# Improve Quality Aircraft Simulation Training in Indonesia using DMAIC Six Sigma Methods

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## Abstract

The development of aviation safety must be supported by reliable pilot competencies. One of the ways to realize the pilot competencies is by employing aircraft simulation. The objective of this research is to reduce the level of discrepancies in the King Air B200GT/350i aircraft simulation by using the six sigma DMAIC method (Define, Measure, Analyze, Improvement, Control). Other tools for analyzing problems are Pareto diagrams, cause and effect diagrams, and FMEA. The discrepancies of aircraft simulation which become priority for improvement are the 47 percent discrepancies of the aircraft control system, the 30 percent discrepancies of modeling, and the 17 percent discrepancies of the cockpit I/O. The order of improvement priority is sorted from the highest RPN value at the repair stage. After the implementation of six sigma, the discrepancies decreased from 45 percent to 14 percent, the sigma level increased from 2.53 to 3.16 and the cost of poor quality fell from IDR 64 million to IDR 28 million per month.

Keywords: *discrepancies, simulation, six sigma, DMAIC.*

## INTRODUCTION

In each operation, both civil aircraft and non-civil aircraft has the potential to pose a risk to the operator as well as other parties although today aircraft is a mode of transportation that uses high technology. With the increasing technology of aviation, consequently, the speed and level of flight safety will be higher. However, the reality proves that accidents in the aviation sectors still occur (Purba Hasim, 2017). The causes of aircraft accidents include humans (67.12%), technical (15.75%), environment (12.33%) and facilities (4.79%) (Kasub Komite Investigasi Kecelakaan Penerbangan Kemenhub, 2016). Human error commonly often occurs due to several factors including the condition of pilots lack expertise in flying aircraft (Purba Hasim, 2017).

According to the Civil Aviation Safety Regulations Part 135 (Kemenhub, 2017) stated that in order to achieve the standards of competency, knowledge and skill, air crews must undergo several trainings, including aircraft simulation training to get an aircraft type rating. The objective of aircraft simulation training is not to replace flight training on actual aircraft, but to prepare pilot students to familiarize and introduce actual aircraft situations.

One of the 142 Training Center Operators in Indonesia is the BBKFP Training Center which operates 2 (two) aircraft simulators with the King Air B200GT/350i aircraft type. Since it was first used in 2014, the aircraft simulators often experiences discrepancies. The discrepancies that occur in aircraft simulation training will reduce the quality of training. Consequently, the quality of pilot graduates will not optimal. The discrepancies that occur in aircraft simulation training will also have direct impact on flight safety. Reported by the National Transport Safety Board on November 12, 2001, regarding an American Airlines aircraft accident, which killed 260 passengers and 5 flight crews. The investigation revealed that one of the triggering factors for accidents was the significant difference in the rudder pedal system between the aircraft simulator used by simulation training and the actual aircraft. This difference actually triggered the pilot to give excessive input when controlling the aircraft and accordingly the accident occurred (NTSB, 2001; NTSB, 2004a; NTSB, 2004b)

According to the descriptive information above, it is known that the human factor phenomenon is the biggest cause of aircraft accidents. The decline in the quality of aircraft simulation training due to the discrepancies of the training is considered to have an effect on the human factor. Therefore, this study will discuss how to fix discrepancies in aircraft simulation training using the DMAIC approach, where DMAIC is a proven concept to improve product quality, reduce processing time and reduce production costs (Lakshmi and Sumukh, 2019).

## LITERATURE REVIEW

In the fast and competitive business sector, quality is one of important factors. In fact, it is a key decision factor used by consumers to buy products and services offered by producers. Therefore, quality should provide satisfaction to customers (Trimarjoko *et al.*, 2019). Likewise in manufacturing companies, the quality of a product is a basic guarantee to customers and is an important guarantee in the existence of a company. Therefore, it is crucial for company management to pay high attention to quality management (Syafwiratama, Hamsal and Purba, 2017). In this reality, the industrial world is required to be able to identify the attributes that are considered influencing customer satisfaction and then implement them in excellent products and services according to customer expectations. One of the company policies that must be carried out to maintain customer satisfaction and loyalty is continuous quality improvement. This process focuses on reducing variations in processes and products with a systematic and measurable method in order to reduce waste (Syafwiratama, Hamsal and Purba, 2017). Relating to the quality of aircraft simulation, the most important thing is fidelity. Fidelity is a level regarding the extent to which the simulator looks like a real aircraft and the ability to act like an actual aircraft which is related to training transfer (Allen *et al.*, 1986). It can be known that the higher the fidelity level of the aircraft simulation, the higher the quality of the aircraft simulation.

