at one of the electrical OEM in India as shown in the Table 1 to reduce waste and flow smoothening (Go Lean Six Sigma, 2020).

From the above value-added flow analysis, we analysed that the % of VA is 4.12, NVA-r is 0.06, and NVA is 95.82. This means that NVA or waste or overhead contributes to 95.82% of the total delivery lead time of the product to the customer.

3.2 Project charter

A project charter is a short official document that includes the details like objectives, actual targets, and executing team to track the project (Wrike, 2020). We formed the project charter as shown in the Table 2 by considering the month on month rising Actual Production Volumes of one of the electrical OEM in India as shown in the Figure 2 and high percentage of the NVA in the total delivery lead time of the product to the customer as shown in Table 1 for reducing the manufacturing process lead time and fastest delivery to the customer.

Table 1 The value-added flow analysis at one of the electrical OEM in India

Value-added flow analysis						
Name:	*Manager*		*Process name:*		*Product MTO*	
Date:	*17-06-2021*		*Time measured in:*		*Minutes*	
Sr. no	*From*	*To*	*Step label (VA, NVA, NVAr)*	*Value added time (Sec)*	*NVAr required work Time (Sec)*	*NVA – wait time (Sec)*
1	Station one	Station two	NVA		19	2730
2	Station two	Station three	VA	24	0	
3	Station three	Station four	VA		0	
4	Station four	Station five	NVA		25	
5	Station five	Station six	NVA-r		23	674
6	Station six	Station seven	VA	24	1	
7	Station seven	Station eight	NVA-r		1	
8	Station eight	Station nine	VA	28	8	
9	Station nine	Station ten	NVA-r		13	
10	Station ten	Station 11	NVA-r		1	
11	Station 11	Station 12	VA	14	2	312
12	Station 12	Station 13	NVA-r		1	
13	Station 13	Station 14	VA	47	0	800
14	Station 14	Station 15	NVA-r		7	
15	Station 15	Station 16	NVA-r		1	
16	Station 16	Station 17	NVA-r		6	
17	Station 17	Station 18	NVA-r		1	
18	Station 18	Station 19	VA	33	7	
19	Station 19	Station 20	NVA		0	233
20	Station 20	Station 21	NVA-r		11	

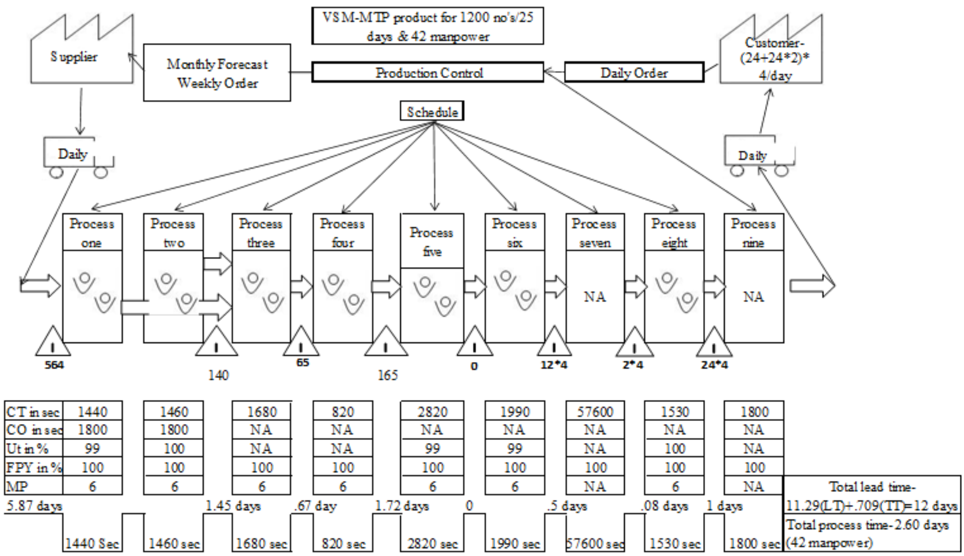
Table 1 The value-added flow analysis at one of the electrical OEM in India (continued)

