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Effectivity of Digital Information Systems in improving the productions of Palm Oil Plantation using Six Sigma DMAIC (Case study in PT. Alam Plantase Indah)

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Abstract

Palm oil and its processed products is one of the highest foreign trades in Indonesia. PT. Alam Plantase Indah is one of the palm oil plantations in Indonesia that has high operational challenges, where issues of labor, land, market prices, and production quality are the starting point for the quality of processed products into CPO and other derivative products. However, judging from the productivity of palm oil plantations in Indonesia, it is still inferior to several neighboring countries whose productivity is higher than the national average productivity. From preliminary observation in July 2021 PT. Alam Plantase Indah has Capability Process (CP) value is 77 and sigma score is 2.67 σ. This study aims to measure the effectiveness of the using plantation digitalization system to increase crop productivity in palm oil plantations using DMAIC Six Sigma approach in order to find out the root cause of the problems whether the digitalization model applied is able to solve these problems so that it can participate in increasing the productivity of plantations that apply the system of digitalization.

Keywords
plantation digitalization; DMAIC six sigma; effectivity; quality.

I. Introduction

Palm oil plantations are one of the largest foreign trade-producing industries in Indonesia with a land area of almost 16.38 million hectares (BPS, 2020), and is one of the countries with the largest oil palm plantations in the world. However, along with the large area, it can be seen that the productivity of oil palm plantations in Indonesia is still inferior to neighboring countries which also have oil palm plantations, according to Riyanto in Elbandiansyah (2019), technically productivity is a comparison between the results achieved) with all the required resources (inputs).

Table 1. List of countries with palm oil plantations

Country	Area (Million Ha)	Production (Million Ton)
Indonesia	16,38	43,5
Malaysia	5,35	19,3
Thailand	0,8	3
Kolombia	0,2	1,6
Nigeria	2,5	1

Source: Warta Ekonomi, 2020

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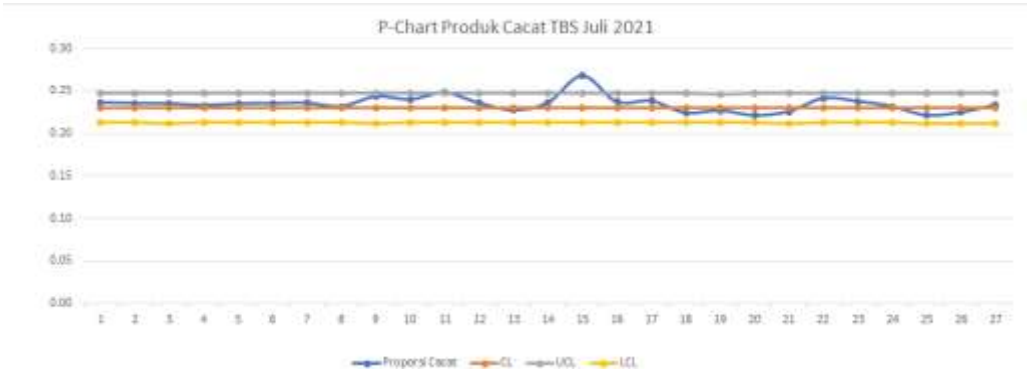
In the development of the industrial revolution 4.0 in Andreja Rojko (2017) Internet of Things (IoT) which is an amalgamation of digital, mechanical and computing machines to carry out various functions through communication connected to the internet, Integration of technical processes and business processes within the organization, Digital Mapping and virtualization into real and Smart locations, Artificial Intelligence and Machine learning to support high efficiency and accuracy processes. This technology in many types of industry is growing rapidly, but there are still many oil palm plantations that are managed using operational governance still manually. In the midst of increasingly fierce competition, business challenges and fluctuations in commodity prices for palm oil and its derivatives, PT. Alam Plantase Indah tries to use its resources so that it can run effectively and efficiently to increase its effectiveness and efficiency in order to compete. For that PT. Alam Plantase Indah started the implementation of plantation digitization in order to increase operational effectiveness by implementing the plantation digitization system. Handayaningrat in Edam S. E. et al (2018) states that effectiveness is a measurement in the sense of achieving predetermined goals, and goals or objectives have been achieved in accordance with what was previously planned, which is called effective. Development is a systematic and continuous effort made to realize something that is aspired. Development is a change towards improvement. Changes towards improvement require the mobilization of all human resources and reason to realize what is aspired. In addition, development is also very dependent on the availability of natural resource wealth. The availability of natural resources is one of the keys to economic growth in an area. (Shah, M. et al. 2020)

