Availability Improvement by Implementing Customize Maintenance Strategy in Rental Operation of Indonesian Forklift Distributor Company

Mohammad Yoga Baskoro
PT Bina Pertiwi, Jakarta
[2] Master of Mechanical Engineering
Swiss German University
Tangerang City, Indonesia
yoga.baskoro20@gmail.com

Sumarsono
Master of Mechanical Engineering
Swiss German University
Tangerang City, Indonesia
sumarsono@elite-tutors.co.id

Gembong Baskoro
Master of Mechanical Engineering
Swiss German University
Tangerang City, Indonesia
gembong.baskoro@sgu.ac.id

Abstract*—Logistic is the core of nation wealth, through distribution of material will impact to the growth of nation economy. Except transportation, warehousing activity is the key of excellent logistic. Forklift truck as one of tools to store and moving material is key equipment of warehousing management. The case study took place in forklift distributor company that also have rental operation, the company already implement various maintenance approach to increase reliability and also manage their cost to optimizing revenue in their rental operation. However, the implementation depends in how each maintenance manager manage the asset. The company suffer high downtime (MTTR) and impact to low unit availability (PA) that finally cost them in revenue opportunity also maintenance cost. Implementation of advance maintenance strategy supposed to aligning company maintenance strategy with the customer requirement is needed to improve the company operation. This thesis method used Critical to Quality (CTQ) combined with Quality Function Deployment (QFD) to determine requirement from Voice of Customer (VOC). Using DMAIC as the frame and analysis approach with Failure Method and Effect Analysis as Tools to combine Preventive Maintenance (PM) with Reliable Centre Maintenance (RCM). With proper maintenance and management, combination of Preventive Maintenance and Reliability Center Maintenance, availability and also maintenance cost can be optimizing

Keywords*—critical to quality (CTQ), quality function deployment (QFD), preventive maintenance (PM), reliability center maintenance (RCM), failure method and effect analysis (FMEA).

I. INTRODUCTION

Indonesia consistent GDP (Gross Domestic Product) growth that equal of 5.2% - 6% during 1998 to 2019 have resulted mid income consumer that generate consumerism in the nation as shown in Fig. 1. They consume more and more products of household that eventually drive economic growth for Indonesia. McKinsey Indonesia in their report on 2018 has undertaken research to explore the impact of online commerce (defined as consumers buying and selling online), now an $8 billion-a-year sector that affects local manufacturing directly. The report explores the dynamics of the digital economy through the lens of online commerce, spelling out priority measures necessary to unlock Indonesia's broader digital economy.

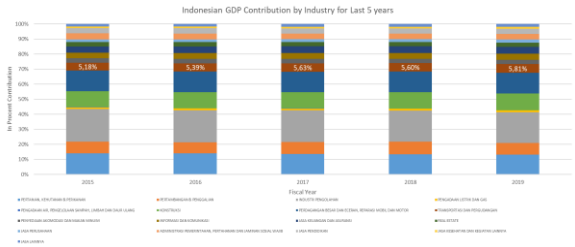


Fig. 1. Indonesian GDP origin at current price

II. LITERATURE REVIEW

Split the mechanism of maintenance to be two big maintenance schemes. Failure Based Maintenance (FBM) is type of maintenance that only performed when a failure or breakdown occurs, there are no action need to be taken to detect the onset of, or to prevent, failure. The maintenance costs are usually high, but it may be considered cost effective in certain cases [1].

The Preventive Maintenance (PM) are designed to reduce the number of failures and their economic consequences if the failures occur, by performing maintenance actions at a pre-determine or before the failure happen at the point of times (age-based or calendar time), regardless of the condition of the equipment/component. The time to action is usually optimized in order to minimize either breakdown quantity and also maintenance costs. PM has several difficulties such as the need of decision, insufficient historical data, also in-accuracy in assessing the time to do maintenance especially when the standard is large.

A. Preventive Maintenance

PM or Productive Maintenance is a Japanese idea that can be traced back to 1951. This is the year when preventive maintenance was first introduced into Japan, from the United States.

Fraser et al. [2] noted that companies that adopt TPM successfully are seeing a 50 percent reduction in breakdown labour rates, a 70 percent reduction in lost production, a 50-90 percent reduction in setup, and a 60 percent reduction in costs per maintenance per unit.