Fidelity is a basic concept in aircraft simulator design which consists of three elements: physical fidelity, cognitive fidelity and functional fidelity. Physical fidelity is the degree to which the aircraft simulator duplicates the flight deck of the physical aircraft and feels (Allen *et al.*, 1986). Existing motion technology does not reproduce a pilot's real motion signals e to 100 percent precision degree (Vaden, 2002).Cognitive fidelity refers to an aircraft simulator environment's ability to simulate the cognitive abilities required on the flight deck (Lee, 2005). In particular, psychological and perspective aspects such as situational awareness, anxiety, stress and decision-making are factors that require cognitive fidelity (Taber, 2017). The degree to which aircraft simulator equipment turns like an actual aircraft is known as Functional fidelity (Allen *et al.*, 1986). high fidelity as the required equipment and materials to adequately simulate the task to be performed by the learner (Fields, Fields and Ph, no date). Commonly, high-perceived self-efficacy will usually contribute to positive performance results (Holbrook and Tech, 2014).

There is substantial discussion concerning about the consequence of simulator fidelity on training transfer, mostly about the effect of motion on training transfer. This is called positive training transfer when performance in the aircraft is higher than if no simulator training contributed. Contrary wise, negative transfer of training applies to those cases in which aircraft performance is lower than if there was no pre-training at all (Lintern, 2001). Several studies found that low fidelity caused in negative training transfer, while other studies determined that the degree of simulator fidelity had little or no influence on training transfer, making the topic argumentative among training experts (Lintern, 2001).

In service operations, uptime is the main indicator of operational effectiveness (Al-aomar, Aljeneibi and Almazroui, 2015). Today, many business organizations make quality improvements and cost savings by implementing six sigma. Six sigma is a systematic method for making process improvements using a statistical approach and scientific methods to reduce the level of defects (Syafwiratama, Hamsal and Purba, 2017). The six sigma method can improve the quality and performance by using a structured method, namely DMAIC (define-measure-analyze-control). DMAIC is a problem-solving approach that has a complete and in-depth analysis of process steps, measures process capability at critical to quality (CTQs), applies six sigma tools and analysis, improves process performance and controls the improvements to be achieved (Al-Aomar, Al-Mansouri and Al-Laban, 2017).

## METHODS

The method used in this research is applied research on problem solving in cases of high levels of discrepancies in aircraft simulation training. This research was conducted in the training area for the simulation of an aircraft type King Air B200GT/350 i. The data and information taken in this study were related to the aircraft simulation training process and aircraft simulation equipment maintenance. The data taken was divided into 2 types, namely primary data and secondary data

Primary data was taken through: (1) observation, which was conducted by directly observing the training activities of the aircraft simulation type King Air B200GT/350 i at the research location, namely the BBKFP Training Center hangar simulator (2) Interview, the data collection technique through interview was gathered by asking directly in verbal to the research subjects, including simulator instructors, simulator training students, simulator technicians and the Chief of Quality Control (3) Focus Group Discussion (FGD), which was regular meeting attended by all key persons and personnel at BBKFP TC. The second data source is secondary data which was taken indirectly, namely the intermediary media. Secondary data in this research were: simulator maintenance log books, task cards, maintenance recordings. In this study, the population taken was all simulation activities of the King Air B200/350 i FFS aircraft at the BBKFP Training Center (TC). While the sample data was the simulation of aircraft type King Air B200/350 i for the period July - December 2019.

The Six Sigma (DMAIC) methodology is used to answer problems of this study. The research phases are as follows: (1) Define, this stage is to define several aspects related to: define the major core processes of the business process, Determine the SIPOC (Supplier, Input, Process, Output, Customer) diagram, Identify CTQ (Critical to Quality) (2) Measure, the measurement of the performance baseline at the output level is called the performance baseline or DPMO and, in this phase, the calculation of the sigma level is conducted. Measurements were carried out in the period July 2019 to December 2019 at BBKFP TC during the FFS (Full Flight Simulator) aircraft simulation training (3) Analyze, in this stage analysis is performed by using fishbone diagram tools to discover the causes of discrepancies in aircraft simulation training (4) Improve, in this stage using FMEA (failure mode & effect analyze). This method will determine and multiply the severity, occurrence and detection, so that the risk priority number (RPN) is obtained. The highest RPN value will be a priority in taking corrective action and proposed for improvements. (5) Control, in this stage, p chart, calculation of DPMO and sigma level of process capability, Four block diagram and COPQ value are conducted and it is included as data after improvement

