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Title: Impact of Operator Development on Improving Overall Equipment Efficiency (OEE): Total Productive Maintenance TPM (Autonomous Maintenance) in One Petrochemical Plant (Methanol Producer) at Industrial Jubail City in KSA

Keywords: Total Productive Maintenance TPM, Overall Equipment Efficiency OEE, Operator Training

1. Introduction

Nowadays, to survive in the competitive industries, organizations require implement a best in class practices .TPM was identified as a best worldwide class for improving manufacturing process. Since achieving quality in all facets of manufacturing operations, implementation of Total Productive Maintenance (TPM) is required [1] .TPM provides a comprehensive, life cycle approach, to equipment management that minimizes equipment failures, production defects, and accidents. It involves everyone in the organization, from top level management to production mechanics, and production support groups to outside suppliers [2] and while TPM was built on pillars that include “ 5S concept , Autonomous maintenance, Planned maintenance, Quality maintenance, Training, Office TPM, Safety, Health & Environment [3] ,

It valuable to see the Implementing Autonomous Maintenance pillar of TPM from point view of operator skills that restricts the Improving Overall Equipment Efficiency (OEE) in one Petrochemical plant, Methanol Producer at Jubail industrial City at KSA
“Methanol Producer JIC-KSA”

2. Previous Studies:

i. What is Total Productive Maintenance (TPM) ?

It can be considered as the medical science of machines. Total Productive Maintenance (TPM) is A maintenance program which involves a newly defined concept for maintaining plants and Equipment. The goal of the TPM program is to markedly increase production while, TPM brings maintenance into focus as a necessary and vitally important part of the business. It is No longer regarded as a non-profit activity. Down time for maintenance is scheduled as a part of. The Goal is to hold emergency and unscheduled maintenance to a minimum. [3]

Bamber (1998) [8] presents the definitions of TPM that contains five main points:

1. To use the equipment more efficiently.
2. It establishes a total preventive maintenance system.
3. It requires a full participation from all department operator (equipment operator, designer, and departments workers)
4. It involves everyone in the company shop floor to the top management.
5. It promotes and implements preventive maintenance based on autonomous.

ii. TPM – History:

The Japanese, based on the planned approach to preventive maintenance (PM), evolved the concept of total productive maintenance (TPM). Nakajima (1986) outlines how, in 1953, 20 Japanese companies formed a PM research group and, after a mission to the USA in 1962 to study equipment maintenance, the Japan Institute of Plant Engineers (JIPE) was formed in 1969, which was the predecessor to the Japan Institute of Plant Maintenance (JIPM). In 1969, JIPE started working closely with the automotive component manufacturer (Nippondenso) on the issue of PM, and when the company decided to change roles of operators to allow them to carry out routine maintenance this was the beginning of TPM [5]

iii. Overall Equipment Effectiveness (OEE) Vs TPM

Total productive maintenance has provided a quantitative metric tool, which is known as overall equipment effectiveness (OEE) to make them fit and agile for this competition. The OEE is a maintenance performance measurement tool that measures different types of production losses and indicates the areas of process improvement [6]

OEE is a result can be expressed as the ration of the actual output of the equipment divided by the maximum output of the equipment under the best performance condition. The Overall Equipment Effectiveness was originated from the Total Productive Maintenance practices, developed by S.Nakajima at the Japan Institute of Plant Maintenance, the aims of TPM is to achieve the ideal performance and achieve the Zero loss which means no production scrap or defect, no breakdown, no accident, no waste in the process running or changeover. The quantification of these accumulations of waste in time and its comparison to the total available time can give the production and the maintenance management a general view of the actual performance of the plant. And it can help them to focus the improvement on the bigger loss. [8]

iv. TPM Implementation:

Understand the TPM implementation in simple way can be found in the Four rules which illustrated the actual processes of TPM in the research “TPM and lean maintenance-A critical review [9]:

1. Dictates that anything done to maintain and improve equipment must be documented in procedures that every employee follows.
2. Proper maintenance tools, parts, and supplies be made available, as they are needed. and that maintenance requests are sent and acknowledged promptly. Lastly, when proper repairs or improvements are made, those who requested them should sign off on them.
3. Every maintenance person knows on what equipment he is qualified to work and where he or she can get help when a problem exceeds their expertise.
4. Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization" indicates that data should be collected, analyzed, and made available to make the improvements more efficient and effective. Additionally, informed people closest to the problem should work out possible solutions and conduct experiments to determine the workability of their solutions. Applying the logic of this rule also requires that formally experienced and trained problem solvers lead improvement effort and that changes are made in the equipment and supporting work processes and people are trained in the new methods.

