Reducing the Waste in the Manufacturing of Sprockets Using Smart Value Stream Mapping to Prepare for the 4.0 Industrial Era.

Review of Integrative Business & Economics Research

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ABSTRACT

The current manufacturing process of sprockets will need to incorporate the use of digital technology and artificial intelligence to improve its efficiency in order to prepare for the 4.0 industrial era. Even though inefficiencies will always be present in manufacturing processes, it is the objective of this research to reduce the inefficiencies in the manufacturing process of sprockets. The aim is to adapt and use Smart Value Stream Mapping to improve the manufacturing process to be ready for the 4.0 industrial era. The researcher has collected data from 22 key informants by way of observation and in-depth interviews. The data was then analyzed using the IDEF0 function modeling methodology and the manufacturing time was also studied. Pareto diagram and Why-Why analysis were also used. Smart Value Stream Mapping was adapted and used along with these methods. The research found that once the inefficiencies have been reduced by using Smart Value Stream Mapping to improve the manufacturing process, the efficiency of the manufacturing process increased by 74.05%. This resulted in an 9.93% reduction in manufacturing time, increasing the manufacturing capacity by 11.11%. This amounted to a 199,857 Baht increase in annual revenue for the manufacturer. The insights gained from this research can also be adapted to help improve other manufacturing lines in the future.

Keywords : Reduction of Inefficiencies, Manufacturing Process of Sprockets, Smart Value Stream Mapping, 4.0 Industrial Era.

1. INTRODUCTION

Sprocket Production Process has improved production processes continuously. Until now requires production process that emphasizes speed with a combination of automated manufacturing processes with the internet of things which the machine can connect to communication in the production process and can be controlled in real time

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by using digital technology and artificial intelligence to improve the production process to be faster and more efficient until the factory can be developed as a smart factory to support the encounters the era of industrial 4.0 Bauer (2018)

Sa-Nga Yont Autowork Co.,Ltd is one of the factories that produce sprocket in Buriram Province which is located in the northeastern part of Thailand which aims to develop the factory to be a smart factory However, found a waste which is non –value added occurs in the sprocket production process affect to the production process lasts 63.34 minutes while produced only 189 pieces affect to the lower production efficiency than 60.07% Therefore affecting the product's ability to be delivered on time and affect to the income only 1,812,693 baht per year

According to studies, it most found that studies the waste in the production process since the issue of application of value stream mapping to reduce the time in the production process.Fawaz and Jayant (2007),Venkataraman (2014) While some have studied the application of value stream mapping in industry 4.0 Wagner (2018) and application of value stream mapping 4.0 in holistic analysis and value stream design in digital transformation, application of value stream mapping in industrial 4.0 Hartmann (2018) but few have yet to study the reduction of waste in the production of sprocket and chain with application of smart value stream mapping. These are tools that have been developed from the value stream mapping which helps to analyze the flow of the production process and find the waste in the production process using digital technology and artificial intelligence to help improve the production process to be more efficient. If can reduce waste in the production process with application of smart value stream mapping. Expected to be beneficial to elimination of non-value added activities of the production process in the 4.0 era. For this reason, the researcher wanted to study the reduction of waste in the chain gear production with application of smart value stream mapping encounters the era of industrial 4.0 by studying from the Sa-Nga Yont Autowork Co.,Ltd located in Thailand. The objective is to study the sprocket and chain production process including studying the wastes that occurred in the sprocket and chain production process and study the causes of the loss in sprocket and chain production process including to propose reduce waste in the sprocket and chain production process with application of smart value stream mapping. The results of the study will enable entrepreneurs in this business know the wastes that occurred in the production process and can improve the production process to be more efficient with application of smart value stream mapping by using it to improve the production process encounters the era of industrial 4.0

2. LITERATURE REVIEW

This study has received tools that help study the production process, data

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collection, analysis, and solutions with various theories.

2.1 Process Flow of IDEF0

Veis(2009) mentioned that process flow of Integrated Definition for Function Modeling (IDEF0) is a diagram showing the details of various complex activities which is linked from the first activity to the last activity through inputs, output, control and mechanism on each activity that occurs. It demonstrates the relationship of the operative in each activity. Resources were used and related factors directed at each process of the supply chain by the composition of the drawing diagram of IDEF0 from the information flow and material flow consists of 5 important parts: 1.) Activity is relates to what shows the duties or actions in each activity which one activity can be subdivided into sub-activities and that have numbers showing the order of activities in the lower right corner of the square frame 2.) Input is relates to the section showing the direction of the flow of raw materials and the information that is needed for activities such as raw material, purchase order, etc. 3.) Control is related to the operation control in that activity to achieve results such as specification of product, working standards, quantity produced, etc. 4.) Mechanism is relates to the section showing that the activity occurred achieved by some factors such as budget, staff, etc. and 5.) Output is relates to the results from activities such as finished work in each process, etc.