## RESULT

The first stage is to collect secondary data which is the main reference, namely the simulator maintenance log books and work orders. From the secondary data collection, then calculating the number of aircraft simulation trainings and the number of discrepancies that occurred during the period July - December 2019. The complete data in the first stage of data collection is presented in the following:

| | | |
|---|---|---|
| Total number of simulation activities | = | 384 sessions |
| Total of discrepancies | = | 174 sessions |
| Percentage of defects | = | 45,3% |

From the discrepancy column in the simulator maintenance log books, data is also obtained regarding the types of discrepancies for the period July - December 2019 which can be categorized as follows:

a. Discrepancy in the Aircraft Control System
b. Discrepancy in the Cockpit I/O system
c. Discrepancy in the Motion Systems
d. Discrepancy in Modeling
e. Discrepancy in Sound System
f. Discrepancy in Visual System

The next stage to obtain the desired results, an analysis is performed using the Six Sigma method in a structured stage known as the DMAIC phases (Define, Measure, Analyze, Improve, and Control)

**Defining Stage**

1. Creating SIPOC diagram (Supplier, Input, Process, Output, Customer) in an aircraft simulation training as follows:

**Table 1** SIPOC Diagram of aircraft simulation training

| **Supplier** | **Input** | **Proses** | **Output** | **Customer** |
|---|---|---|---|---|
| *BBKFP 142 (Training Center (TC) Organization)* | Aircraft simulation equipment, syllabus, training materials, instructor. | aircraft simulation training | *The licence (*aircraft rating certificate*)* | *Pilot* |

2. Determining the CTQ (Critical to Quality) based on data from the simulator maintenance log books in the form of findings regarding the qualifications of aircraft simulation equipment that do not meet the requirements. These findings were outlined in the discrepancies column by the aircraft simulation training instructor and discrepancies data were obtained for the period July - December 2019 based on the following types of defects:

**Table 2** Data on Discrepancies Percentage of Aircraft Simulation Training

| No | Type of Discrepancy | Number (pcs) | Percentage (%) | Total of Accumulation | Accumulation Percentage |
|---|---|---|---|---|---|
| 1 | aircraft control system | 82 | 47 % | 82 | 47 % |
| 2 | modeling | 52 | 30 % | 134 | 77 % |
| 3 | *Cockpit I/O* | 30 | 17 % | 164 | 94 % |
| 4 | *Motion* | 4 | 2 % | 168 | 96 % |
| 5 | *Visual* | 3 | 2 % | 171 | 98 % |
| 6 | *Sound* | 3 | 2 % | 174 | 100.00% |
| | Total | 174 | | | |

Source: Data processed, 2020

The accumulated data based on the type of discrepancies in aircraft simulation, and the priority of improvements can be explained in the Pareto diagram as the Figure 1. From the Pareto diagram data, there are 3 types of CTQ that need corrective actions, namely the discrepancy type of aircraft control system with a percentage of 47%, modeling with a percentage of 30%, and cockpit I/O with a percentage of 17%.