In brief, the meaning of the four rules is : maintenance work is governed by planned maintenance routines and that frequent joint production/maintenance planning and status meetings are scheduled to keep efforts focused [9]

v. TPM Pillar “Autonomous maintenance” and Importance of Operator Maintenance Skills :

Mobley, R. K. (2008). Autonomous maintenance requires the proactive involvement of equipment operators to eliminate accelerated equipment deterioration to perform some of the routine maintenance tasks. [2].

Almeanazel, O. T. R. (2010) was conclude that The operator in the shop floor should involve in each maintenance operation because he is the one close to the machine and he know what are the abnormality of the machine [8] .

McAdam and Duffner found that the Barriers for TPM Implementation was mainly due to worker’s fear that the only drive is to improve production efficiency, reduce workforce and increase shop floor job load. Many production operators do not want to accept additional responsibilities and they are happy with the current situation. In additional research was concluded with that “As TPM is a concept that focuses on the

human involvement, human participation and transfer of the maintenance job function to the production operators, the production department must drive and lead TPM program since they are having the greatest degree of influence to make TPM a success. [10]

Acharya (2018) Operator is given a sort of semi ownership, and he is taught so that production does not stop even when machine faces minor failures. [6]

Brah, S. A., & Chong, W. K. (2004), Morale and performance of employees is another performance aspect of TPM. When operators and maintenance crew work together as a team, the result is fewer breakdowns and higher productivity. Conceivably, morale of both group of employees turn out to be higher as operators get a sense of ownership of the equipment and the maintenance crew avoids calls for simple maintenance jobs. [7]

3. Research Problem:

since Methanol Producer JIC-KSA ,actually implemented TPM approach as four rules that been mentioned in pervious section “TPM implementation” ,TPM four rules have been embedded in “Methanol Producer JIC-KSA” organization structure as department wise and we can find them as Table-A:

Rule #	Rule Description	Department handle the Rule
1	anything done to maintain and improve equipment must be documented	Execution & Technical Department
2	Request Maintenance need , preparation & Maintenance improvement acknowledgment	Planning & Operation Department
3	Leveling work skills authority	Execution & Technical Department
4	Continual improvement	Excellence and Specialist Sections

Table -001

We observed that Rule#2 of Maintenance improvement acknowledgment in Methanol Producer JIC-KSA impact Improving OEE Overall equipment Efficiency as mentioned in Maintenance Engineering Handbook [2] that Equipment efficiency is commonly used to metric when evaluating a manufacturing system. The Efficiency is typically maximized by running the equipment at its highest speed, for as long as possible, to increase the product throughput. The efficiency is reduced by time spent with the equipment Idling (waiting for parts to load), time lost due to minor stops (to make small adjustments to The equipment), and lower throughput from running the equipment at a reduced

speed. These efficiency Losses can be the result of **low operator skill**, worn equipment, or poorly designed manufacturing System

while a TPM program typically enlarges the responsibility of production employees from merely operating machines to such areas as detecting machine failures, performing basic maintenance, and keeping work area as clean and organized [4].

Our observation is that TPM pillar “Autonomous maintenance” not implemented effectively due to the Operator Skills been impacted by only provide maintenance & technical training to maintenance & technical staff

4. Importance & Objectives of Research

- i. What is the correlation between Operation department objective and Autonomous maintenance aim?
- ii. What the Possibility for implementing the acquired new skills and Operator wellness for implementation?