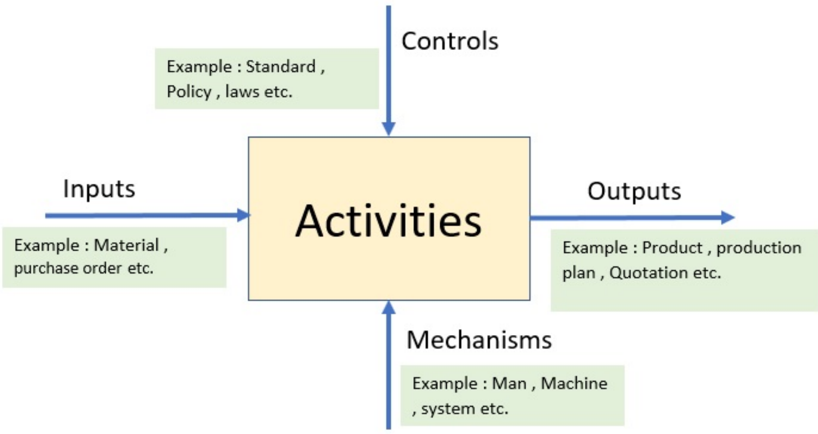

Figure 1: Diagram of IDEF0

The researcher will analyze IDEF0 with Version 9.3 will be in the form of activity modeling which will indicate the operation in each activity that shows the relationship of the Performance in each activity. There are resources used and factors that govern each process in the supply chain as shown in Figure 1.

2.2 Analysis of Production Process with Value Stream Mapping

Tapping (2003) mentioned the value stream mapping as shown in Figure 2 is tool to be able to see the flow of production started from ordering the material to

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delivering the product to the customer. This value stream mapping also presents the current state of production. The data can be used to analyze and improve the production process to reduce the loss. When finish improving, it will have the future state with high efficiency by simulation to help with analyzing and improving the production process for later on.

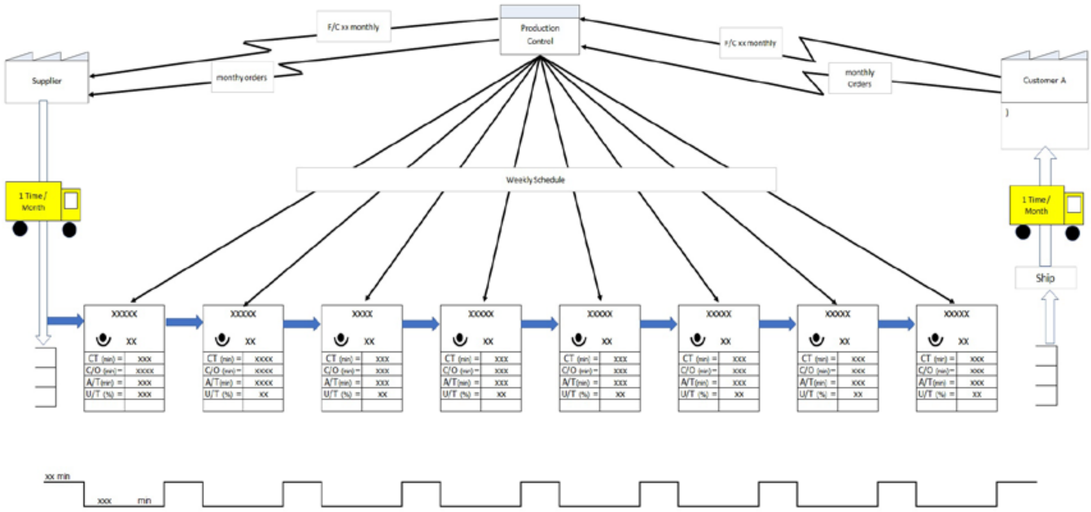

Figure 2: The example of Value Stream Mapping

Moreover, Hines and Taylor (2000) proposed the value stream mapping that it can indicate the characteristics of the activity in the 3 types of production process. 1) Value Added: VA is activities that have value for the production process and product by starting from raw materials or parts used in production until the end of the production process which determining whether activities are value-added activities or not, it must be viewed in the corner of the customer. 2) Non Value Added: NVA is the activities that do not make the product more valuable. And 3) Necessary Non Value Added: NNVA is activities that do not make the product more value but need to carry out activities in order to be able to produce products.

2.3 The analysis of Why Why analysis with 5 Gen

Ogura (2006) mentions Why Why analysis is a tool used to analyze the root causes of real problems. Which, when able to find the root of the problem and get rid of it, it will prevent the problem from recurring again but if the original problem is repeated, new analysis must be made. When the 5 Gen principles are incorporated into the analysis, the analysis will be more effective. 5 Gen principle consists of 1) Genba which means the real site or the working area such as plant area, product storage area, quality checking area and so on, 2) Genbutsu means the item or work that is the problem or the piece being examined, 3) Genjitsu means real situations or events that are causing problems which may be a problem from the environment,

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process, work process or time that causes waste or frequent problems, 4) Genri means the related theories or working principle or the control production standard including various production formulas, and 5) Gensoku means related condition such as the agreement, limitation, rule or regulation. All these things are necessary to find the causes and analyze the problem in the correct point. The example of why why analysis is shown in Figure 3.