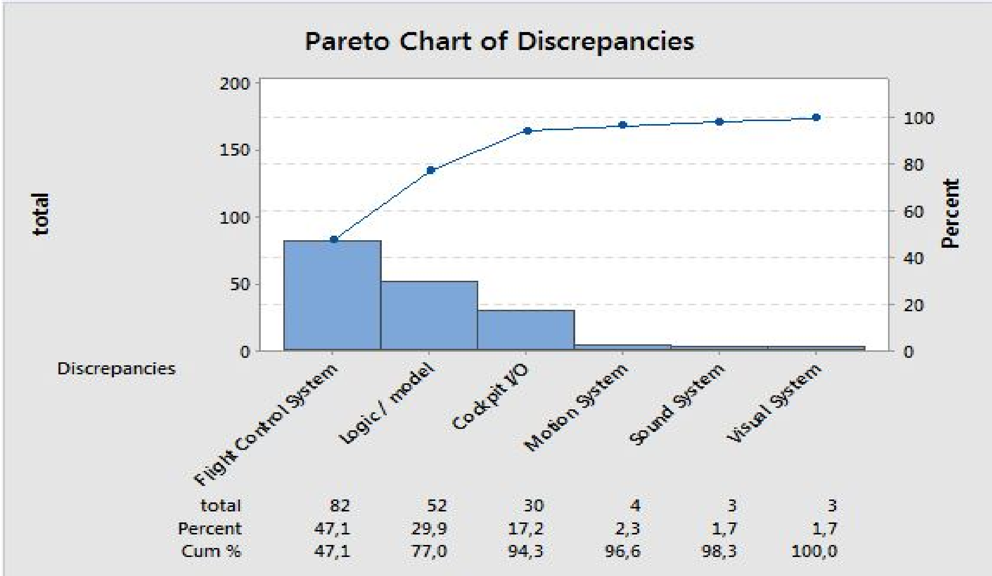



**Figure 1.** Pareto Diagram of Discrepancies of Aircraft Simulation Training
(Source: Data processed, 2020)

**Measuring Stage**

At the measure stage, an aircraft simulator equipment discrepancies control mapping was carried out by measuring the proportion of discrepancies (p chart), measuring the initial performance baseline, and measuring the cost of poor quality (COPQ). The complete explanation is as follows:

1) Discrepancies Proportion Measurement (p chart)

Based on the production data collection (numbers of training sessions) and discrepancies data for the period July - December 2019 obtained from the simulator maintenance log books data, the calculation of the discrepancies proportion (p chart) is calculated as follows:

a) Discrepancies Proportion Measurement
The formula: p = Number of Defective Products / Size of Subgroup
b) Calculating the Center Line (CL):
The formula: p = Total of Discrepancies / Total of Inspections
c) Calculating Control Limits
<u>Upper Control Limit:</u>

$$UCL = p + 3\sqrt{\frac{p\,(1-p)}{Size\ of\ sub\ group}}$$

<u>Lower Control:</u>

$$LCL = p - 3\sqrt{\frac{p\,(1-p)}{Size\ of\ \ sub\ group}}$$

From the results of the calculation of the p control chart above, table of defective proportions, CL, UCL and LCL for the period July-December 2019 can be made. Therefore, from the p chart of discrepancy table can be made the following control map in Figure 2.

From the p chart control map in Figure 2, it is shown that there is no outlier data (outside the control limit) which means that the proportion of discrepancies in July - December 2019 can be categorized as controlled and further analysis can be carried out.

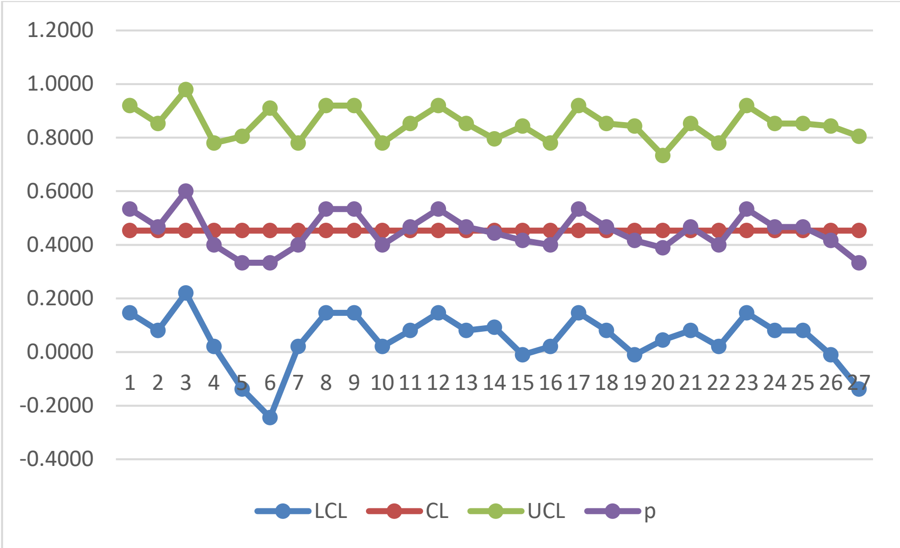



**Figure 2** Control Map of p chart of Discrepancies period Juli - Desember 2019

2) Measuring the initial performance baseline

Initial performance baseline measurement aims to determine the ability of the process before improvement using the following equation:

| | | |
|---|---|---|
| DPO formula | = | Number of Defective Products / Number of production x CTQ |
| DPMO formula | = | DPO x 1000000 |

From the calculation for the period July - December 2019, the average DPMO value is 177800 and the sigma value is 2.42. The DPMO value and the sigma value need to be improved. The quality targets of the company towards zero discrepancies close to 0 or sigma level close to 6 sigma.