5. Research Hypothesis

- o Operation department objectives that been cascaded from firm objectives which been distribute based on departments functions not support operator learning assignments to enhance operator knowledge about equipment failure root cause and enhance fundamental maintenance skills as required of TPM pillar “Autonomous maintenance”.
- o Why Research Hypothesis been taken

The lack of effective organizational communication on TPM implementation to all levels of the workforce contributes to the failure of the TPM program. The objectives and aims of TPM implementation must clearly inform to all levels of staff. Shop floor staff would only give their full support and commitment if they understand the main purpose of TPM implementation [6]. Besides this, TPM goals and objectives need to be fully integrated into the strategic and business plans of the organization and need to communicated to all levels of staff, failing to communicate this will make TPM program not a success [10]

6. Research Methodology

Questionnaire to measure Individual development Plan for operator in one Petrochemical plant (Methanol producer) in Jubail Industrial City at KSA.

7. Research Questionnaire Validation :

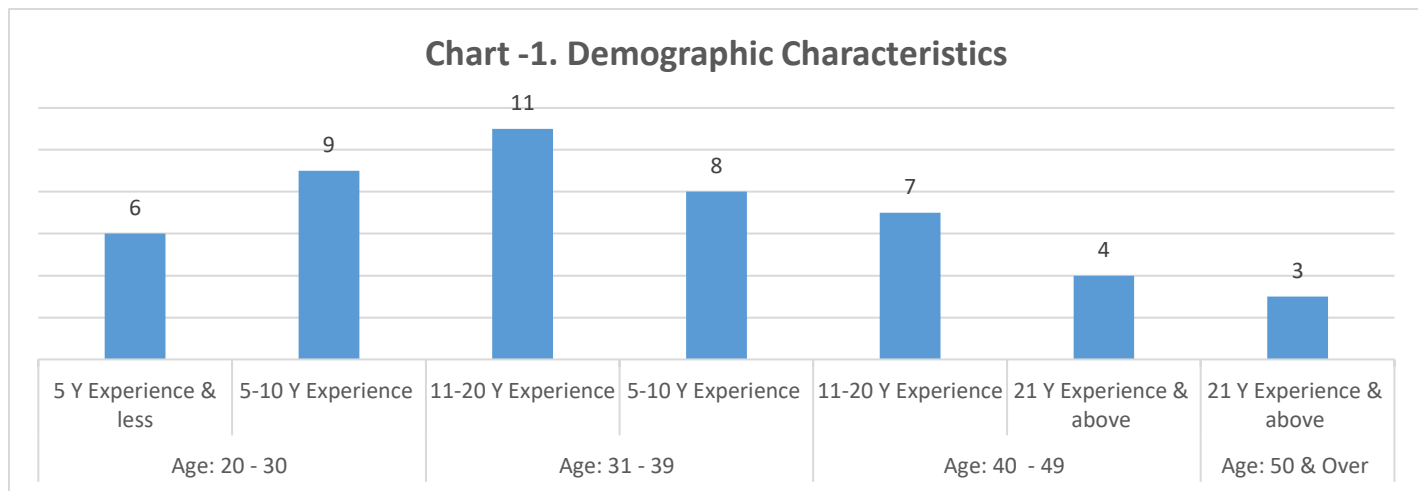
Questionnaire was validated by two Experienced Members, and comments been taken to improve Questionnaire:

1. Mr. Nabeel, Specialist Operation Excellence, 26 years' Experience, Master Degree ,SABIC. (Appendix A)
2. Mr. Rashed ,Translation Section Head , 19 years' Experience , Master Degree ,Saudi Central Bank. (Appendix B)
3. Published Questionnaire Appendix C.

8. Questionnaire results

Study population is 55 shift operators (All Male) and 48 Respondent been received and result as followed

i.