The harvest foreman team is the front line responsible for the harvest in each division or division in accordance with the schedule and harvest rotation that has been set in the plantation scope of PT. Alam Plantase Indah, where the production quality of the harvest / defect is above the lower threshold of the standard set by the company. The low quality of this crop resulted in low yields of tons / ha because a lot of the harvest was not paid for by the client and or cut, this would affect the income of the workers and the company PT. Alam Plantase Indah.



Source: Data olahan Peneliti

Figure 1. *P-Chart Fruit Production Defect*

Based on the diagram above, it can be seen that the amount of harvested production of PT. Alam Plantase Indah that has defects / defects outside of the standard limits set by the company. The number of these products has made PT. Alam Plantase Indah wishes to reduce the number of defects and seeks to eliminate them by measuring through the Six Sigma project to find out the root of the existing problems and their solutions and one of

the efforts to reduce the factors that have been found, PT. Alam Plantase Indah implements a harvest digitization system in its company.

This research was conducted to measure the effectiveness of using the harvest digitization system at PT. Alam Plantase Indah uses the DMAIC Six Sigma cycle approach to analyze the root problems that occur in the "before, shortly and after" period, namely planning, harvesting and delivering fruit to clients, in an effort to control the quality of harvest production to suppress and eliminate defects in an effort to increase fruit bunch production. fresh quality to the customers of PT. A B C.

II. Review of Literature

2.1 Effectiveness

Effectiveness is the main element in the organization that is measured for achieving the goals and objectives of the activities or programs that have been determined in each organization, which will be called effective if the goals or objectives of the program or activity are as determined. Effectiveness is a form of achievement of an organizational goal by using its resources efficiently input-process-output, the resources in question include the availability of 5M namely:

1. Man, Expert Employees
2. Material, Includes production material,
3. Money, Funding
4. Machine, Production machines and work tools.
5. Method, Work Methods, SOP

According to Ali Muhidin in Claudia et. al (2019), explains that effectiveness is also related to the problem of how to achieve the goals or results obtained, the usefulness or benefits of the results obtained, the level of functional power of elements or components, as well as the problem of the level of user/client satisfaction.

2.2 Digital Harvesting Information System

An effective system is defined as a system that can provide added value and can have a positive influence on its users in a process within an organization. According to Martin, et al (2016) states that a system that is said to be effective can be analyzed based on several criteria such as: it can increase business effectiveness, can expand business or services, and can increase the competitive advantage of an organization. According to Marshall B. Romney (2016) Information Systems consist of five components, namely:

a. Humans who operate and carry out various functions of the system.
b. Method, the method of work used in entering, storing, processing, and reporting in every activity in the organization.
c. Data about the organization's business processes
d. Applications or software used to process the data of an organization.
e. Information Technology infrastructure, computer hardware and various supporting equipment as well as equipment for network communication both local and internet..

2.3 Six Sigma DMAIC

The Six Sigma method is generally known as a technique that allows a company to improve the quality of its products. The Six Sigma approach was first developed by Bill Smith, Vice President of Motorola Inc. (Hiroshi Kume, 1989) as a practical design for improving manufacturing processes and eliminating defects. In the Six Sigma method, the term defect is known as a form of output from a process that does not meet the quality

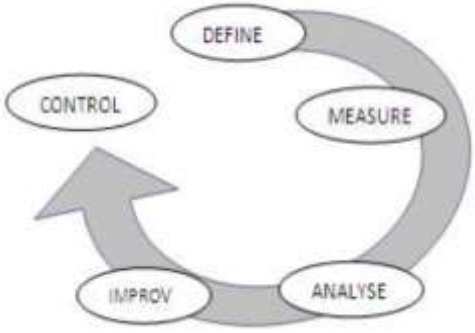
criteria and specifications from the customer or something that can result in output or product that does not match the planned criteria and specifications.