**Table 3** Measuring Sigma Level on the first week of July 2019

| Item | Value |
|---|---|
| Number of Production | 381 |
| Number of Discrepancies | 174 |
| CTQ | 3 |
| DPMO | 152231 |
| *Sigma Value* | 2,53 |

Source: Data processed, 2020

3) Measurement of the cost of poor quality (COPQ)

Measurement of the cost of poor quality (COPQ) aims to determine the financial losses caused by the discrepancies that occurs. The calculation was done by identifying the time lost in the Simulator Maintenance log books. With a rental fee of IDR 7,250,000 per hour, the calculation is as Table 4. Table 4 shows the cost of losses caused by the discrepancies for the period July - December 2019. The Cost of Poor Quality was IDR 389,542,500.00 with an average of IDR 64,923,750.00 per month.

**Analyzing Stage**

At the analyzing stage, an analysis was carried out related to the causes of the high discrepancies that occurred in the aircraft simulator equipment and why it kept repeating and why it did not meet expectations of zero discrepancies. The results of the analysis were compiled using a cause and effect diagram (Fishbone Chart) with a brainstorming system or FGD (Focus Group Discussion) with related parties in aircraft simulation training including the Head of Training Center, Chief of Quality Control, Coordinator of Instructor and

Maintenance Personnel. Based on the FGD of Type of Problem of aircraft control system discrepancies, it was obtained the following results in Table 5.

**Table 4** Measurement of *Cost of Poor Quality* July - December 2019

| No | Month | Time lost (hour) | Total COPQ (IDR) |
|---|---|---|---|
| 1 | July 2019 | 10,2 | 73.950.000 |
| 2 | August 2019 | 9,85 | 71.412.500 |
| 3 | Sept 2019 | 8,15 | 59.087.500 |
| 4 | October 2019 | 10 | 72.500.000 |
| 5 | November 2019 | 8,2 | 59.450.000 |
| 6 | December 2019 | 7,33 | 53.142.500 |
| | Total | | 389.542.500 |

Source: Company Internal Data, 2019

**Table 5** FGD of type of discrepancies of aircraft control system

| No | Cause | Causative Factor |
|---|---|---|
| 1 | Pilot gave excessive input (force too high > 200 N) | *Man* |
| 2 | Long Repair time (more than 10 minutes) | *Method* |
| 3 | Room Temperature was not standard (more than 18 °C) | *Environment* |

The data above Table 5 is compiled in a fishbone diagram for discrepancies in the aircraft control system as follows Figure 3.

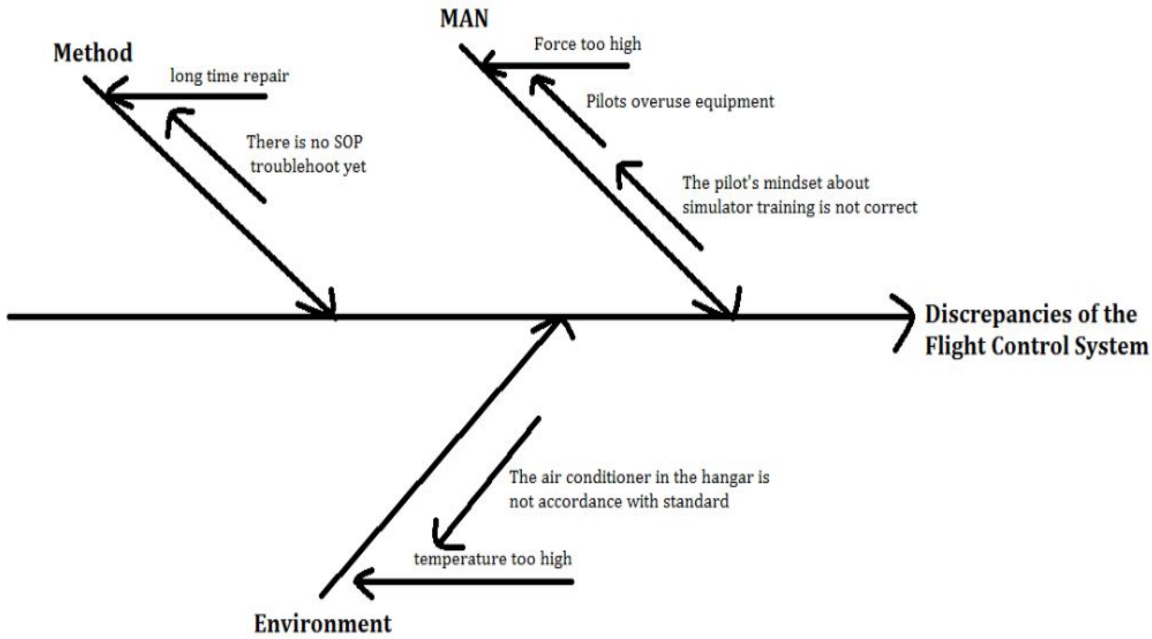



**Figure 3** Fishbone Diagram of Discrepancies in Aircraft Control System

Based on the above mentioned fishbone diagram of discrepancies in Aircraft Control System, it can be known that the root of the problems for discrepancies in aircraft control system were:

a. The pilot students had incorrect mindset and knowledge about aircraft simulation training, this caused the operation of the equipment was procedurally inappropriate resulting the discrepancies.

b. There is no Standard Operating Procedure (SOP) regarding troubleshoot which caused long troubleshoot time.
c. The air conditioning facility in the hangar is not standard so the temperature of the equipment is too high

Based on the FGD of Type of Problem of discrepancies in aircraft simulation modeling obtained the following results in Table 6.

**Table 6** Focus Group Discussion (FGD) of Type of Problem of discrepancies in aircraft simulation modeling

| No | Cause | Causative Factor |
|---|---|---|
| 1 | Modeling software on simulator equipment was rudimentary (not 100% as same as the actual aircraft) | *Machine* |
| 2 | Testing and designing the aircraft simulation model had not gone well. | *Method* |

Source: Data processed, 2020

Fishbone diagram of discrepancies based on modelling is as follows Figure 4.

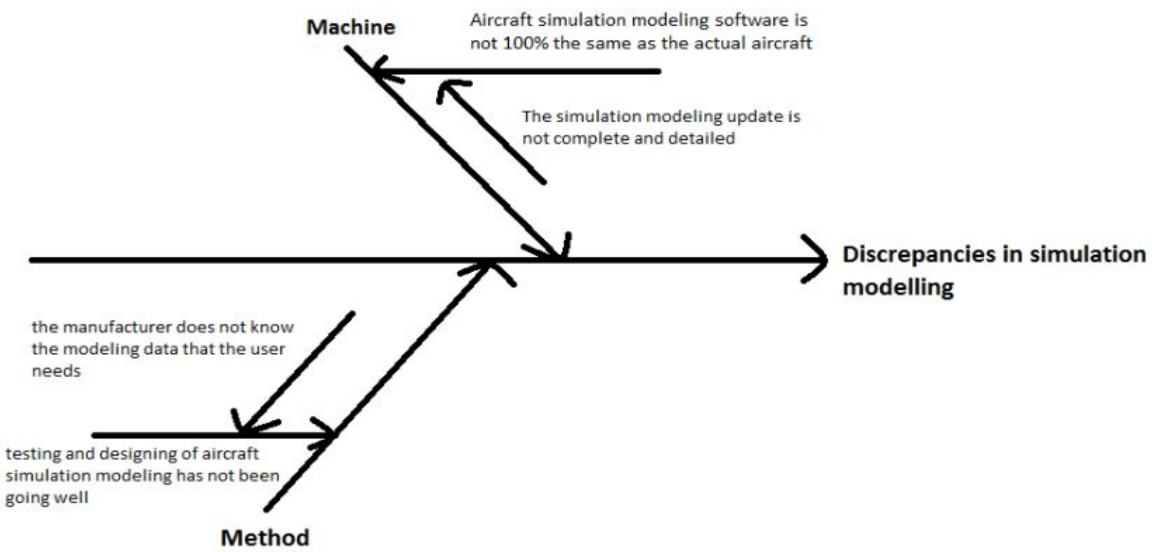



**Figure 4** Fishbone diagram of discrepancies based on modelling

From the fishbone diagram above, it can be seen that the root cause of the problem of high discrepancies in modeling was that the aircraft simulation modeling software was not 100% the same as the actual aircraft and the manufacturer did not know what kind of modeling data that the user needs. Following are some suggestions by conducting a Focus Group Discussion (FGD) based on the types of problems with the I/O cockpit as follows in Table 7.

**Table 7** Focus Group Discussion (FGD) of Type of Problem of Discrepancies in Cockpit I/O.

| No | Cause | Causative Factor |
|---|---|---|
| 1 | The schedule for the instrument calibration period is too long, which was 6 months | *Method* |
| 2 | The difference in knowledge between technicians and pilots results in operational faults | *Man* |

Source: Data processed, 2020

Fishbone Diagram of Discrepancies in Cockpit I/O as follows in Figure 5.