- ii. Questionnaire questions Results of first research objective which related to measures the correlation between Operation Department objectives and autonomous maintenance objectives as followed:

Chart A-Operator Training Plan been set based on

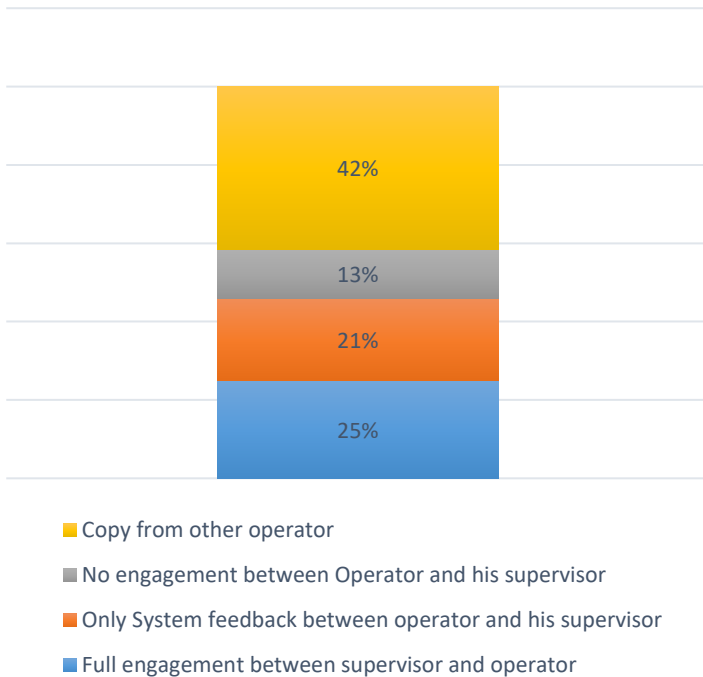


Chart B- Operator describe the link between operation division Objectives & operator training