TINGKAT SIGMA	DPMO	COPQ
1-sigma	691.462 (sangat tidak kompetitif)	Tidak dapat dihitung
2-sigma	308.538 (rata–rata industri Indonesia)	Tidak dapat dihitung
3-sigma	66.807	25-40% dari penjualan
4-sigma	6.210 (rata–rata industri USA)	15-25% dari penjualan
5-sigma	233 (rata–rata industri Jepang)	5-15% dari penjualan
6-sigma	3.4 (industri kelas dunia)	< 1% dari penjualan

Source: Gasperz, (2003)
Figure 2. *Sigma Achievement Table*

According to Gaspersz, (2003), the Six Sigma strategy method aims to improve business performance by reducing various variations of detrimental processes, such as reducing production or process failures, suppressing product defects, boosting employee morale and always trying to maximize the quality of a product[6].

The DMAIC method, which is Define, Measure, Analyze, Improve and Control is a process for continuous improvement to achieve Six Sigma targets. DMAIC is carried out systematically, based on science, data and facts. This DMAIC cycle process seeks to eliminate the steps of one or more process processes that are not productive, continue to focus on new measurements, and establish technology for quality improvement towards Six Sigma targets[6], (Gaspersz, 2003). The DMAIC method is one of the cycles used in the Six Sigma method that works continuously and continuously until the goals to be achieved by the company are achieved.



Source: Gasperz, (2003)
Figure 3. *DMAIC Process*

DMAIC is a problem-solving method model that is widely used in quality improvement and improvement of existing processes as well as better process planning. DMAIC is often associated with activities in the implementation of Six Sigma, and vice versa, many Six Sigma applications often also use the DMAIC approach.

III. Research Method

This research is descriptive qualitative (Qualitative descriptive research) which is research that solves a problem that exists now systematically and factually based on existing data by measuring baseline and sigma performance of current conditions and compared with performance data and sigma after the implementation of the digitization system. harvest, quality control.

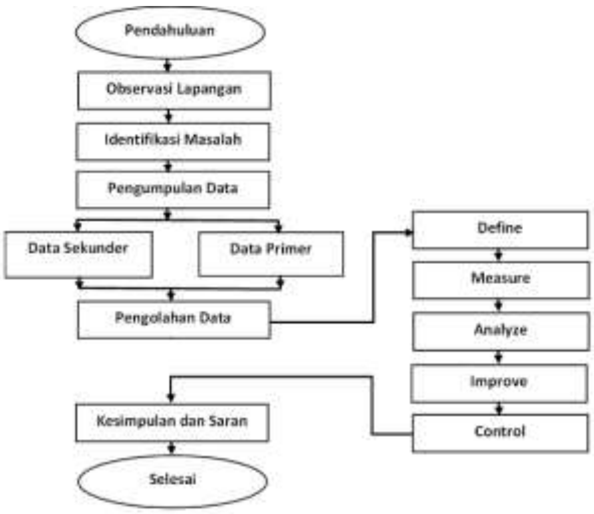


***Figure 4.** Research Method*

This research was conducted from production data for FFB of PT. Alam Plantase Indah during the period July 2021 – September 2021. The sample data obtained is saturated, mapped using the P-Chart Control Map. Performance Baseline calculations are carried out to obtain Process Capabilities using the average proportion of defects and production are as follows:

1. The formula for calculating the average value of the proportions carried out with the production data is as follows:

$$\bar{p} = \frac{\sum_{i=1}^{g} p_1}{g} \quad \text{……………………………………………………….(1)}$$

2. Calculating Center Line/CL, Upper Control Limit/ UCL and Lower Control Limit/ LCL, to get a quality control map, is as follows:

$$CL = \bar{p} \quad \text{……………………………………………………….(2)}$$

$$UCL_1 = \bar{p} + 3 \cdot \frac{\sqrt{\bar{p}(1-\bar{p})}}{n_1} \quad \text{…………………………………….(3)}$$

$$LCL_1 = \bar{p} - 3 \cdot \frac{\sqrt{\bar{p}(1-\bar{p})}}{n_1} \quad \text{…………………………………….(4)}$$

3. Defect per Unit (DPU)
   This measure shows the average number of defects of all types to the total number of units.

$$DPU = \frac{Total\ Defect\ (D)}{Total\ Produksi} \quad \text{……………………………………….(5)}$$