B. Reliability Centre Maintenance

Reliability Centre Maintenance (RCM) is a corporate level maintenance strategy that is implemented to optimize the maintenance program of a company or facility. The final result of an RCM program is the implementation of a specific maintenance strategy on each of the assets of the facility. The maintenance strategies are optimized so that the productivity of the plant is maintained using cost-effective maintenance techniques.

C. Quality Function Deployment

Kosicka and Gola [3] mention that The QFD (Quality Function Deployment) was first used back in the 1960s, and its original purpose was to validate voice of customer or customer demands into final product characteristics. The method consists in associating engineering parameters of the designed or existing product/system with customer demands voiced in their natural.

D. FMEA Analysis

Failure Modes and Effects Analysis (FMEA) is a tool that used to implement Reliability Centre Maintenance (RCM) and also widely used in the automotive, and electronics industries to identify, eliminate, and prioritize known potential failures, problems also errors from systems design before the product is mass production or released. Several industrial use FMEA standards such as the Society of Automotive Engineers, Automotive Industry Action Group, also US Military. They employ the Risk Priority Number (RPN) to measure risk and severity of failures. RPN is a product of three indices [4]:

1. Occurrence (O), How many times that the failure happens, calls of failure or sequence of failure.
2. Severity (S), How important or significant if the failure occurred will damage or injure to user or operator.
3. Detection (D). How we can detect or evaluate this failure in term or check or preventive.

E. Previous Journal Review

Review of scientific publications such as Gilabert et al. [5] that focus in Optimizing Maintenance Strategy, by using CBM (Condition Based Maintenance). This re-search using Failure Methods and Effect Analysis as tools approach to get optimization of maintenance cost.

Youssouf et al. [6] mention that “Efficiency of the Maintenance of Industrial Sector” specially in automotive. Even though the research more global to country industrial sector. This research use DMAIC (Define Measure Analysis Improve and Control) platform with FMEA (Failure Method and Effect Analysis) as their tools of improvement and standardization.

Rizlan et al. [7] mention related with reliability and cost output, she focusses in fabrication company then how to make simplified maintenance approach with QFD tools. Maintenance scheme will be Preventive Maintenance but being align with customer and also competitiveness of the industry by using QFD (Quality Function Deployment)

Hassan et al. [8] using Quality Function Deployment (QFD) and combination with Failure Method and Effect Analysis (FMEA) to increase reliability in manufacturing industry. His team maintenance scheme is Preventive Maintenance.

Afefy [4] about reliability and cost in power plant using RCM approach in maintenance and also FMEA (Failure Method and Effect Analysis) as the tools.

III. PRELIMINARY STUDY OF THE COMPANY

The case study will take in one of distributor forklift in Indonesia, this distributor also has rental operation. The decision refer to how maintenance management can be optimizing by shortening the supply chain from supplier to company and at the end to customer.

A. Research Problems

The challenge of increase amount of rental business is the unit that need to be maintain as asset become bigger and larger. In Fig. 2 that unit quantity increases 28 from 2015.

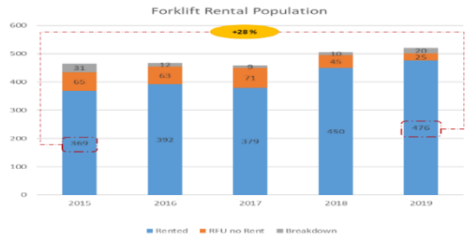


Fig. 2. Total unit of company rental forklift operation (Source: Internal)

From Fig. 2, the company operate 521 units at the end of 2019. That 476 of them operate in customer or in rental contract. While 45 units that not rented half of them or 20 units in breakdown condition.

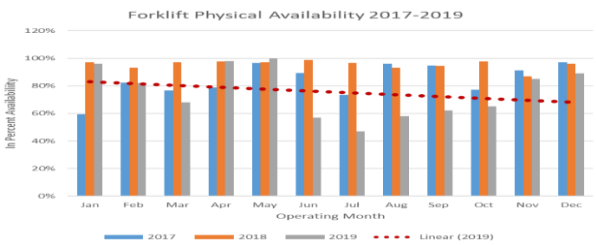


Fig. 3. Company physical availability last three year (Internal)

From Fig. 3 we can see that company Physical Availability declination and at the end of 2019 only achieve 72% in average. We can see there might be problem related with company physical availability that then impact to company physical availability level, its only be assumption before we can do further research related with the data support.