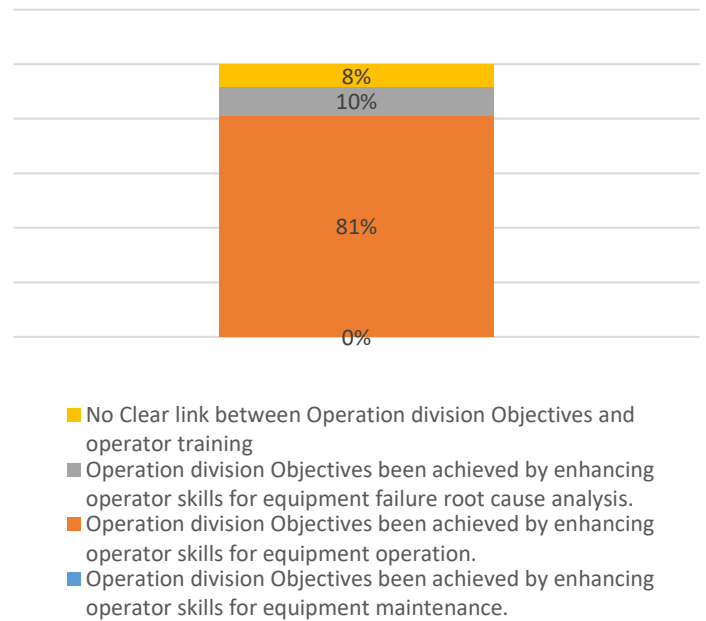


Chart C- Review Operator training progress by his supervisor

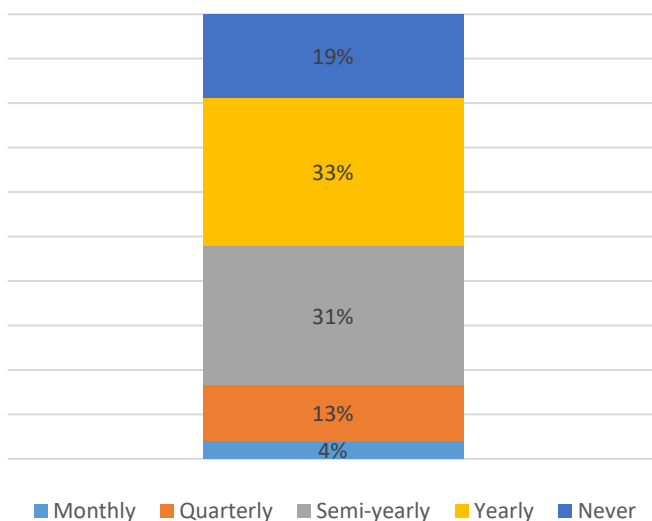


Chart D- way of assure operator skills been enhanced

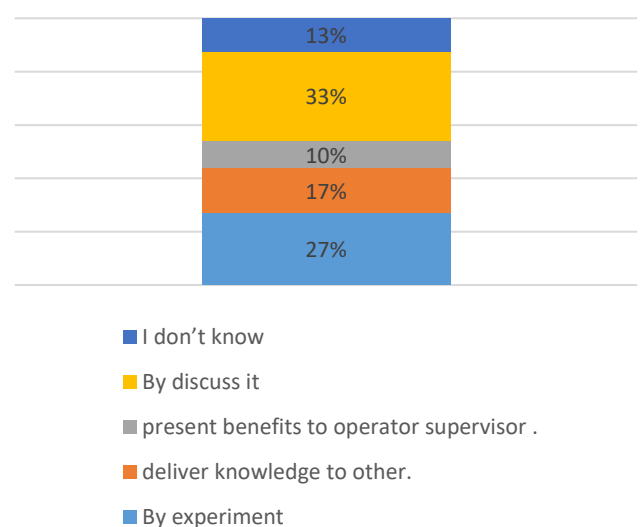
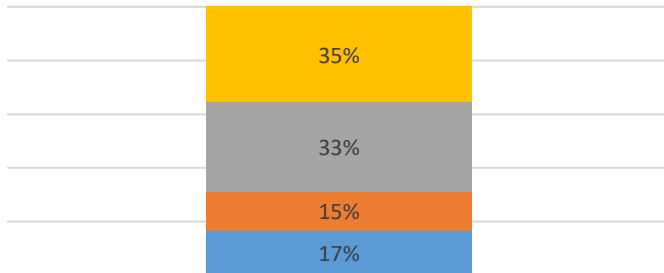
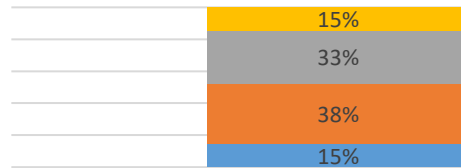


Chart E-Operator supervisor treat operator learning assignments progress



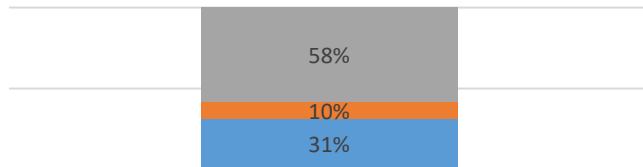
- no interfere from operator supervisor
- By Initial advice in beginning
- By Assign expert for mentoring
- By coaching & mentoring

Chart F -Operator Training plan been amendment



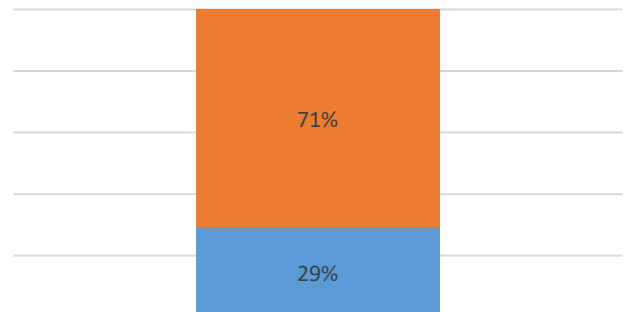
- Opportunities for learning assignment improvement occurred with events ,but not been considered.
- Set review Plan only but not implemented
- Reviewed but not improved
- Usually Reviewed & improved

Chart G- Operator can do Maintenance work for equipment



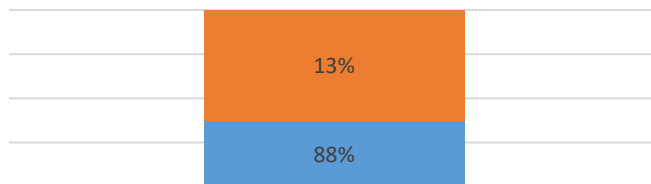
- Operator can give recommendation only for maintenance staff.
- Based on urgency
- Easy to get permission