4. Total Opportunities (TOP)
   Indicates the number of opportunities for defective products and defects in the product.

$$TOP = Total\ Produksi\ (Unit)\ x\ CTQ \quad \ldots\ldots(6)$$

5. Defect per Opportunities (DPO)
   Shows the proportion of defects to the sum of the total opportunities.

$$DPO = \frac{Total\ Defect\ (D)}{Total\ Opportunities\ (TOP)} \quad \ldots\ldots(7)$$

6. Defects per Million Opportunities (DPMO)

$$DPMO = DPO\ x\ 1{,}000{,}000 \quad \ldots\ldots(8)$$

7. Sigma Value
   The sigma value is obtained from the DPMO conversion using Microsoft Excel with the following calculation formula:

$$Sigma\ Level = NORMSINV\left(\frac{10^6 - DPMO}{10^6}\right) + 1.5 \quad \ldots\ldots(9)$$

To measure the improvement in statistical calculations, Cause-effect analysis, and 5W+1H diagrams to find the root cause of the problem and find solutions for improvement and control used in the DMAIC method.

IV. Result and Discussion

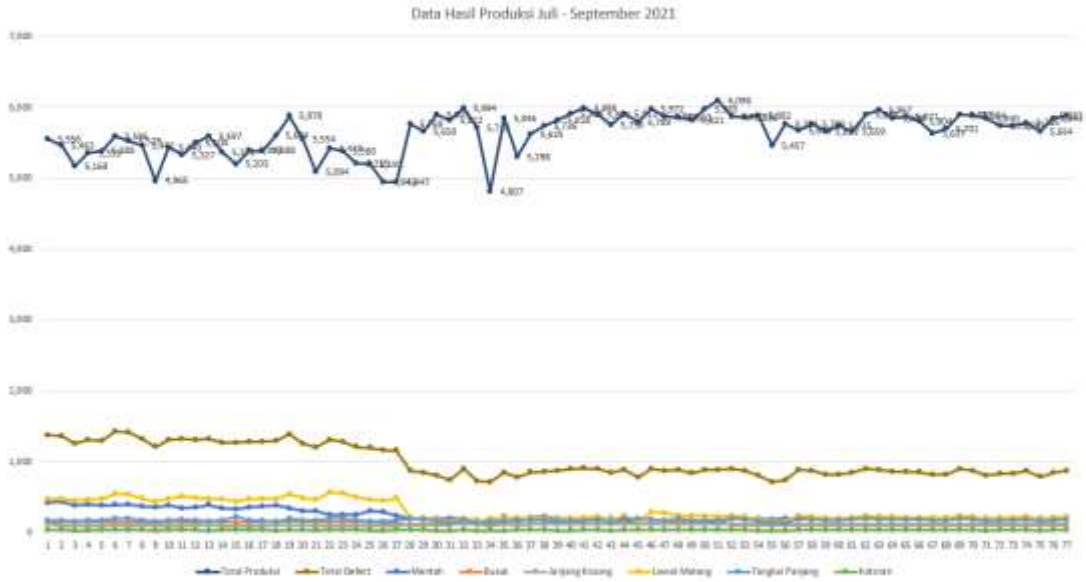
At the beginning of the study, the baseline performance measurement used data on the period where the harvest digitization system had not been carried out and the period when the harvest digitization system was used, so that the capability process value and sigma value were obtained before and after use. From the data, it will be compared whether there is an increase in terms of process capability and sigma value as expected.

No	Kriteria	Kode	Keterangan
1	Unripe Fruit	BM	The criteria for FFB are that there are no loose fractions and usually the fruit is still black.
2	Overripe Fruit	OR	FFB with fruit criteria have broken more than 75%
3	Rotten Fruit	OR1	FFB affected by diseases
4	Long Stalk	TP	Stalk of uncut fruit bunches less than 2cm
5	Empty Bunches	JK	Bunches with 100% pure fruit
6	Dirt Contamination	DB	Fruit bunches containing dirt impurities
7	Water Contamination	AR	Fruit bunches containing water

Source: PT. Alam Plantase Indah

Figure 5. *FFB Defect Data Production*

Production data of PT. Alam Plantase Indah for the period July 2021 – September 2021 is as shown in the following graph:



Source: Data processed

Figure 6. *FFB Production Data Results*

Table 2. FFB Production Data Results

Period	Sample	FFB Defect						Total Defect
		FFB Reject			FFB Penalty			
		Unripe	Rotten	Empty Bunches	Overripe	Long Stalk	Contaminated	
July	144,925	9,320	3,982	2,659	13,158	4,733	948	34,800
Augustus	138,845	4,160	3,369	2,846	5,000	4,092	826	20,293
September	150,309	5,136	2,697	3,082	5,490	4,577	919	21,901
∑ TOTAL	**434,079**	**18,616**	**10,048**	**8,587**	**23,648**	**13,402**	**2,693**	**76,994**

Source: Data olahan

4.1 Performance Baseline Before System Implementation

In the period where the system has not been implemented, namely in July 2021, a performance baseline calculation is carried out by obtaining the Capability Process value, which starts from determining the proportion of defects in each sample.

a. Proportion and Average Defects

$$\bar{p} = \frac{\sum_{i=1}^{g} p_1}{g} = \frac{6.48}{27} = 0.24$$

b. (Center Line/CL), Upper Control Limit (UCL) and Lower Control Limit (LCL), are as follows:

$$CL = \bar{p} = 0.24$$

$$UCL_1 = \bar{p} + 3 . \frac{\sqrt{\bar{p}(1-\bar{p})}}{n_1} = 0.24 + 3 . \frac{\sqrt{0.24\ (1-0.24)}}{5556} = 0.26$$

$$LCL_1 = \bar{p} - 3 . \frac{\sqrt{\bar{p}(1-\bar{p})}}{n_1} = 0.24 - 3 . \frac{\sqrt{0.24\ (1-0.24)}}{5556} = 0.22$$

c. Capability Process

$$Cp = 1 - \bar{p} = 1 - 0.23 = \underline{\mathbf{0.77}}$$

Continue with Calculating the sigma score value:

a. Defect Per Unit

$$DPU = \frac{Total\ Defect\ (D)}{Total\ Produksi} = \frac{34{,}800}{144{,}925} = 0.24$$

b. Total Per Opportunities

$$TOP = Total\ Produksi\ (Unit)\ x\ CTQ = 144{,}925\ x\ 2 = 289{,}850$$

c. Defect per Opportunities (DPO)

$$DPO = \frac{Total\ Defect\ (D)}{Total\ Opportunities\ (TOP)} = \frac{34{,}800}{289{,}850} = 0.12$$

d. Defect per Million Opportunities

$$DPMO = DPO\ x\ 1{,}000{,}000 = 0.12\ x\ 1{,}000{,}000 = 120{,}000$$

e. Sigma Value

$$Sigma\ Level = NORMSINV\left(\frac{10^6 - DPMO}{10^6}\right) + 1.5$$

$$= NORMSINV\left(\frac{10^6 - 120{,}000}{10^6}\right) + 1.5$$

$$= \underline{\mathbf{2.67}}$$

From the performance baseline calculation and analysis of the sigma value above in the period where before the implementation of field digitization, the DPMO value was 120,000, this shows that for every 1,000,000 times of harvest production, the possibility of defects is 120,000 times of production. While the sigma value obtained is equal to 2.67 σ.

4.2 Performance Baseline After System Usage

In the period where the system has not been implemented, namely August - September 2021, a performance baseline calculation is carried out by obtaining the Capability Process value, which starts from determining the proportion of defects in each sample.

a. Proportion and Average Defects

$$\bar{p} = \frac{\sum_{i=1}^{g} p_1}{g} = \frac{7.29}{50} = 0.14$$

b. (Center Line/CL), Upper Control Limit (UCL) and Lower Control Limit (LCL), are as follows :

$$CL = \bar{p} = 0.14$$

$$UCL_1 = \bar{p} + 3\,.\frac{\sqrt{\bar{p}(1-\bar{p})}}{n_1} = 0.14 + 3\,.\frac{\sqrt{0.14\,(1-0.14)}}{5972} = 0.1634$$

$$LCL_1 = \bar{p} - 3 . \frac{\sqrt{\bar{p}(1-\bar{p})}}{n_1} = 0.14 - 3 . \frac{\sqrt{0.14\,(1-0.14)}}{5972} = 0.1353$$

