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INDUSTRIAL IOT – FROM VISIBILITY TO EFFICIENCY

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ABSTRACT

Industrial Internet of Things which was a buzzword earlier has risen to prominence in recent years. Enterprises are now realizing Industrial Internet of Things (IIOT) as a value driver in connecting physical and digital worlds to improve visibility, enhance mobility, drive operational efficiencies, and improve customer experience. In this respect OEE (Overall Equipment Efficiency) plays a major factor in understanding how efficiently a machine is working with respect to the reference or benchmark set by the organization.

The purpose of the research is to understand how IIOT services have helped to increase Overall Equipment Efficiency (OEE), performance and discover related hidden costs to save Opex with the help of a case study of an irrigation product manufacturing company through downtime and performance analysis methods

A case study approach has been utilized for this study and downtime Analysis, Rejection Analysis and Performance Analysis has been incorporated for analysis

1. Introduction

The 4th Industrial Revolution or popularly known as Industry 4.0 deals with interconnection and machine level communication of Cyber-physical systems, Internet of Things (IoT), Cloud Computing and Cognitive computing. In this process the enterprises are on course to transform and further develop themselves to Intelligent Enterprises. It comprises of 11 metrics out of which IoT vision is one of them **[1]**. The IOT market is expected to reach 3000 Billon

USD by end of 2020. The majority of investments in industry sector is from the manufacturing and utilities verticals **[2]**. The need was pretty much clear as the firms wanted to have more controls and visibility on the operations and processes. It was observed that companies implementing Industrial IOT solutions have experienced significant value addition. It was observed that there was increase in production by 3-5%, 30-50% reduction in machine downtime, 10-40% decrease in maintenance costs, inventory holding costs decreased by 20-50% **[3].** These are dream numbers for any company to achieve which helps to have a clear visibility and in turn increase Overall Equipment Effectiveness (OEE).

OEE is one of the major factors which is a clear indication of quality and performance of any manufacturing plant. It also plays a major role in creating sustainable competitive advantage in the market **[4]**.The dynamic development of IIOT has helped to record, monitor various KPIs such as downtimes, MTTR which helps to identify various associated costs due to inactivity and also helps to find accountable personnel. It facilitates information sharing and real time communication on a common platform too **[5]**. So, the companies are trying to achieve most optimized production levels by adoption of IIOT.

The companies nowadays are trying to reduce Opex to a great extent. This is due to increase in competition, the prices are getting consolidated and the margins are drying up. So, optimization in technology and processes has become the absolute necessity for the manufacturers. Optimization can be achieved only when all the processes are efficient. Processes will be efficient when machines are efficient. For this OEE of machines and plant need to be high. Good OEE can be achieved by having more visibility. Various papers have been published on smart manufacturing based on IIOT which basically focus more on advantages of IIOT solutions such as predictive analytics which indirectly affect parameters such as OEE.

Objective of research:

There has been no study on how increase in visibility, traceability and analysis of activities, performance and wastage can help to increase OEE which is being addressed in this paper. The purpose of the research is to understand how IIOT services have helped to increase Overall Equipment Efficiency (OEE), performance and discover related hidden costs to save Opex with the help of a case study.

2. Literature Review

The focused literature review highlights various developments under Industrial IOT. First there is a need to understand the difference between Industrial IOT and Industry 4.0 as the terms are generally confused. IOT can be defined as a subset of Industry 4.0 as IOT solutions are applied to industries and smart industries are discussed in context on Industry 4.0 **[6].** Various IIOT services which we will discuss further are basically enablers of a broader concept called Industry 4.0. The research in Industrial IOT space have been carried out extensively on technical and conceptual fronts to provide certain solutions and angles to the industrial processes and the way to view the generated data

2.1) Differentiating Industry 4.0 and Industrial IoT

Industrial IOT is a combination of various broad technical components namely Big Data Analytics, Edge computing, Cyber Physical Systems and Network Communications which contributes towards creation of IIOT services to improve production parameters **[9].** The optimization and increase in efficiency in functioning of each component is equally important for a value adding IIOT application. For example, Machine to Machine communication is very important where a system generates a lot of data. Possibility and scope of using 5G has been considered for the same. Since it is Ultra Reliable Low Latency Communication method, faster machine to machine communication for industrial automation can be achieved. This also helps in faster acquisition, recording, computation and uploading of large volume of manufacturing data. With use of 5G large number of nodes can be monitored simultaneously and helps in edge computing **[10].**

2.2 Industrial IoT as a mean to attain Sustainability based on OEE

Goal 12 of United Nations' SDGs (Sustainable Development Goals) is "Ensure Sustainable Consumption and Production Patterns". Sustainable Manufacturing Model can help to improve production related parameters by combination of Smart Production, Smart Maintenance and Energy in presence of various IIOT services **[7].** Sustainable manufacturing also depends on the perspective of how the industry is viewed namely Macro perspective where cross linked product lifecycles is the central element of value creation and Micro perspective which is based on horizontal integrations and vertical integrations within the smart factories **[8].**

Sustainability can be achieved by use of IIOT solutions to improve manufacturing parameters such as OEE (Overall Equipment Efficiency), performance, availability, quality etc. According to **[4]** IIOT can be used to achieve world class OEE of 85% by exploring and prioritizing minor losses on basis of Risk Priority Number which is done by assigning weights on detection, severity, and occurrence level. Mathematically, **OEE = Availability * Performance * Quality** and considering the elimination of losses (breakdowns, setup and adjustments, small stops, reduced speed, start-up rejects and production rejects). It not only helps to understand the downtime but also reveals capacity loss and cycle times **[13]**. Research on development of conceptual models to counter these losses have been developed based on Cross Functional Team approach **[14]**. Production costs can further be reduced by knowing of probable failure in advance and scheduling proper maintenance procedures. With rise of predictive analytics, predictive maintenance has been a very important feature in any IIOT application. Visual analytics can be coupled with predictive analytics can be used for an integrated analysis and finding out meaningful relations and insights from data such as comparing high and low productivity days, finding correlations, patterns and pin pointing improvement areas by fetching production data from heterogeneous data stems from various data sources such as MES, ERP **[11]**. Selection of a proper prediction algorithm is important too. Proof of accuracy of predictive maintenance is an important evaluation parameter. By applying various analytics algorithms and checking their accuracy with and without use of metadata to predict certain outcomes or event helps to choose the correct algorithm for a set of processes or a process **[12].**