We can see in Fig. 4 that incremental of preventive maintenance achievement that been done from the company at the end of 2019 in order to catch the lack of maintenance being delivered on previous years.

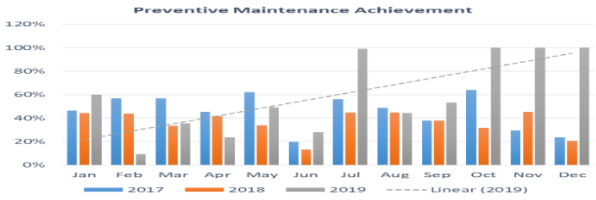


Fig. 4. Company preventive maintenance accuracy on 2019 (Internal)

Availability crucial in rental business, same as reliability. Customer believe they rent the machine to us and expect that in 22 working days in a month and minimum 8 working hour they will have at least 90% of unit availability. This is why the research problems is how to increase the Physical Availability of rental unit while optimizing maintenance cost.

B. This Research Objectives

With current most of operation and also data from single company that operate forklift as rental asset . The research objective from last suction will be state as: "*Designing a Customize Maintenance Strategy to Improve Forklift Reliability While Optimizing Maintenance Cost."*

C. Research Question

Based on data above and related to data that already shown by figures in previous suction then our important research question will be: "How to Improve the Forklift Physical Availability while Optimizing Its Maintenance Cost?"

D. Scope and Limitation

From Fig. 5, most of unit population is in Jakarta area. Most of unit that being used by customer in Jakarta are Forklift Diesel and Battery, for specific detail measurement and also effect analysis.

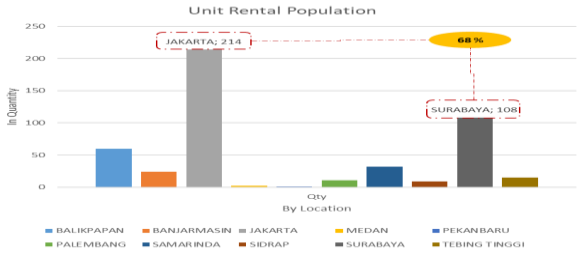


Fig. 5. The company unit distribution on 2019 (Internal)

Fig. 6 is showing the most popular unit model in Jakarta region will be Forklift Diesel 3-ton class.

Fig. 6. Jakarta area unit model on 2019 (Internal)

As the summary of preliminary data analysis to find out the scope and limitation we can conclude there are several scope and limitation needed to finish the research. There are 2 (two) limitation . "Jakarta Region Operation" and only focus in "Forklift Diesel 3 ton".

E. Research Hypothesis

Hypothesis that possible causing the availability in such low performances is "how maintenance accuracy achievement very low and maintenance planning not properly executed due lack of resources and in-accurate process in maintenance planning".

IV. DMAIC FRAME IMPLEMENTATION

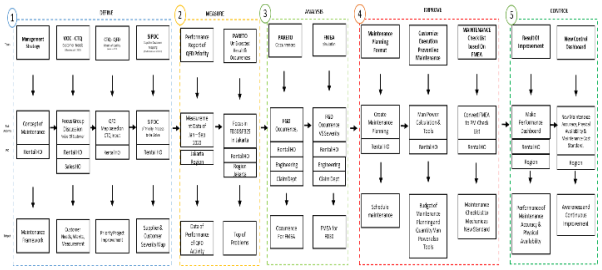


Fig. 7. Research framework using DMAIC

We use DMAIC frame work as shown in Fig, 7 that taken from SIX SIGMA method, in order to get the research have limited data and resources to proof the hypothesis.

A. Define Phase

1. Voice of Customer to Critical to Quality

We use Focus Group Discussion by calling several senior salesmen that have significant customer basis in rental that willing to share us their experience and also perspective in customer that they found in regular meeting or discussion. And from that occasion we have Critical to Quality item that will be fill in Quality Function Deployment in WHAT area (Fig.8).