c. Capability Process

$$Cp = 1 - \bar{p} = 1 - 0.14 = \underline{\mathbf{0.86}}$$

Continue with Calculating the sigma score value:

a. Defect Per Unit

$$DPU = \frac{Total\ Defect\ (D)}{Total\ Produksi} = \frac{42{,}194}{289{,}154} = 0.14$$

b. Total Per Opportunities

$$TOP = Total\ Produksi\ (Unit)\ x\ CTQ = 289{,}1542\ x\ 2 = 578{,}307$$

c. Defect per Opportunities (DPO)

$$DPO = \frac{Total\ Defect\ (D)}{Total\ Opportunities\ (TOP)} = \frac{34{,}800}{578{,}307} = 0.07$$

d. Defect per Million Opportunities

$$DPMO = DPO\ x\ 1{,}000{,}000 = 0.07\ x\ 1{,}000{,}000 = 70{,}000$$

e. Sigma Value

$$Sigma\ Level = NORMSINV\left(\frac{10^6 - DPMO}{10^6}\right) + 1.5$$

$$= NORMSINV\left(\frac{10^6 - 70{,}000}{10^6}\right) + 1.5$$

$$= \underline{\mathbf{2.97}}$$

From the calculation after the implementation of the digitization system, the DPMO value is 70,000, this shows that for every 1,000,000 times of harvest, the possibility of defects is 70,000 times of production. While the sigma value obtained is equal to 2.97 σ.

Table 3. 5w + 1 H Definitions

No	Caused	Problem	What	Who	Why	Where	When	How
1	Human Factor	Employees did not do proper inspection	Not carrying out inspections according to the harvest schedule	Harvest Assistant and Foreman	- Undisciplined - Busy production time during high season crop	Harvest Block according to harvest plan	Shortly after Harvest	- Provided disciplinary training - Given reward and Punishment - Managers and supervision teams are required to monitor the system dashboard to improve monitoring and control functions
2	Human Factor	Employees did something wrong during	Did not do proper sorting	Harvest Crew	- Lack of knowledge of fruit quality and condition	Where to collect results	Harvest time	- Provided training on the quality and condition of the fruit

		sorting						
3	Human Factor	Employees are present but not working	Not doing work according to the location	Harvest Foreman, Harvest Crew	- Undisciplined	Harvest Block	Harvest time	- Provided disciplinary training - Given reward and Punishment - Managers and supervision teams are required to monitor the system dashboard to improve monitoring and control functions - Mandatory verification and inspection and recorded in the system
4	Human Factor	Employees take attendance	Employees are not present but leave attendance	Harvest Crew	- Undisciplined	Estate Office	Harvest time	- Provided disciplinary training - Given reward and Punishment - Managers and supervision teams are required to monitor the system dashboard to improve monitoring and control functions
5	Human Factor	Employees are wrong in harvesting fruit	Did not harvest it right	Harvest Crew	- Lack of knowledge of fruit quality and condition - Inaccurate harvest daily plant	Harvest Block	Harvest time	- Provided training on the quality and condition of the fruit - SOP for harvesting plans must be made based on the minimum PPA sampling percentage which was revised to 10%. - Assistant Head is required to monitor the system dashboard to improve monitoring and control functions. - Managers are required to monitor the system dashboard to improve monitoring and control functions - Harvest inspection as field control function
6	Human Factor	Employees lack specifications and skills	New employees lack specifications and skills	Harvest Crew	- No Experience	Recruitment center	Recruitment time	Mandatory for minimum 6 month experience
7	Machine	Transport trucks often breaks down	Transport truck not working properly	Driver	- The preventive maintenance schedule is not updated, it often breaks first	Collection Road	When transporting FFB	- Schedule of preventive maintenance is reviewed according to the latest environmental conditions - Garden path repair - Reduce the stack of FFB when transported to

					- Damaged garden roads that often make trucks often break their legs - Overload			the Factory - Provided disciplinary training - Given reward and Punishment
8	Machine	machetes that are often blunt	Fruit cutting tools that are often not sharp	Harvest Crew	- Material is not good - sharpening often takes a lot time	Harvest Block	Harvest time	- Replacement of harvesting support tools with better materials
9	Machine	Servers often down	Garden servers that often die due to blackouts	IT Admin	- Power outage - Generator off	Estate Office	In the afternoon and evening	- Make sure the generator is working properly - Added UPS as backup power