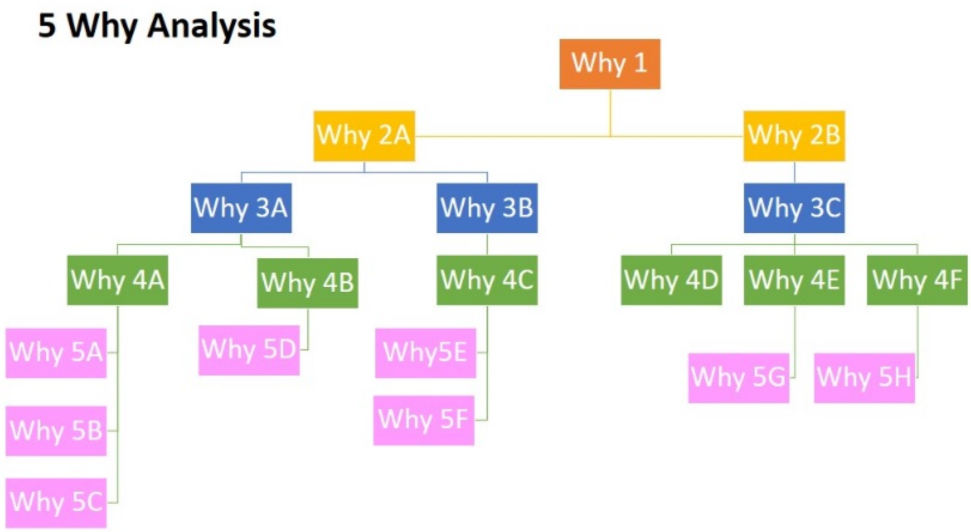

Figure 3: The example of why why analysis

2.4 Smart Value Stream Mapping

Haichemi (2017) discusses the combination of lean and digital production that both will be one of the key success factors in the future for the production system to cope with more challenges. Smart Value Stream Mapping (SVSM) was developed from Value Stream Mapping (VSM) which is origin and popular and it becomes one of the methods of production that very efficiency and generally uses for adding the effective of the core principle. By eliminating activities that do not add value, it is one of the key principles that is the goal of the value stream mapping. In the past few years, Digital Manufacturing or Industry 4.0 has been revised to improve the complexity and change of modern production systems. Vision including high-level digital transformation, data flow, material flow for the factory as an automated system and including suppliers and customers.

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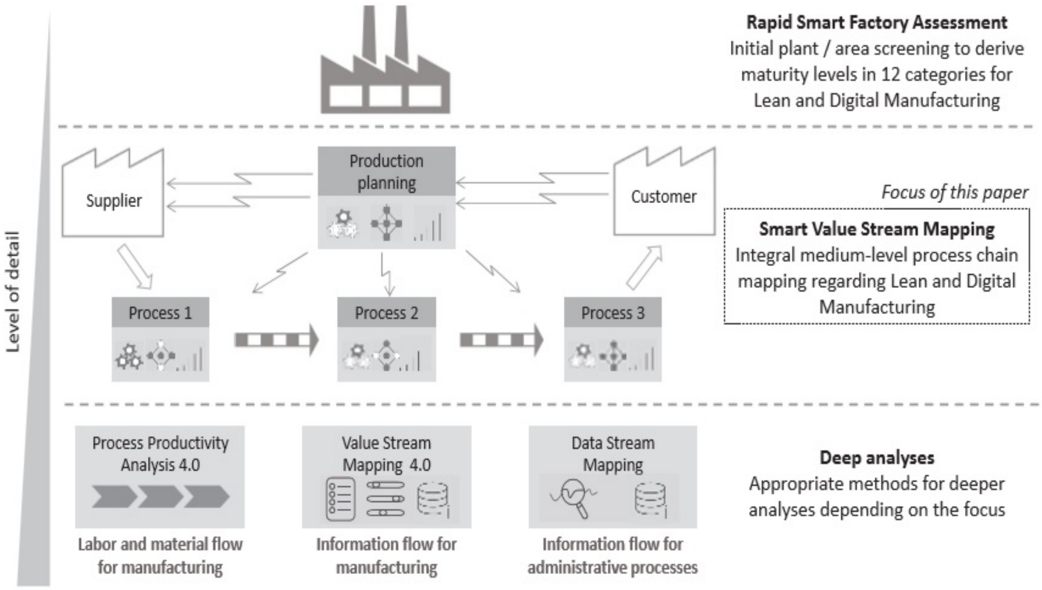

Figure 4: Smart Value Stream Mapping
Source: Haichemi (2017)

3. METHODOLOGY

This study aims to study the production process, the sprocket to find the waste, resulting in the process, and reduce waste in the manufacturing process sprocket by the application of smart value stream mapping, which is a leading digital use with value stream to make more efficient, can communicate information quickly, including analysis and response to manufacturing process in industry 4.0 era who need quick process and effectiveness most studies were conducted as follows:

3.1 Data collection

The researchers had brainstormed together with the participants such as the manager and 22 production officers. The criteria of selecting the participant include 1) the direct officers on sprocket and chain, 2) those who relates to the production process in order to plan the data collection in each activity of the production of sprocket started from cutting activity, digging activity, welding activity, turning activities, planning activities, tapping activities, solid activity and coloring activities through smartphone with application Line as shown in Figure 5 by create the line group in order to communicate and send the real time data which was determined the manager to timer in each activity of the sprocket production to find the average in each one and sent the data via smartphone.