Value-added flow analysis						
Name:	*Manager*		*Process name:*		*Product MTO*	
Date:	*17-06-2021*		*Time measured in:*		*Minutes*	
Sr. no	*From*	*To*	*Step label (VA, NVA, NVAr)*	*Value added time (Sec)*	*NVAr required work Time (Sec)*	*NVA – wait time (Sec)*
21	Station 21	Station 22	NVA-r		11	
22	Station 22	Station 22	VA	8	4	37
23	Station 23	Station 24	NVA-r		3	
24	Station 24	Station 25	NVA-r		9	
25	Station 25	Station 26	NVA-r	17	12	
26	Station 26	Station 27	VA		4	465
27	Station 27	Station 28	NVA-r	30	3	
28	Station 27	Station 29	NVA-r		32	
			Time in min	% of total		
Total value-added work time			225.67	4.12		10,957
Total non-value-added or NVA-r work time			3.4154	0.06		
NVA – wait time			5,249.5	95.82		
Total lead time			5,478.2	100		
Total lead time in day (1,200 no's in 25 days)			11,789			

Table 2 Lean Six Sigma deployment project charter

Main objective	*Deployment of the lean flow at product manufacturing process*		
Sub-objectives	*Description*	*Base line*	*Goal*
Business one	Reducing the in-house product manufacturing process lead time in days	14.6	10
Business two	Reducing the total product movement throughout the manufacturing process in metres	287	170
Consequential	Total manpower in no's	42	39

Figure 3 Current state VSM for one of the electrical OEM in India



3.3 *Current state value stream mapping*

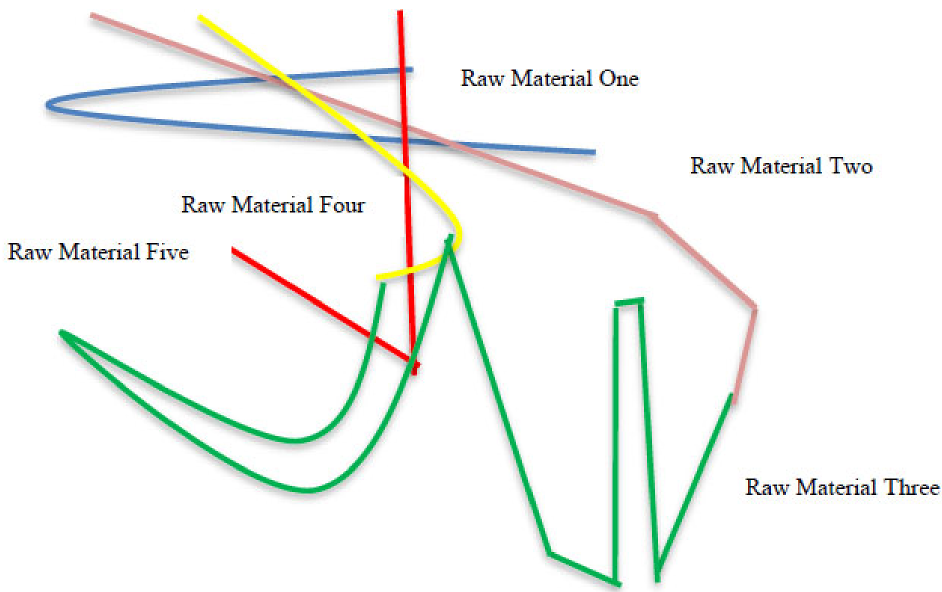
Value stream mapping (VSM) is one of the tools of the lean where every step of the manufacturing process is captured with all the details. VSM is a basic tool to calculate waste and improve the process. VSM combines the processing of the raw material with information or communication flow (ASQ, 2020a). We plotted the below VSM for one of the electrical OEM in India as shown in Figure 1. We calculated the total lead time is 14.6 days with 1,200 no's/month target and 42 no's of the manpower. Here, we identified the major area of concern as overhead that is raw material inventory and work in progress inventory causing higher product delivery lead time.

3.4 *Current state spaghetti diagram*

Spaghetti is a visual diagram of a flow of manufacturing line showing the actual path of product through a process. It helps a team to track the redundancies in the manufacturing flow and find out improvements to smoothen the flow (ASQ, 2020b). We mapped the spaghetti diagram as shown in the following Figure 2 for one of the electrical OEM in

India. We noticed that the actual manufacturing flow is zigzag, consuming lots of shop floor space, took 287 metre distance and 206 sec time to move one product throughout the process.