Table 4. 5w + 1 H Definitions

No	Causative factor	Problem	What	Who	Why	Where	When	How
10	Machine	Generator often turns off	Diesel powered power backup tool	Electricity	- Auto start is broken - Likes to catch a cold, the engine is difficult to start - Likes to overheat	Estate Office	In the afternoon and evening	- Scheduled good preventive maintenance - Repairs that must come first - Scheduled Overhaul when production stops
11	Material	Trees cannot be accessed at harvest	The access road to the trees are damaged and impassable	Maintenance	- The land is sloping and there is often landslides	Harvest Block	Harvest time	- Made to feel better harvest access - Scheduled more frequent preventive maintenance during the rainy season - Managers and supervision teams are required to monitor the system dashboard to improve monitoring and control functions
12	Method	SOP System not run completely	The system SOP is not understood by all employees, especially new employees	Harvest Foreman, Gardener, Assistant	Many employees transfer from other plantations / new employees	Estate office, Harvest Block	Every time there is a change of employees	- Provided continuous system usage training - Managers and supervision teams are required to monitor the system dashboard to improve monitoring and control functions - Given reward and Punishment
13	Method	Incorrect/inaccurate harvest taxation	Estimated harvest tax wrong location and/or count	Harvest Foreman, Assistant	- Undisciplined - Many employees transfer from other plantations / new employees	Harvest Block	Shortly after Harvest	- Provided training in using the system - Managers and supervision teams are required to monitor the system dashboard to improve monitoring and control functions - Given reward and Punishment
14	Method	Harvest Yields often swapped	Because it still uses manual leaves for recording empty bunches	Harvest Crew	- Often lost	Harvest Blcok	Shortly after Harvest	- Provided training in using the system - Managers and supervision teams are required to monitor the system dashboard to improve monitoring and control functions - Given reward and Punishment

15	Method	Lack of inspection	Harvest inspections are carried out only in a few places	Harvest Foreman, Assistant, Manager	Harvest inspections are only carried out with a small number of sampling locations	Harvest Block	Shortly after Harvest	- Managers and supervision teams are required to monitor the system dashboard to improve monitoring and control functions - Given reward and Punishment - Reviewing the amount of inspection that must be carried out

4.3 Comparation Data Before and After

Table 5. Comparation Calculations

Period	Index Capability	DPMO	Index Sigma
Juli 2021 (Before)	0.76	120,000	2.67
Agustus – September 2021 (After)	0.86	70,000	2.97

Figure 7. *Pareto Diagram Defect Production*

V. Conclusion

Based on the results of data processing on the production of Fresh Fruit Bunches (FFB) at PT. Alam Plantase Indah using the Six Sigma method, the following conclusions are obtained, namely:

1. The value of the process capability before the implementation of the harvest digitization system was obtained by 76% while the value of the process capability after the implementation of the harvest digitization system was obtained a value of 86%. The application of the harvest digitization system can increase the value of the process capability by 10%. The company's DPMO value after implementing the harvest digitization system is 70,000, which means that for every 1,000,000 times of production, there will be a possibility of production defects of 70,000 times. While the sigma value obtained is 2.97, which means that the harvest digitization system has a role in increasing process capability and increasing the sigma value which leads to increasing the number of products that are not defective to be sent to customers.
2. With the implementation of the field digitization system, reducing errors in the work activities undertaken, because the activities of workers can be recorded and recorded according to the GPS coordinates of each employee's work device, these data can be reviewed by the plantation management team in monitoring daily work. This has resulted in better coordination of work between Management, supervision, and field

workers in plantations, especially in the production team. It can be seen from the monthly production graph and the process capability that we produce.

3. Constraints and challenges of palm oil companies on the man and method side can be reduced, such as employees who are present, employees are present but do not work in the field, or employees are present and work in the field but in the wrong area, harvest inspection, harvest estimation, verification of work results, evidence of harvest results and monitoring of locations. workers can begin to be eliminated through the implementation of a field digitization system that is run.

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