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3.2 Data Analysis

When having the data, the researchers brought this information to analyze with the diagram of IDEF0 Version 9.3 and Why Why analysis + 5Gen by calculating since cycle time, Task time, Uptime, Changeover time, and so on. From the formula of Haichemi (2017) through the use of applications from smartphone for quick calculation such as Application Takt Application Lean Manufacturing as shown in Figure 5. Then using the calculated data was analyzed by the value stream mapping and smart value stream mapping in order to analyze which activities take much time and which activities that do not increase the value. This is necessary to eliminate in the production process. When knowing which activities need to improve and then sending the data to manager, the meeting and analysis will be hold with the participants from smartphone to present the way to reduce loss of sprocket production by applying smart value stream mapping.

Figure 5: Applications that were used to collect and analyze data

3.3 Data reliability testing

From the study, the researcher relied on the use of real data by recording conversations and recording still images. The study examined the reliability of the data using a triangular method which is a method that can prove that the information that the study has acquired is correct.

4. RESULT AND DISCUSSION

The result was from the data collection that can bring to analyze due to each purpose as follow:

4.1 The result of the study of sprocket and chain production

The result from the communication group found that the sprocket production consists of 8 activities since cutting activity, drilling activity, welding activity, turning activities, shaping activities, tapping activities, hardening activity and coloring activities as shown in Figure 6.

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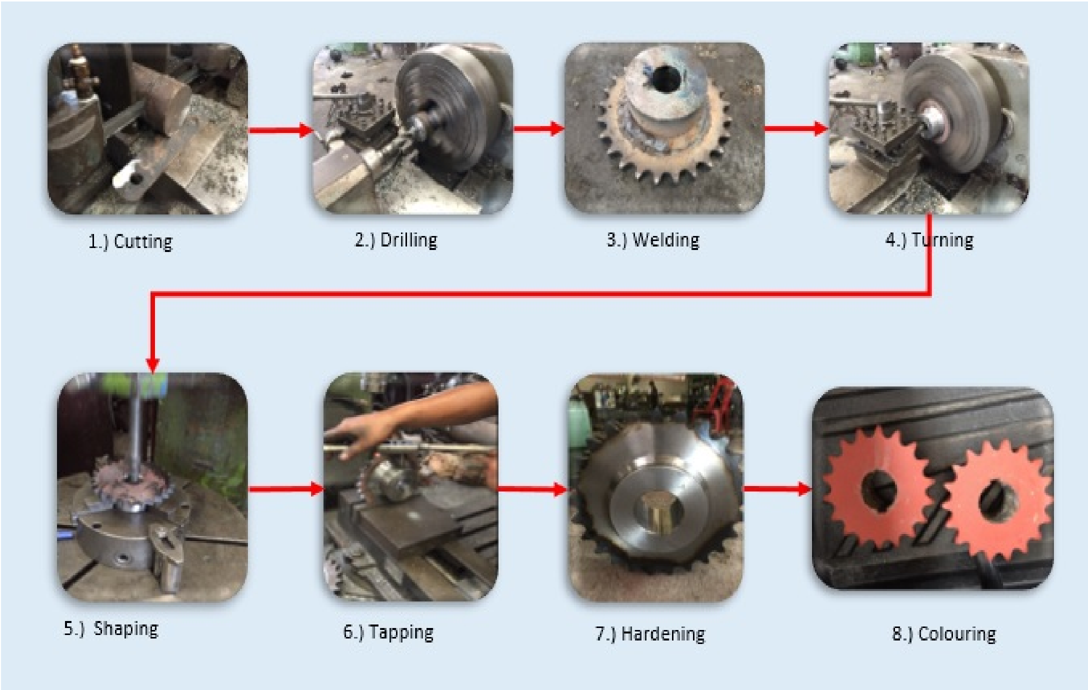

Figure 6: Each activities in the sprocket production.

When analyzing the above activities, the IDEFO process found activity from receiving orders from customers. Then start the production process by cutting the steel to the size used by the cutter. Then sent to the drill work to drill to the size of the drill, then sent to the welding activity, which will connect the chain hub to the chain face. It will inspect the weld with the eyes not to have cracks. Then forwarded to the turning activity will be machined to the size that is used and will be measured with a measuring instrument. Then will be sent to shaping activities to perform the keyway on the hub sprocket, the keyway size will be checked by measuring instruments. Then, will be sent to the tapping activity to drill holes and thread taps. For locking the shaft and the sprocket tightly, then will be sent to the hardening activity to increase the hardness and wear resistance of the sprocket. Then, will be sent to the coloring activity to prevent rust and output will get the sprocket that is ready to use according to the size that the customer wants as shown in Figure 7.