Figure 4 Current state spaghetti diagram for one of the electrical OEM in India (see online version for colours)



3.5 Ishikawa diagram

An Ishikawa diagram is used to decide the cause and its probable effect to identify the reasons for waste and failures in a manufacturing process. It is also called an Ishikawa diagram which is a main root cause analysis tool used in lean. The main problem is kept at the right facing and the probable causes annexed to the left (Reliable Plant, 2020). We plotted the Ishikawa diagram in Figure 3 as shown where the main objective is setting a single piece flow or the main problem is disturbed flow at one of the electrical OEM in India.

3.6 Current state FMEA that is failure modes and effects analysis

FMEA that is failure modes and effects analysis is a proactive standard process for checking a process to track how and where it will get fail. Further, we try to assess the impact of failures on the process that is in requirement of continuous improvement (IHI, 2020). We prepared the current state FMEA as shown in Table 3 and found out 5 main problems for probable improvement opportunities.

Table 3 Current state FMEA for one of the electrical OEM in India

Process/product name:						*MTO product manufacturing*			
Responsible:									
Sr. no	*Process step/input*	*Potential failure mode*	*Potential failure effects*	*Severity (1–10)*	*Potential causes*	*Occurrence (1–10)*	*Current controls*	*Detection (1–10)*	*RPN*
	What is the process step or feature under investigation?	In what ways could the step or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?		What causes the step or feature to go wrong? (How could it occur?)		What controls exist that either prevent or detect the failure?		
1	RM high inventory	High overhead cost	High lead time/SQ hamper/overall cost increases	6	No overhead limits defined	8	Visual	5	240
2	Imbalance manufacturing assembly line	Uncontrolled delivery	Delayed delivery/excess handling	8	Need effective method study	7	Daily production tracking	3	168
3	Cutting machine large size	Excess Handling	Excess handling	5	Need flow analysis	6	Visual	3	90
4	Layout constraint	Excess handling	Slow delivery	6	Layout constraint	5	Excess movement	5	150
5	Only Permanent operators work on assembly	Training matrix not followed	Quality hampers	7	No Skill matrix planed	7	Visual	4	196
6	Hourly output not constant	Delivery vary	Late delivery	8	Variable output	8	Hourly production tracking	3	192

Figure 5 Ishikawa diagram for one of the electrical OEM in India (see online version for colours)

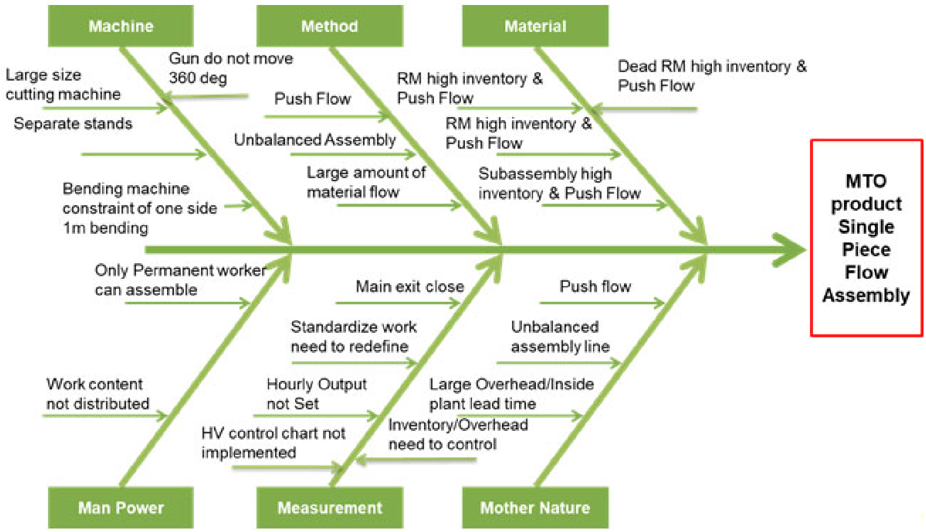


Table 4 Identified Kaizens at one of the electrical OEM in India

Sr. no	*Problem*	*Action plan*	*Status*
X1	RM High inventory	Kanban deployment	Close
X2	Imbalance manufacturing assembly line	Layout improvement and work balancing	Close
X3	Cutting machine large size	Machine layout improvement	Close
X4	Layout constraint	Layout improvement and work balancing	Close
X5	Only Permanent operators work on assembly	Training matrix improvement	Close
X6	Hourly output not constant	Single piece flow application	Close