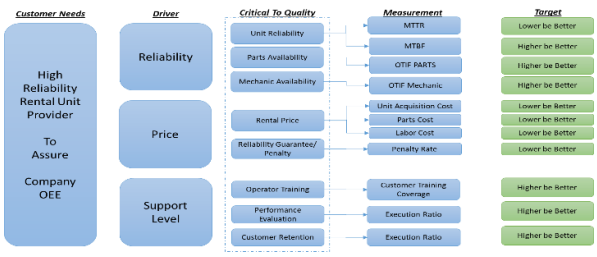


Fig. 8. Voice of customer to critical to quality matrix (Internal)

2. Critical to Quality – Quality Function Deployment

Quality Function Deployment then need to be clarified by SIPOC (Nandakumar et al., 2020) method. From "voice of customer" researcher need to get WHAT to be converted as program need to be improve by "critical to quality" method. And the research must find which process or sub process (How) by creating House of Quality. The first House of Quality that can be delivered from the data will be as shown in Fig. 9.

Competitor data being shared by salesmen in focus discussion group in order to reshape the company strategy. From this we have the data that shown in figure 10. There are several priority of process that the company need improve such as:

Maintenance Planning Accuracy, Mechanic Availability and Competencies and Parts Availability/Readiness

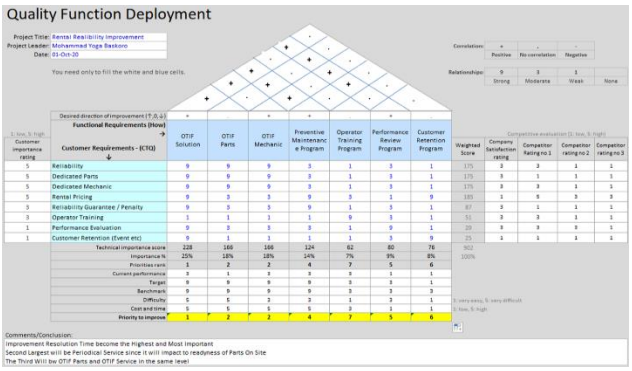


Fig. 9. 1st House of quality from CTQ of VOC result of focus group discussion (Internal Resources)

These three items that we need to improve, will then deliver the value of the company to end user that first being recognize in CTQ process of voice of customer mitigation. The number then calculating in measurement process either it's still in improvement or need improvement or already in good condition by the quantitative data or historical data of the company report in ERP system as shown in Fig. 10.

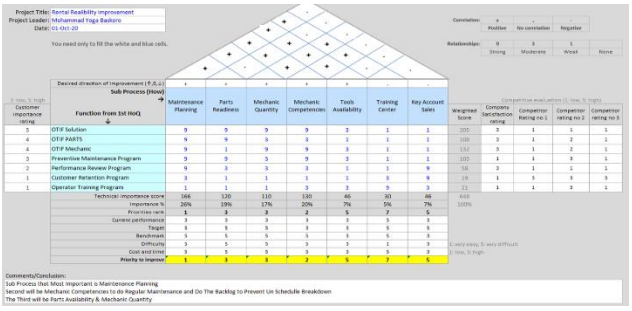


Fig. 10. 2nd House of quality from CTQ of VOC result of focus group discussion (Internal Resources)

3. Quality Function Deployment – SIPOC

There is no relation between QFD and SIPOC analysis. However, since we need to know the flow process and which process will significant need support from supplier we do need to remap which process and what activity to do so in the future there will be enough concern due to relationship and also events between the company and also the principal. From the flow process and also main concern of improvement we can draw SIPOC analysis as shown in Fig.11.

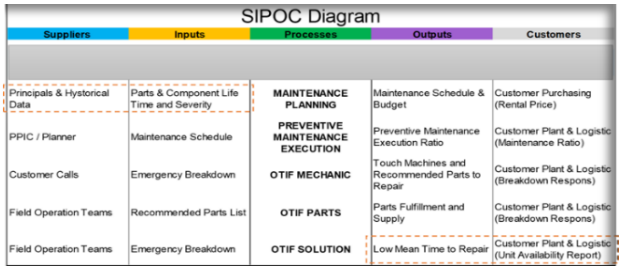


Fig. 11. SIPOC Diagram from result of major steps in process improvement (Internal)

B. Measure Phase

Measurement phase, we use data analytics that generated from historical 2020 maintenance execution as shown in Fig. 12. Because it will reflect in actual condition in how the company already revolve in their maintenance approach.