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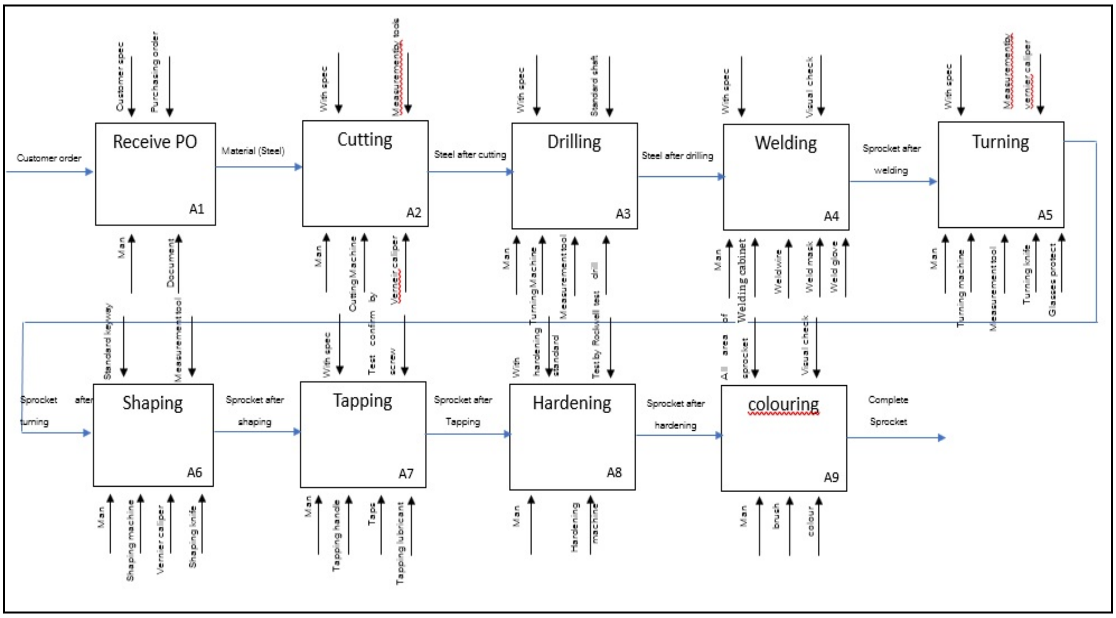

Figure 7: The analysis of the activity on the sprocket production process with the diagram IDEF0

4.2 The result of study loss that occurred in the sprocket production

Results from the above study, when analyzed for all activities in the production sprockets, value stream mapping was found that Planning activities are activities that take the most time up to 13.04 minutes, as shown in Figure 8.

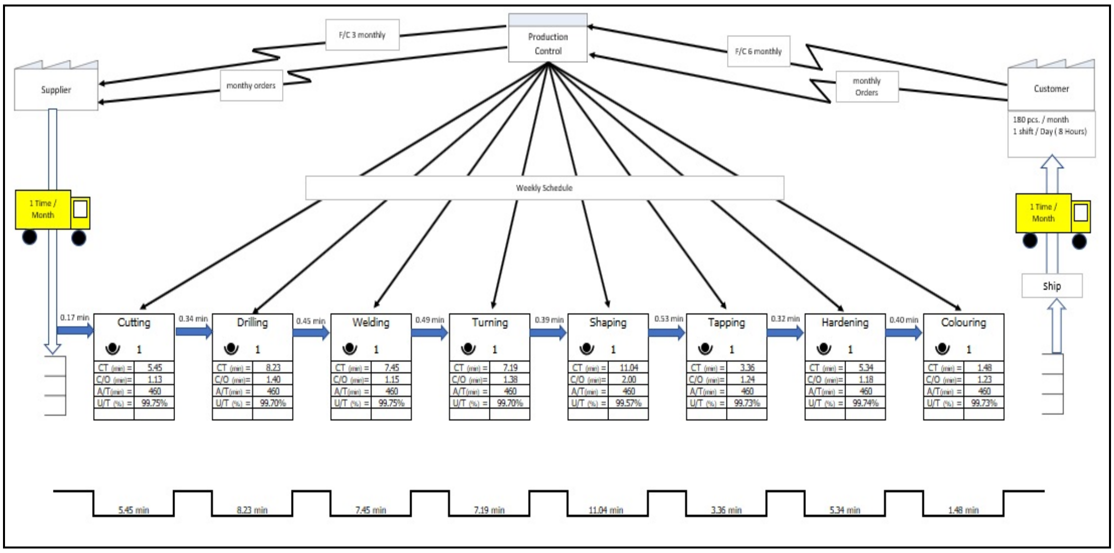

Figure 8: Value stream mapping of the sprocket production process

From the image above, when analyzing activities that occur as activities that increase the value of VA including cutting activity, drilling activity, welding activity, turning activities, shaping activities, tapping activities, hardening activity, coloring activity, machine setup activities and activities that do not add value but necessary

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NNVA such as moving the product and measuring the product are the loss that occurred in the sprocket production process which is necessary to get rid of this activities from the production process as shown in Table 1.

Table 1: The analysis of the activities of the sprocket production process.