3.7 Identified Kaizen that is continuous improvement's

Kaizen is a continuous or ongoing improvement. The first Japanese word 'kai' means 'change' and the second Japanese word 'zen' means 'good'. It was started by Toyota in the decade 1980s and has been used by many companies across the world. Kaizen culture continuously improves quality, cost, and efficiency (Rever Score, January 29, 2019). We listed the following 6 improvement opportunities at our manufacturing process under consideration. As shown in the Table 4.

3.8 After Failure mode and effect analysis

We prepared the after state FMEA as shown in Table 5 and found out 6 main problems for the single-piece flow deployment Risk Priority Number is reduced drastically after the improvement is done.

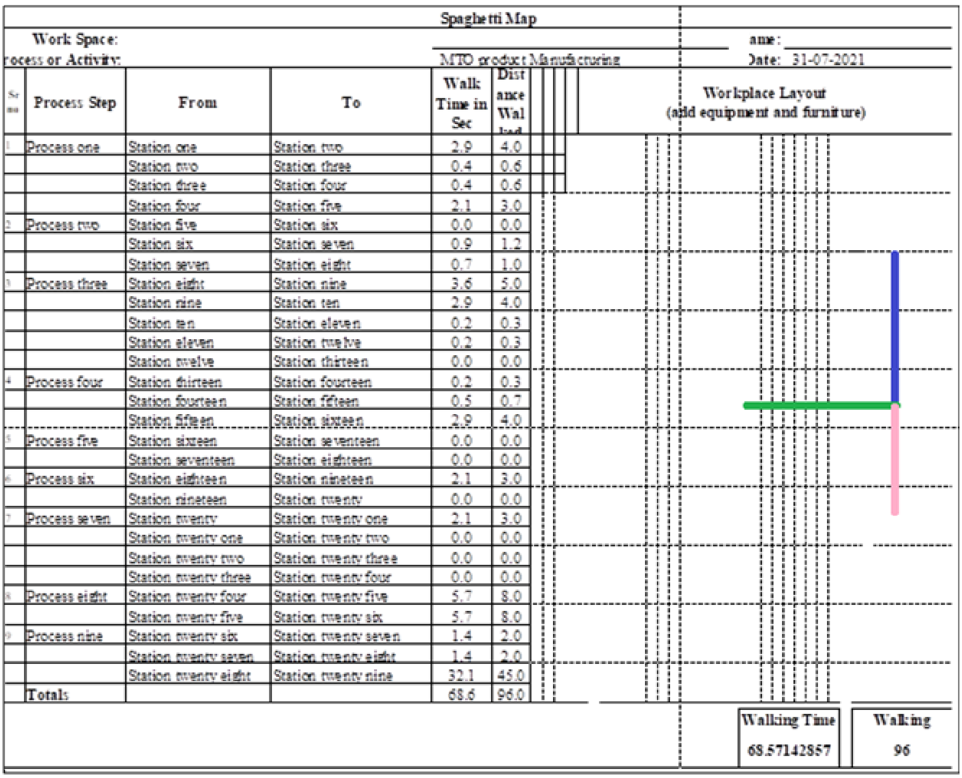
Table 5 After FMEA for one of the electrical OEM in India

Process/product name:								
Responsible:							*(Rev.):*	
Sr. no	*Process step/input*	*Potential failure mode*	*Potential failure effects*	*Actions taken*	*Severity (1–10)*	*Occurrence (1–10)*	*Detection (1–10)*	*RPN*
	What is the process step or feature under investigation?	In what ways could the step or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?	What actions were completed (and when) for the RPN?				
1	RM high inventory	High overhead cost	high lead time/sq. hamper/overall cost increases	Close	5	3	2	30
2	Imbalance manufacturing assembly line	Uncontrolled delivery	Delayed delivery/excess handling	Close	6	3	3	54
3	Cutting machine large size	Excess handling	Excess handling	Close	5	3	2	30
4	Layout constraint	Excess handling	Slow delivery	Close	4	3	3	36
5	Only permanent operators work on assembly	Training matrix not followed	Quality hampers	Close	5	5	3	75
6	Hourly output not constant	Delivery vary	Late delivery	Close	4	3	3	36