Chart H -Operator can access to get equipment maintenance strategy



- Easy to get the data
- Based on urgency

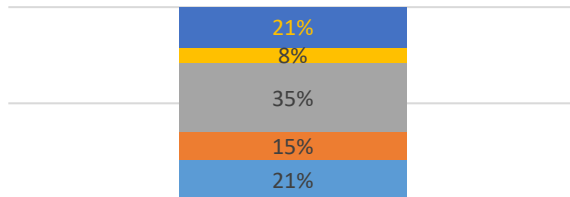
Chart I -Operator can get maintenance work instruction



- Easy to get the data
- Based on urgency

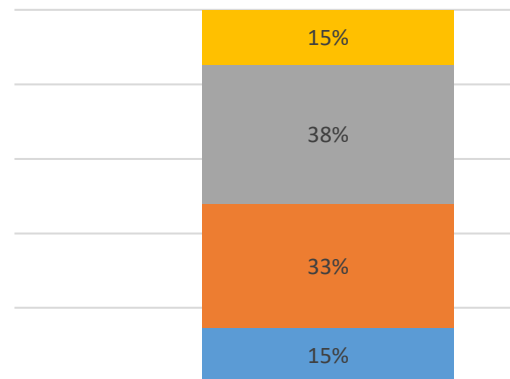
- iii. Questionnaire questions Results of second research objective which related to the Possibility for implementing the acquired new skills and Operator wellness for implementation as followed:

Chart J -Operator perform his learning assignment becuse



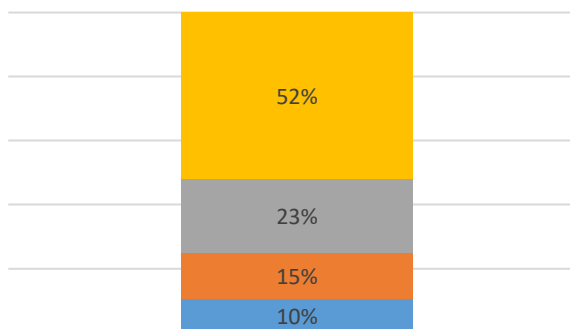
- Only closed in system as complete assignment
- because operator monitor by Superior
- Because it routine work activity.
- company invests in developing Operator potentials

Chart K -Operator Learning assignment Implementation Possibility



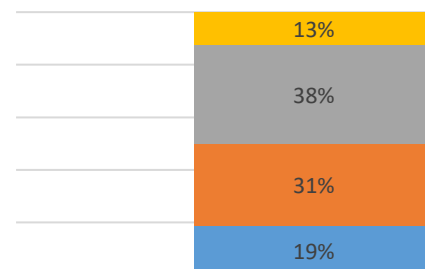
- Usually
- Some time
- based on event occurred.
- No opportunity