Main Activity	Sub activity	Time (Min.)	Activity process	analysis Activity
Cutting	Move material to cutting machine	0.17	Transpotation	NNVA
	Changeover Time machine	1.13	Operation	VA
	Cutting	5.35	Operation	VA
	Measurement	0.10	Inspection	NNVA
Drilling	Move material to Drilling machine	0.34	Transpotation	NNVA
	Changeover Time machine	1.40	Operation	VA
	Drilling	8.11	Operation	VA
	Measurement	0.12	Inspection	NNVA
Welding	Move material to Welding machine	0.45	Transpotation	NNVA
	Changeover Time machine	1.15	Operation	VA
	Welding	7.21	Operation	VA
	Visual check	0.24	Inspection	NNVA
Turning	Move material to Turning machine	0.49	Transpotation	NNVA
	Changeover Time machine	1.38	Operation	VA
	Turning	6.95	Operation	VA
	Measurement	0.24	Inspection	NNVA
Shaping	Move material to Shaping machine	0.39	Transpotation	NNVA
	Changeover Time machine	2.00	Operation	VA
	Shaping	4.50	Operation	VA
	Measurement	6.54	Inspection	NNVA
Tapping	Move material to Tapping machine	0.53	Transpotation	NNVA
	Changeover Time machine	1.24	Operation	VA
	Tapping	3.26	Operation	VA
	Measurement	0.10	Inspection	NNVA
Hardening	Move material to Hardening machine	0.32	Transpotation	NNVA
	Changeover Time machine	1.18	Operation	VA
	Hardening	5.22	Operation	VA
	Measurement	0.12	Inspection	NNVA
Colouring	Move material to Colouring	0.40	Transpotation	NNVA
	Changeover Time machine	1.23	Operation	VA
	Colouring	1.33	Operation	VA
	Visual check	0.15	Inspection	NNVA
Total	**32 Activities**	**63.34**		

According to the table of analysis of the activities in the sprocket production process, it can show the ratio of the value of the activities as shown in Table 2.

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Table 2: The ratio of the value of activities on the sprocket production process

Value Activities	Activity		Time	
	Amount	Percentage	Min.	Percentage
Value Added (VA)	16.00	50%	52.64	83.11%
Non Value Added (NVA)	0.00	0%	0	0%
Necessary Non Value Added (NNVA)	16.00	50%	10.70	16.89%
Total	32.00	100%	63.34	100.00%

From the activities above, it was found that the activities that increase the value VA consist of 16 activities by using time up to 83.51% and the NNVA consist of 16 activities by using time up to 16.49%. But from the analysis it can be seen that in the shaping activities An activity that does not add value but needs NNVA by spending time to 6.54 minutes, the activity measurement is higher than activity that does not add value but needs NNVA in all activities result in more time spent in activities shaping higher with up to Figure 9.

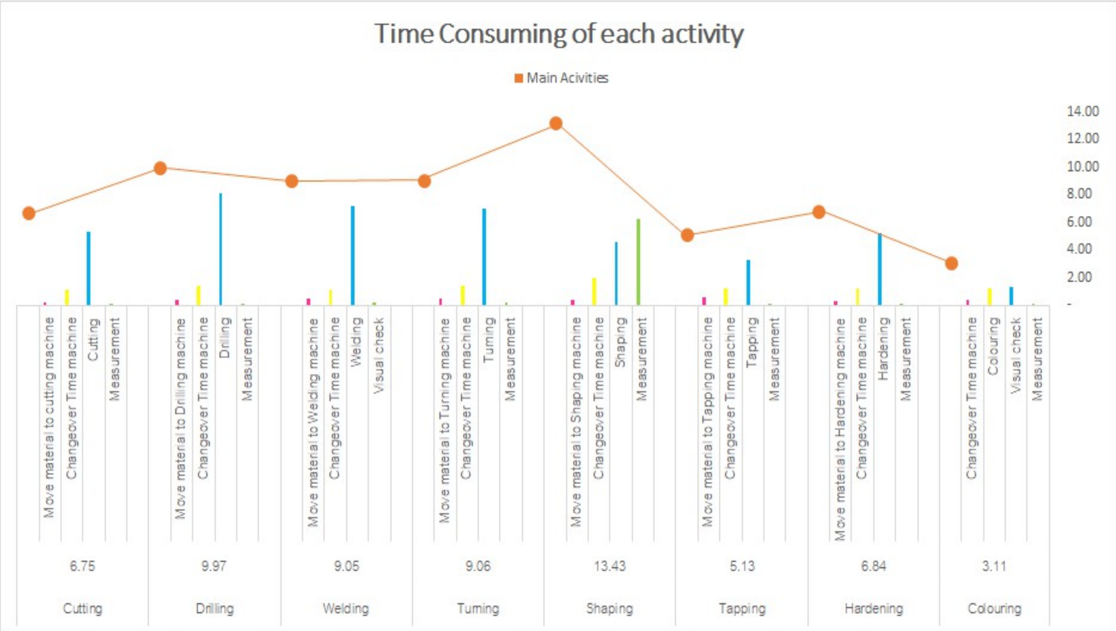

Figure 9: Diagram of used time in each activity of the sprocket production process

Therefore, it is necessary to analyze the cause of loss on the sprocket production process next.