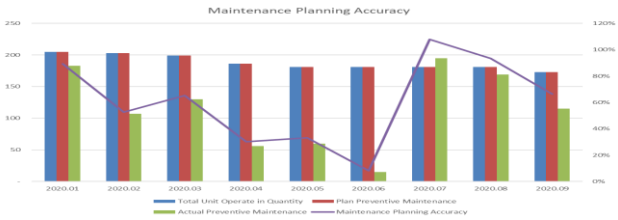


Fig. 12. The company maintenance accuracy Jan – Sept 2020 (Internal)

As shown in Fig. 13, the maintenance accuracy still in level of 61% year to date on 2020. There are several months that the accuracy even far below the standard. On June, May the number seems very low to manage as their maintenance accuracy flops.

Either in quantity, and competencies. Length of experience mechanic are in 50:50 between senior (above 5 years' experience) with the rest is below of 5 years' experience as shown in Fig. 13 and Fig. 14.

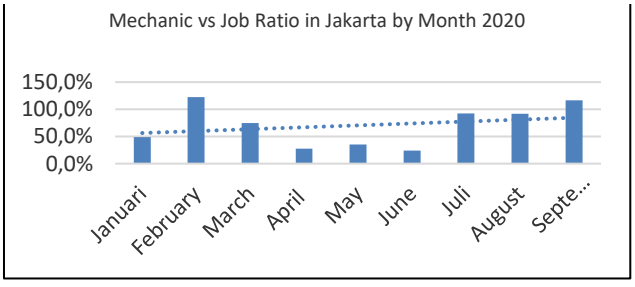


Fig. 13. Measurement result of mechanic load in Jakarta area (Internal)

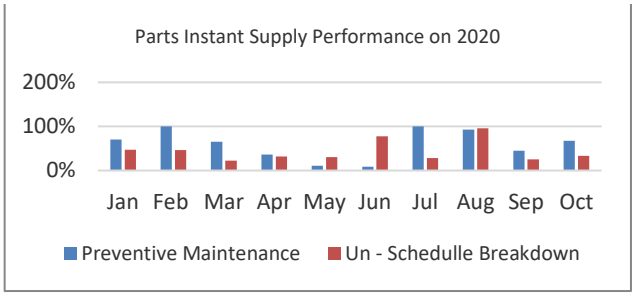
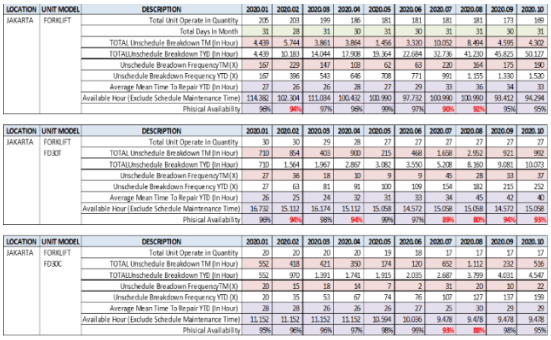


Fig. 14. Measurement result of parts availability in Jakarta area (Internal)

C. Analysis Phase

In data analysis, researcher will focus in FD 30T type, since this type of unit is one of the most popular and also have most problems in the Jakarta Area.



LOCATION	UNIT MODEL	DESCRIPTION	2020.01	2020.02	2020.03	2020.04	2020.05	2020.06	2020.07	2020.08	2020.09	2020.10
JAKARTA	FORKLIFT	Total Unit Operate In Quantity	205	203	199	186	181	181	181	181	173	169
		Total Days In Month	31	28	31	30	31	30	31	31	30	31
		TOTAL Unschedule Breakdown TM (In Hour)	4.439	5.744	3.861	3.864	1.456	3.330	10.052	8.494	4.595	4.302
		TOTALUnschedule Breakdown TYD (In Hour)	4.439	10.183	14.044	17.908	19.364	22.694	32.736	41.230	45.825	50.127
		Unschedule Breadown Frequency/TM (X)	167	229	147	118	62	63	220	164	175	190
		Unschedule Breakdown Frequency YTD (X)	167	396	543	646	708	771	991	1.155	1.330	1.520
		Average Mean Time To Repair YTD (In Hour)	27	26	26	28	27	29	33	36	34	33
		Available Hour (Exclude Schedule Maintenance Time)	114.382	102.304	111.034	100.432	103.900	97.732	100.990	100.990	93.452	94.294
		Phisical Availability	96%	94%	97%	98%	99%	97%	90%	92%	95%	95%