3.9 After state spaghetti diagram

We deployed all the improvement actions identified above at our manufacturing line. We again plotted the after-state spaghetti diagram to check and evaluate the effect of the improvements done as shown in Figure 4. Here, we found out that the flow is a single piece now, the total travel of product under manufacturing is reduced from 287 metres to 96 metres and the time taken for travel is reduced from 206 sec to 68.57 sec. Also, the total shop floor space is saved by approximately half of earlier.

Figure 6 After spaghetti diagram at one of the electrical OEM in India (see online version for colours)



Spaghetti Map

Work Space:
rocess or Activity: MTO product Manufacturing
ame:
Date: 31-07-2021

Sr no	Process Step	From	To	Walk Time in Sec	Distance Walked
1	Process one	Station one	Station two	2.9	4.0
		Station two	Station three	0.4	0.6
		Station three	Station four	0.4	0.6
		Station four	Station five	2.1	3.0
2	Process two	Station five	Station six	0.0	0.0
		Station six	Station seven	0.9	1.2
		Station seven	Station eight	0.7	1.0
3	Process three	Station eight	Station nine	3.6	5.0
		Station nine	Station ten	2.9	4.0
		Station ten	Station eleven	0.2	0.3
		Station eleven	Station twelve	0.2	0.3
		Station twelve	Station thirteen	0.0	0.0
4	Process four	Station thirteen	Station fourteen	0.2	0.3
		Station fourteen	Station fifteen	0.5	0.7
		Station fifteen	Station sixteen	2.9	4.0
5	Process five	Station sixteen	Station seventeen	0.0	0.0
		Station seventeen	Station eighteen	0.0	0.0
6	Process six	Station eighteen	Station nineteen	2.1	3.0
		Station nineteen	Station twenty	0.0	0.0
7	Process seven	Station twenty	Station twenty one	2.1	3.0
		Station twenty one	Station twenty two	0.0	0.0
		Station twenty two	Station twenty three	0.0	0.0
		Station twenty three	Station twenty four	0.0	0.0
8	Process eight	Station twenty four	Station twenty five	5.7	8.0
		Station twenty five	Station twenty six	5.7	8.0
9	Process nine	Station twenty six	Station twenty seven	1.4	2.0
		Station twenty seven	Station twenty eight	1.4	2.0
		Station twenty eight	Station twenty nine	32.1	45.0
	Totals			68.6	96.0

3.10 After state value stream map

We further plotted the after state VSM with all the proposed improvements deployment at one of the electrical OEM in India and found out that the total lead time is reduced from 14.6 days to 7.72 days as shown in Figure 5.

3.11 Consolidated results

We captured the actual values of the improvements done after deployment of Lean manufacturing at one of the electrical OEM in India as shown the Table 6.