Chart L- Operator has time for complete learning assignment

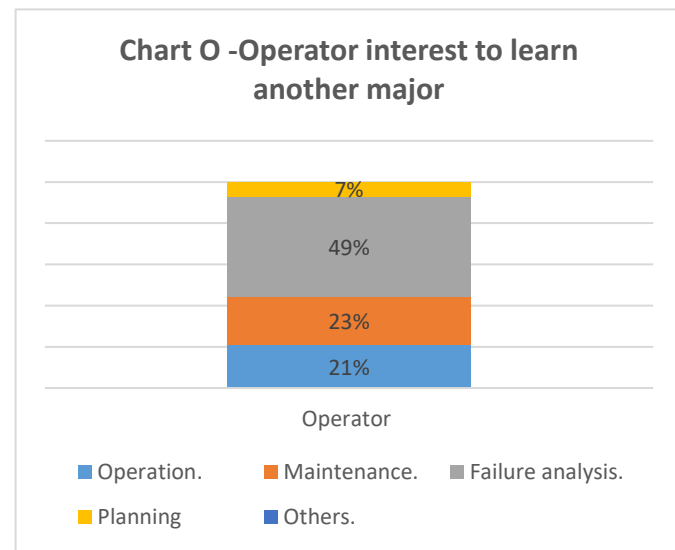
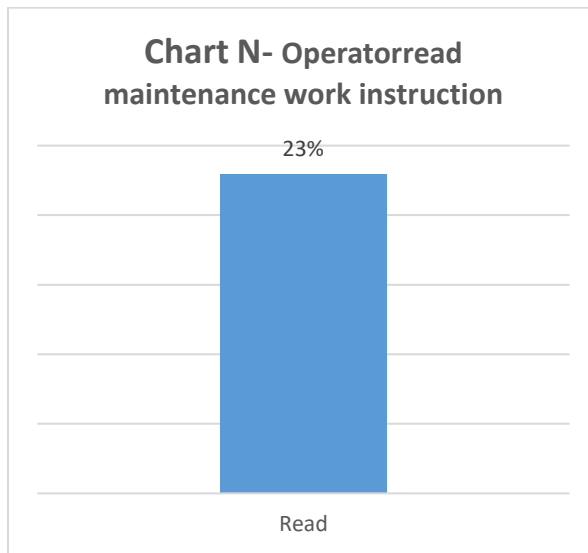


- No time ,load
- Partially completed
- has time for completing
- has time for completing in quality

Chart M- Operator Learning assignment add value



- Not add value at all
- no value while filling career paths.
- Some time it add value for Operator career path .



9. Analysis

Analysis of Questionnaire result start with segregate Good Observation from Not Good observation. Moreover and for more clarity, Good observations were count from perspective that “Observation will add value to TPM approach implementation by enhance operator knowledge for implementing and achieving TPM autonomous maintenance pillar objective.

Questions related to Objective 1 : Correlation between Operation department objective and Autonomous maintenance aim

Chart A-Operator Training Plan been set based on.

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
Full engagement	25	46%	Copy from other operator	42%	55%
System feedback	21%		No engagement	13%	

Chart B- Operator describe the link between operation division Objectives & operator training

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
Operation division Objectives achieved by enhancing operator skills for equipment failure root cause analysis.	10%	10%	Achieving Operation Department objectives by enhancing operator skills for equipment operation.	81%	89%
			No Clear link between Operation division Objectives and operator training	8%	

Chart C- Review Operator training progress by his supervisor

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
Quarterly	13%	17%	Never	19%	52%
Monthly	4%		Yearly	33%	

Chart D- way of assure operator skills been enhanced

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
1-By discuss it 2-Present benefits to supervisor. 3-Deliver knowledge to other.	60%	87%	don't know how	13%	13%
By experiment	27%				

Chart E-Operator supervisor treat operator learning assignments progress

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
By Assign expert for mentoring	15%	32%	no interfere from operator supervisor	35%	68%
By coaching & mentoring	17%		By Initial advice in beginning	33%	

Chart F -Operator Training plan been amendment

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
Usually Reviewed & improved	15%	15%	Reviewed but not improved	38%	86%
			Set review Plan only but not implemented	33%	
			Opportunities for learning assignment improvement occurred with events ,but not been considered.	15%	

Chart G- Operator can do Maintenance work for equipment

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
Easy to get permission	31%	31%	Operator can give recommendation only for maintenance staff.	58%	68%
			Based on urgency	10%	

Chart H- Operator can access to get equipment maintenance strategy

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
Easy to get permission	29%	29%	Based on urgency	71%	71%

Chart I- Operator can get maintenance work instruction

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
Easy to get the data	88%	88%	Based on urgency	13%	13%

Questions related to Objective 2 : Possibility for implementing the acquired new skills and Operator wellness for implementation

Chart J -Operator perform his learning assignment because

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
company invests in developing Operator potentials	15%	44%	Only closed in system as complete assignment	21%	21%
because operator monitor by Superior	8				
Usually operator has opportunity to implement what he have learned.	21%				