LOCATION	UNIT MODEL	DESCRIPTION	2020.01	2020.02	2020.03	2020.04	2020.05	2020.06	2020.07	2020.08	2020.09	2020.10
JAKARTA	FORKLIFT	Total Unit Operate In Quantity	30	30	29	28	27	27	27	27	27	27
	FD30T	TOTAL Unschedule Breakdown TM (In Hour)	719	854	403	900	215	468	1.658	2.952	921	992
		TOTALUnschedule Breakdown TYD (In Hour)	719	1.564	1.967	2.867	3.082	3.550	5.208	8.160	9.081	10.073
		Unschedule Breadown Frequency/TM (X)	27	38	18	30	9	9	45	28	33	37
		Unschedule Breakdown Frequency YTD (X)	27	63	81	91	100	109	154	182	215	252
		Average Mean Time To Repair YTD (In Hour)	26	25	24	32	31	33	34	45	42	40
		Available Hour (Exclude Schedule Maintenance Time)	16.732	15.112	16.174	15.112	15.058	14.572	15.058	15.058	14.572	15.058
		Phisical Availability	96%	94%	98%	94%	90%	97%	89%	80%	94%	93%

LOCATION	UNIT MODEL	DESCRIPTION	2020.01	2020.02	2020.03	2020.04	2020.05	2020.06	2020.07	2020.08	2020.09	2020.10
JAKARTA	FORKLIFT	Total Unit Operate In Quantity	20	20	20	20	19	18	17	17	17	17
	FD30C	TOTAL Unschedule Breakdown TM (In Hour)	552	418	421	330	174	120	652	1.112	232	536
		TOTALUnschedule Breakdown TYD (In Hour)	552	970	1.391	1.741	1.915	2.035	2.687	3.799	4.031	4.547
		Unschedule Breadown Frequency/TM (X)	20	33	18	14	7	2	31	20	10	22
		Unschedule Breakdown Frequency YTD (X)	20	35	53	67	74	76	107	127	137	159
		Average Mean Time To Repair YTD (In Hour)	28	28	26	26	26	27	25	30	29	29
		Available Hour (Exclude Schedule Maintenance Time)	11.152	11.152	11.152	11.152	10.594	10.036	9.478	9.478	9.478	9.478
		Phisical Availability	95%	96%	96%	97%	98%	99%	93%	88%	98%	95%

Fig. 15. Reliability of each popular model in Jakarta area (Internal)

As shown in Fig. 15, for FD 30T there are 6 problems below standard that occurred in this year since January to October. With this data, researcher will focus in Failure Mode and Effect Analysis (FMEA) in this model (Fig. 16).

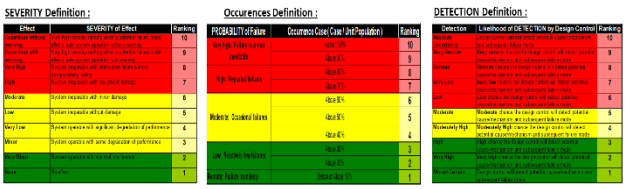


Fig. 16. Measurement in severity, occurrence and detection for FMEA phase (Internal)

While to calculate RPN we will use the standard:

Risk Priority Number = Severity x Occurrences x Detection

And after Calculation of FMEA we find that this following Part Number become the highest number in RPN:

1. Fuel Filter Clogging (RPN 560)
2. V Belt Crack (RPN 490)
3. Tire Worn Out (RPN 450)

And from then need to re-calculate in the maintenance preparation of parts also of budget, so it will maintain the proper parts preparation and also availability of maintenance budget in the future.

D. Improvement Phase

Improvement of how we delivering maintenance planning process and also measure or control the accuracy is needed where there are team that enable to monitor also execute if the process doesn't work. With PPC position as shown in Fig. 17.