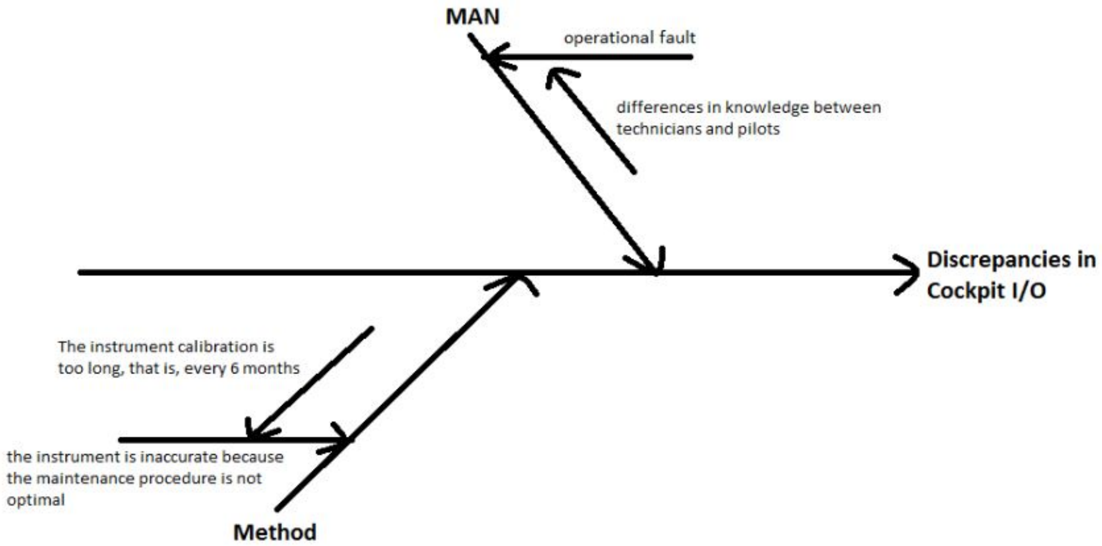



**Figure 5** Fishbone Diagram of Discrepancies in Cockpit I/O

Based on the Figure 5, the data shows that the root of the problems in the cockpit I/O component is an operational fault caused by differences in knowledge between the pilot and the technician. Moreover, this is because maintenance procedures are not optimal where the instrument calibration periodization is too long, which is every 6 months.

**Improving Stage**

At the Improving Stage, priority levels are determined in taking corrective actions based on the root cause of the predetermined aircraft simulation training discrepancies. The method used to determine the priority level is FMEA (Failure Mode and Effects Analysis).

**Table 8** Failure Mode and Effects Analysis (FMEA)

| No | Potential Failure Model (s) | Sev | Prob | Det | RPN | Corrective Actions | PIC, and Due Date |
|---|---|---|---|---|---|---|---|
| 1 | Pilot gave excessive input (force too high > 200 N) | 8 | 8 | 9 | 576 | Include safety briefings in the training syllabus that emphasizes the use of tools safely and correctly | Quality Dept., January 2021 |
| 2 | Long Repair time (more than 10 minutes) | 7 | 7 | 8 | 392 | Develop discrepancies database system and SOPs of troubleshoot so that the handling of discrepancies can be resolved quickly and appropriately | Maintenance Dept., February 2021 |
| 3 | Room Temperature was not standard (more than 18 °C) | 8 | 7 | 3 | 168 | Propose the addition of air conditioning so that the room temperature for cooling the equipment reaches standard | Maintenance Dept., January 2021 |
| 4 | Aircraft Simulator equipment modeling Software is not 100% the same as the real aircraft. | 9 | 8 | 8 | 576 | Compile a list of discrepancies about modeling and propose budget for modeling software updates. | Maintenance Dept., February 2021 |

| No | Potential Failure Model (s) | Sev | Prob | Det | RPN | Corrective Actions | PIC, and Due Date |
|---|---|---|---|---|---|---|---|
| 5 | The design and testing of aircraft simulation equipment is not optimal because the manufacturer does not know the detailed data required by the user | 8 | 3 | 8 | 192 | Evaluate the procurement system to ensure that it is not repeated in the future. | Procurement, January 2021 |
| 6 | The maintenance procedure has not been effective yet, so the schedule for the instrument calibration period is too long. | 5 | 6 | 3 | 90 | Develop an effective maintenance program, especially a schedule of instrument calibration period. | Maintenance, January 2021 |
| 7 | The difference in knowledge between technicians and pilots results in operational faults | 7 | 7 | 8 | 392 | Increase training for technicians and pilots as needed | Quality, January 2021 |