4.3 The result of the study the cause of loss in the sprocket production process

After brainstorming and analyzing with Why Why analysis and 5 Gen to find the cause of loss in the sprocket production process, Genri and Gensoku found that the cause of shaping activity takes much time in accordance with having check the size of

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keyway frequently to get the size that wanted. Therefore, the experiment of drawing the size of the keyway before shaping activity was found that it does not take much time so that this data was sent in line group and brainstorming suddenly how to do so and it had been presented to make a sheet of keyway standard by using zinc sheet. Then, considering and ordering immediately with digital technology so that it makes the communication goes faster and gets the faster solution as shown in Figure 10.

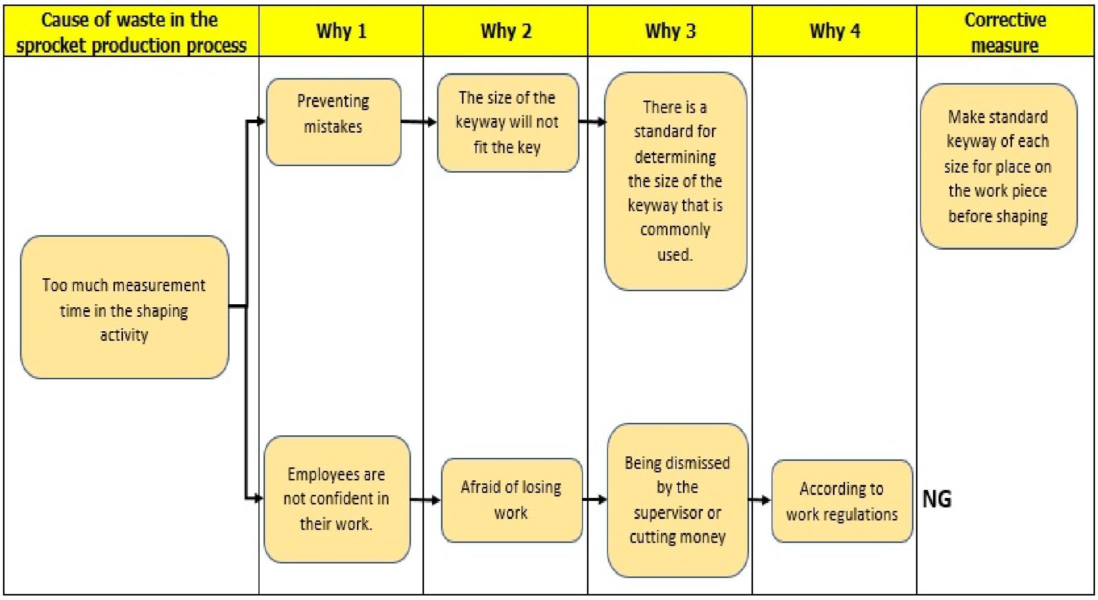

Figure 10: The mapping of cause analysis with why why analysis with 5 gen

4.4 The result of study loss that occurred in the sprocket production with the application of smart value stream mapping

The result of study loss that occurred in the sprocket production above provide the suggestion to reduce the loss on the production process faster with the application of smart value stream mapping by creating the standard sheet of the keyway to reduce the procedure of measuring that occurred most frequently out and creating loss on the production process. The keyway standard sheet was created due to industrial product standard TISI 289-2521 as shown in Figure 11.

This standard for industrial products determines the type, shape, dimension and criteria for moving according to

ISO 773-1969 Rectangular or square parallel keys and their corresponding keyways

ISO 774-1969 Taper keys with or without gid head and their corresponding keyways

This standard keyway sheet is used to place on the workpiece before making the employee to be able to plan the keyway groove by looking at the size of the groove from the sheet immediately. There is no need to stop the machine in order to measure

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the workpiece.

Shaft		Key	Keyway											
Diameter (mm.)		Size	Size	Width (W) mm.					Height (b) mm.				Radius ®	
		w x b (mm.)	specified	Stardard tolerance					Shaft l_1		Wheel l_2			
From	To			Shake		Fit		Compress					Maximum	Minimum
				Shaft	Wheel	Shaft	Wheel	Shaft & Wheel					(mm)	(mm)
12	17	5 x 5	5	+0.030	+0.078	0	+0.015 0	-0.012	3.0	+0.1	2.3	+0.1	0.25	0.16
17	22	6 x 6	6	0	+0.030	-0.030	-0.015 0	-0.042	3.5	0	2.8	0	0.25	0.16
22	30	8 x 7	8	+0.036	+0.098	0	+0.018 0	-0.015	4.0		3.3		0.25	0.16
30	38	10 x 8	10	0	+0.040	-0.036	-0.018 0	-0.051	5.0		3.3		0.40	0.25
38	44	12 x 8	12						5.0		3.3		0.40	0.25
44	50	14 x 9	14	+0.043	+0.120	0	+0.021 5	-0.018	5.5		3.8		0.40	0.25
50	58	16 x 10	16	0	+0.050	-0.043	-0.021 5	-0.061	6.0		4.3		0.40	0.25
58	65	18 x 11	18						7.0	+0.2	4.4	+0.2	0.40	0.25
65	75	20 x 12	20						7.5	0	4.9	0	0.60	0.40
75	85	22 x 14	22	0.052	+0.149	0	+0.026 0	-0.022	9.0		5.4		0.60	0.40
85	95	25 x 14	25	0	+0.065	-0.052	-0.026 0	-0.074	9.0		5.4		0.60	0.40
95	110	28 x 16	28						10.0		6.4		0.60	0.40
110	130	32 x 18	32						11.0		7.4		0.60	0.40
130	150	36 x 20	36	0.062	+0.180	0	+0.031 0	-0.026	12.0		8.4		1.00	0.70
150	170	40 x 22	40	0	+0.080	-0.062	-0.031 0	-0.088	13.0	+0.3	9.4	+0.3	1.00	0.70
170	200	45 x 25	45						15.0	0	10.4	0	1.00	0.70