Figure 7 After state VSM at one of the electrical OEM in India

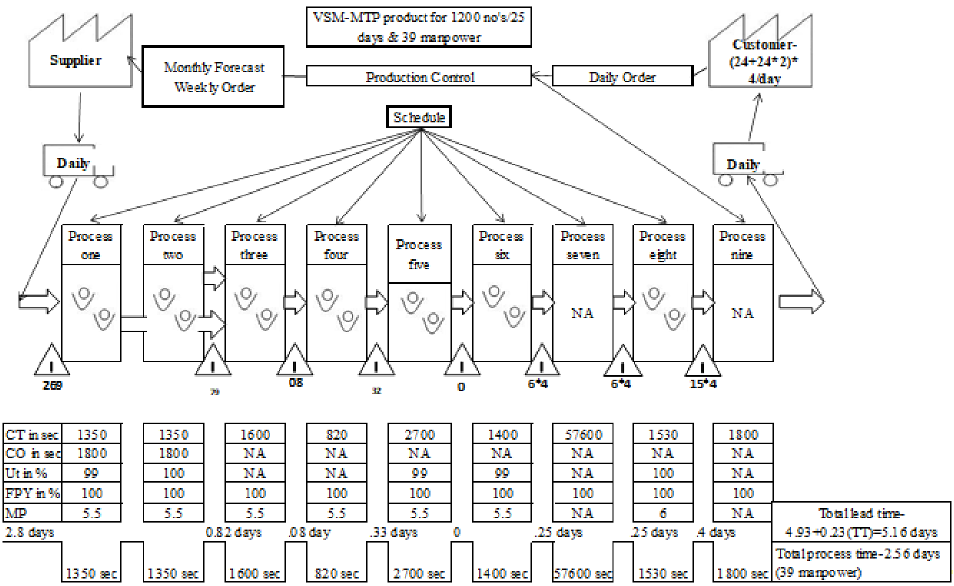


Table 6 Consolidated results after lean Six Sigma deployment

Sr. no	*Description*	*Base line*	*Goal*	*Actual*	*Reduction*
1	Reducing in house lead time	14.6 Days	10 Days	7.72 Days	47.12%
2	Reduction in product travel or run throughout the manufacturing process	287 metre	170 metre	96 metre	66.52%
3	Total required Manpower	42 No's	39 No's	39 No's	7.10%
4	Total small Kaizens done	NA	NA	108	NA
5	Total space saving	500 m2	200 m2	210 m2	42%
6	Process time	1,206 min	1,200 min	1,189.5 min	1.50%

4 Conclusions

The main manufacturing industry was badly affected by the 1st and the 2nd COVID-19 wave in India. In this case study, we analysed the impact of COVID-19 on one of the electrical OEM manufacturing industries in India through a lean manufacturing step-by-step guide. We found out that the product demand is falling and rising month on month in the year 2020 and 2021 while we were facing the COVID-19 pandemic. The value added-Flow analysis showed approximately 96% and the VSM study showed 85% of total delivery lead time is contributed by Non Value-added activities at the manufacturing process. We also plotted the spaghetti diagram and analysed that total product movement is 287 metres in the current state with the complex flow. We did total of six main Kaizens after the Ishikawa diagram and FMEA. We achieved the single-piece flow with half shop floor space-saving and total product movement reduced from 287 to 96 metres, while total delivery lead time reduced from 14.6 to 7.72 days. We concluded that lean Six Sigma deployment in the manufacturing industry helped to solve the problems of high inventories caused during COVID-19 due to demand fluctuations.

References

ASQ (2020a) *Spaghetti-Diagram* [online] https://asq.org/quality-resources/spaghetti-diagram (accessed 12 March 2021).

ASQ (2020b) *Value Stream Mapping* [online] https://asq.org/quality-resources/lean/value-stream-mapping (accessed 12 March 2021).

Economic Times (2021) *Index for Industrial Production* [online] https://economictimes.indiatimes.com/definition/index-for-industrial-production#:~:text=DefinitionATheIndexofIndustrial,CSOonamonthlybasis (accessed 6 July 2021).

Go Lean Six Sigma (2020) *Cycle-Time* [online] https://goleansixsigma.com/cycle-time/? (accessed 19 June 2021).

IHI (2020) *Failure Modes and Effects Analysis Tool* [online] http://www.ihi.org/resources/Pages/Tools/FailureModesandEffectsAnalysisTool.aspx (accessed 26 June 2021).

Reliable Plant (2020) *Fishbone Diagram* [online] https://www.reliableplant.com/fishbone-diagram-31877 (accessed 2 June 2021).

Rever Score (2019) *What is Kaizen Definition*? [online] https://reverscore.com/what-is-kaizen-definition/ (accessed 29 January 2019).

Twi-Global (2021) *What is Lean Manufacturing*? [online] https://www.twi-global.com/technical-knowledge/faqs/faq-what-is-lean-manufacturing (accessed 12 July 2021).

Wrike (2020) *What is a Project Charter in Project Management*? [online] https://www.wrike.com/project-management-guide/faq/what-is-a-project-charter-in-project-management/ (accessed 29 May 2021).