Source: Data processed, 2020

Based on the calculation of cause of failure, the largest RPN value is priority for corrective actions. The proposed recommendations are as follows:

| No | Cause of failure priority | RPN | Recommendation |
|---|---|---|---|
| 1. | Discrepancies of the aircraft control system due to the pilot giving excessive input | 576 | a. Include safety briefings in the training syllabus at the beginning of the session which emphasizes the use of equipment safely and correctly to avoid excessive input (force too high) on equipment that has a very sensitive transducer force & position<br>b. the maintenance division reports to the manufacturer regarding to transducer force and position component which is very sensitive to be evaluated in terms of material, brand and others to make it more reliable in its use |
| 2. | Discrepancies in simulation modeling | 576 | Compile a list of discrepancies by experienced instructors and submit software updates to the aircraft simulation manufacturer. |
| 3. | Discrepancies in the aircraft control system, namely the long repair time (more than 10 minutes) | 392 | establish Troubleshoot SOPs based on a database of discrepancies occurred that will provide guidance to maintenance personnel in order to isolate the disturbances quickly |
| 4. | Discrepancies in cockpit I/O (*operational fault happened)* | 392 | include a training syllabus about aircraft systems to technicians who have electrical engineering as their basic education and strengthen training on aircraft instruments to initial pilot training |

**Control Stage**

The final step of the DMAIC stage is the controlling stage. At controlling stage, the results after improvement are monitored and controlled. Data collection was carried out in May - August 2020. At this control stage, the calculation of P chart, DPMO value, sigma level and COPQ was carried out as in the measuring stage. The following is the comparison data of the results before and after repair:

**Table 9** Result Data Before and After Repair

| Item | Before repair | After repair |
|---|---|---|
| DPMO | 152231 | 48226 |
| Sigma value | 2,53 | 3,16 |
| COPQ | IDR 64.923.750,00 | IDR 28.329.375,00 |

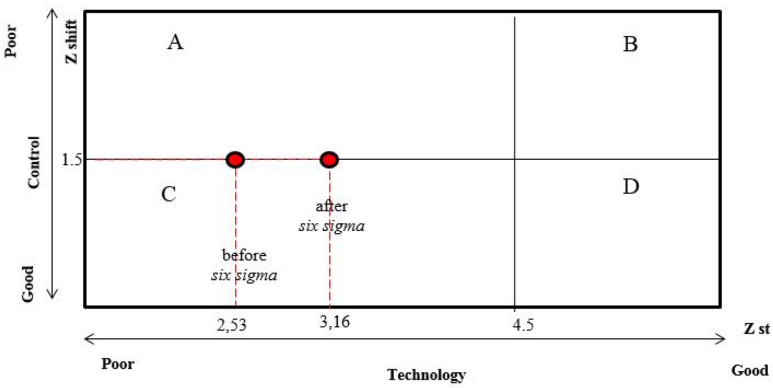
Source: Data processed, 2020

Based on Table 9, the duration before repair is in the first week of July 2019 to the fourth week of December 2019.The duration after repair is from the first week of May 2020 to the fourth week of August 2020.The table shows that the discrepancies of aircraft simulation training shows improvements and an increase in the result of the sigma level value from 2.53 to 3.16.

Four block diagram is a description of a process which elaborates about improvement direction that leads to two sides of improvement, namely technology and control.

$$\text{Z Shift} = Z_{ST} - Z_{LT}$$

$$= 3{,}16 - 1{,}66 = 1{,}5$$




According to the four block diagram above, it is known that it has suitable control to the user but it needs appropriate implementation of technology. For that reason, in order to obtain optimal results, further improvements are required to achieve the proper control and technology.

## CONCLUSION

Based on the results of the analysis described in the stages of define, measure, analyze, improve and control, it appears that the use of the six sigma DMAIC method can increase the quality of aircraft simulation training. This can be seen from the DPMO data which decreased from 152231 to 48226, the sigma value increased from 2.53 to 3.16 and the COPQ decreased from IDR 64,923,750.00 to IDR 28,329,375.00. This study also generally confirms previous research that the DMAIC six sigma method is proven to be effective in reporting and analysis of defective products and can increase the capability / sigma level to obtain a higher quality product. It is hoped that the aircraft simulation will be enhanced with a wide variety of methods so that it will improve the quality of aircraft simulation training which in turn will create high flight safety.

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