Figure 11: keyway standard

Sheet of standard keyway made of galvanized sheet with a size of 0.1 mm. The cut to the size of the hole and shaft size keyway the standard set by the first stage of this plan standard keyway 4. Size including 1) the size of shaft Ø 30.0 mm. with the width of keyway at 8.00 mm. deep at 7.00 mm., 2) the size of shaft Ø 38.0 mm. with the width of keyway at 10.00 mm. deep at 8.00 mm., 3) the size of shaft Ø 44.0 mm. with the width of keyway at 12.00 mm. deep at 8.00 mm., and 4) the size of shaft Ø 50.0 mm. with the width of keyway at 14.00 mm. deep at 9.00 mm. as shown in Figure 12 by all 4 sizes are the usual size that always used. What if it makes the better result, the standard sheet will be created with any sizes in later on.

Figure 12: The example of keyway standard sheet of 4 sizes

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5. CONCLUSION

The result of study loss that occurred in the sprocket production with the application of smart value stream mapping found that the activity that is NNVA which is the loss that needs to get rid of from the production process.

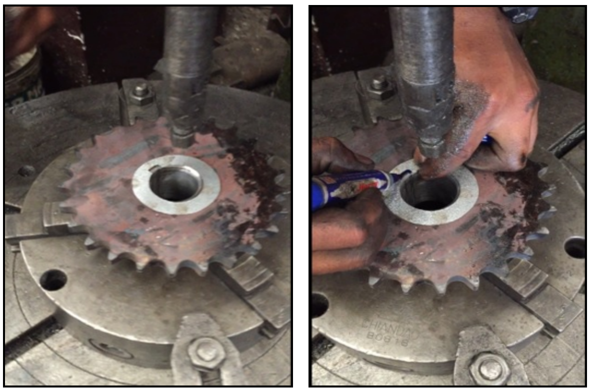

Figure 13: The demonstration of using keyway standard sheet

When experimenting with standard keyway in shaping activities, it was found that the measurement procedure can be reduced from 6.54 minutes to 0.25 minutes. It is an activity that does not add value relevant with Guo, Ding and Mei (2010) who use the value stream mapping to analyze NNVA and get rid of by using lean machine with digital technology. It results to the employees who do not have to frequently check and stop the machine so it can continue the machine regularly. It leads to the decreasing time of produce the product from 63.34 minutes to 57.05 minutes or reduce 9.93% which related to Fawaz and Jayant (2007) who also use the value stream mapping to analyze the loss so that it makes more efficient in the production process up to 74.05% which can reduce time of shaping activity from 13.43 minutes to 7.14 minutes as shown in Figure 14 and can increase the products up to 11.11% which resulting to have more revenue up to 199,857 baht per year.

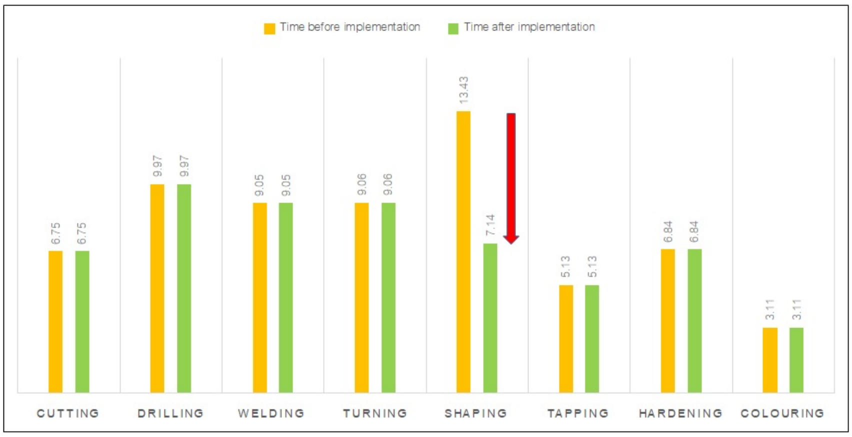

Figure 14: The comparison of time on sprocket production process for before and after.

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6. RECOMMENDATIONS

6.1 The recommendations in this study

Management should formulate policies to reduce loss in the production process for each department by arranging for responsible persons, pay attention to and encourage enthusiasm in continuing to reduce loss.

6.2 The recommendations for further study

Improving the production process to be more efficient should use tools to analyze and improve processes that can help reduce loss that covers all loss so that it can be used to improve in other production processes.

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