Chart K -Operator Learning assignment Implementation Possibility

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
Usually	15%	15%	No opportunity	15%	43%
			Some time	33%	

Chart L- Operator has time for complete learning assignment

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
has time for complete	25%	25%	No time ,load	52%	52%

Chart M- Operator Learning assignment add value

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
it is main factors in Operator career path advancement.	19%	19%	Not add value at all	13%	51%
			No value while filling career paths.	38%	

Chart O -Operator interest to learn another major

Frequency of Good Observation		Total % of Good Observation	Frequency of NOT Good Observation		Total % of Not Good Observation
Maintenance. Failure analysis.	23% 49%	72%			

10. Analysis Output

- 55% of operators learning assignments plan been developed without engagement between operator and his supervisor to discuss and review the targeted knowledge that need for operator to ensure overall efficiency equipment (OEE)
- 81% of operators see that Operation Department objectives can be achieved by enhance equipment operation knowledge for operator (how operate the equipment)
- During the year, 52% of operator learning assignment progress not monitor in frequent proper way such as quarterly or monthly.
- 86% of operators training not been changed to be improved or catch Opportunities for learning that been occurred (lesion learning).
- 68 % of operators not been allowed routinely to do maintenance activity and also equipment maintenance strategy data not easy to be access in routine condition as maintenance work instruction.
- 21% of operators learning assignment not implemented actually and only been closed in system (fake historical data).
- 43 % of operators not have always chance to implement what they been learned and in addition 53% of operators not have enough time to complete learning assignments.
- 51 % of operators believe that their learning assignments not add value for their career
- 72 % of operators want to learn maintenance and failure analysis knowledge

11. Conclusion (Abstract)

Since TPM pillar, Autonomous, maintenance requires the proactive involvement of equipment operators to eliminate accelerated equipment deterioration to perform some of the routine maintenance tasks Mobley, R. K. (2008). [2]. The research questionnaire analysis outputs of one plant in Petrochemical Plant (Methanol Producer) at Industrial Jubail City in KSA, shown that with regardless of confirm Operation department objectives either support TPM Autonomous maintenance aim or not, the way of develop operators learning assignments not support Autonomous maintenance implementation. Operators learning assignments are key factor to equipped Operators with required maintenance skills to implement TPM Autonomous maintenance.

While learning assignments should be built with ensure their alignment with operation division objectives, questionnaire output shown that high percentage (55%) of learning assignment built without management and operators engagement ,also without effective learning assignment progress monitor, revise or amendment (52% either been monitored once in year or never been monitored and 86% of learning assignments not been changed).in addition, the knowledge enhancement been forced

by operation department objectives focus on how to operate equipment as being described by 81% of operators feedback.

And when we look from learning assignments implementation point view, 68% of operators not have permission to implement maintenance task and 43% of operators implement what they learned which mean that not all acquired knowledge has chance to be practiced which was lead to loose the trust to operator development system as mentioned on questionnaire outputs that 51% of operator not believe learning assignment will add value on their career enrichment, while the 72% of operators have willingness and passion to learn maintenance and failure analysis skills and knowledge

whereas the Overall Equipment Effectiveness (OEE) was originated from the Total Productive Maintenance practices and Autonomous maintenance is one of main pillars of that. The research observations shown that operation department objectives impact operators development and possibility of practice the skills to achieve Autonomous maintenance requirement and therefore OEE targets been impacted

12. Research Limitation

- i. Due to time limitation,
 - a. Analysis period was focused and emphasis on Not good observations to discover negative impact on TPM pillar “Autonomous maintenance”. However, Good observations is area need to be analyzed.
 - b. Operator passion to learn different than operation skills is worth area to be investigated.
 - c. Link between Company strategic objectives and operational objectives not been researched which might be have gaps impact operator development.

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14. Appendix

- A. Appendix Questionnaire Validation, reviewed by Mr. Rashed Translation Section Head ,Saudi Central Bank .
- B. Appendix Questionnaire Validation ,reviewed by Mr. Nabeel , Specialist Operation Excellence , SABIC
- C. Published Questionnaire.