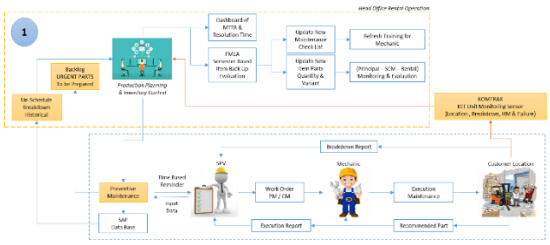


Fig. 17. Improvement in organization (Internal)

The second is implementation of new mechanism of check list to improve tools for mechanic, so it will be shortening the gap between junior to senior mechanic by standardize system. The third is how to re-calculate activity based costing for budgeting approach by setting up new part number in dashboard.

E. Control Phase

There are several new parameters after improvement such as, Maintenance Planning Accuracy to 95% and Physical Availability to 95% as shown in Fig. 18 and Fig. 19. This is increase number from before statement of 90% achievement, however with new process on board of new PPIC as before in improvement also new preparation of parts and more approachable with deterministic basis maintenance planning surely improvement in maintenance accuracy also reliability become achievable.

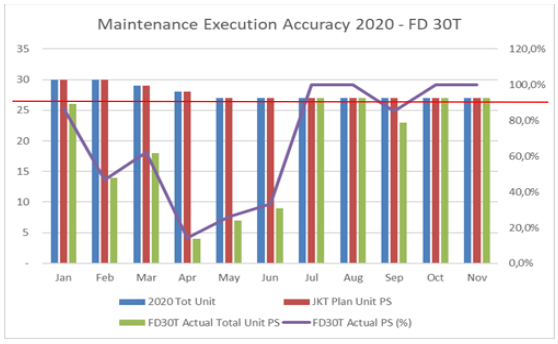


Fig. 18. New parameter of maintenance execution-redline 95% (Internal)

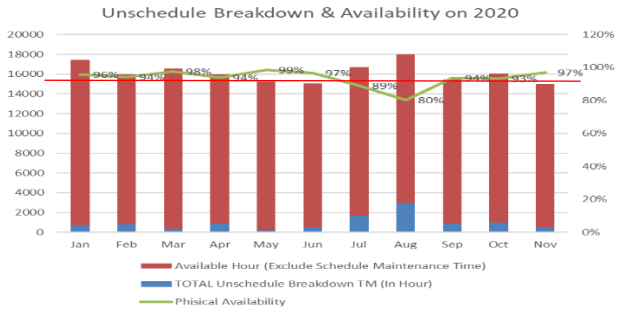


Fig. 19. New parameter of physical availability redline 95% (Internal)

From the cost optimization there are new line of cost control need to be adapted in control phase of the company and applied in maintenance cost monitoring. The company will gain benefit estimated around Rp 1.5 Billion per annum with the implementation of this method if the unit population nationally for FD30 will still 113 unit.

V. CONCLUSION & DISCUSSION

From the measurement data and also verification of Current Statement of Company we find that, researcher Agree that QFD technique can be used to assessing process quality and give us full information about the possible combined resources. It's the same resume of what [8] mention in their journal.

On the Maintenance Planning Accuracy that the company use (TPM approach), we also get data and Agree that collaboration between Voice of Customer – Critical to Quality – Quality Function Deployment to improve Total Productive Maintenance implementation as mention from [7].

Researcher also agree related with 1st hypothesis in this thesis that taken from Al-Najjar and Alsyouf [9] that The accuracy of maintenance action highly affects life length of the maintained equipment/component, number of failures, mean time to repair (MTTR), maintenance direct costs.

By implementing same method of Life Cost based FMEA that used by Afefy [4] and Rhee and Ishii [10] in simulation. Researcher resume that Increase Forklift Reliability can be done while optimizing Maintenance Cost with Combi-nation of TPM and RCM by continuously monitoring & evaluation using Quality Function Deployment and Failure Method and Effect Analysis tools.

VI. SUGGESTION

The paper already developed combination of TPM with RCM with implementing QFD and FMEA tools in the frame of DMAIC. With several findings such are:

1. Maintenance Accuracy Increase from average 61% to 95% by implementing PPIC & Time-Based Maintenance.
2. Physical Availability Increase from average 93% to 97% by implementing Backlog base on FMEA Check Sheet and better preparation of parts.
3. Implementation of Internet of Things as mention in Acep et al. [11]. That the data can be taken by real time by the maintenance manager.

This paper also already contributes to the academic in such field by providing a novel method for improving a maintenance management system for forklift truck.

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