3. Research Method

A case study approach has been adopted for this study wherein the activities of a plastic irrigation products manufacturing plant has been taken into consideration. Raw data from various reports generated by the on premise IIOT solution stored in server had been extracted for previous months to be studied. The collected data was later used to gather insights on various aspects of manufacturing. The research study based on this case study tries to find out how increased visibility has helped in increasing OEE by means of Downtime Analysis, Rejection Analysis and Performance Analysis.

4. Introduction Of The Case Study

The company considered here is one of the largest manufacturers of plastic irrigation products. It has more than 300 products in its catalogue and has a strong international presence of having a market in more than 70 countries. A company with such a massive scale of production, on time delivery and maintaining highest quality standards is very important. At the same time optimization of cost is very important factor in producing such huge volumes. In this process there are lot of hidden costs that are present which can only be identified with proper monitoring and digital data maintenance.

4.1. Problem Statement:

Before analysing the case in question, following problem statements were identified which needed to be solved by the IIOT solution:

4.1.1 Lower OEE

Since all the data was manually maintained manually, there was no clear visibility on Overall Equipment Effectiveness (OEE).

4.1.2 No visibility on machine performance, utilization, and availability

There was no clear picture on individual machine performance, availability, maintenance, and the production levels. Maintenance reports did not provide proper actionable insights and record maintenance was generally fudged.

4.1.2 No proper visibility on downtime

There was no mechanism to track downtime and its related effects. Moreover, there was no mechanism where reasons of downtime could be recorded, and steps taken to get the system up and running.

So, money was being pumped into the system but there was no clarity when and where was it lost. So, after careful inspection of the manufacturing processes it was realized that there is a need of a system which can:

- Provide clear visibility on the plant dynamics, efficiency factors which includes KPIs such as Downtime, Availability, Performance based on cycle time trends, energy consumption.
- Shift from manual paper-based record maintenance system to machine enabled and supervised record maintenance system that can be accessible anytime, anywhere and any platform.

4.2. Blueprint of the solution

The blueprint for the required solution was designed as mentioned in Fig. 1. The machines were connected to the PLC or via sensors (depending the machine type and compatibility). The PLC readings are logged in a Data logger which is uploaded and stored in the installed-On Premise application server. The application installed in the server helps to generate reports for analysis, create alarms for any events that are configured. It is also responsible for accessing data from Workstation computer and in mobile platforms.

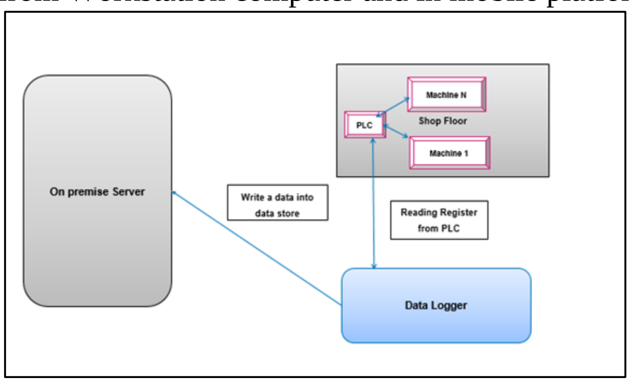

Fig. 1: Blueprint of the solution

4.3. Implementation in the shop floor

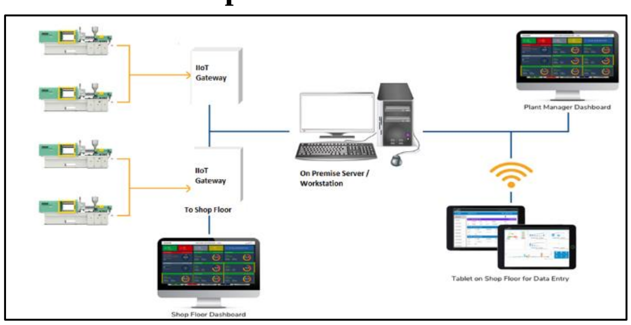

Fig. 2: Process flow of the implemented solution

Fig. 2 describes the process flow of the implemented solution. As we can see, the machines which are connected via PLC or sensors. The data is further aggregated in IIOT gateway. IIOT Gateway apart from data aggregation from various upstream devices, acts as a vital component for edge computing. This not only reduces bandwidth consumed but also increases reliability. The Shop Floor dashboard provides real time monitored data on various KPIs and other configured factors to the operators and relevant personnel on the shop floor to identify areas of improvement and identify any potential breakdowns in advance. Moreover, alarms are also generated and displayed for alerting the operators. The on-Premise Server acts as the application server for generating timely reports which is accessible on various platforms as mentioned in the diagram.

4.4. Connecting the assets:

Based on the above flow diagram (Fig 2), the following assets were connected to the system:

- Connecting 36 Injection Molding machines with the help of parallel connection with relays.
- Integration of machines with energy meters.
- Integration with on premise ERP to import plans and pump in required configured data into the system and extract relevant data for operational purposes.

5. OBSERVATION AND INSIGHTS:

5.1 Downtime Analysis:

Machine downtime whether it is planned or unplanned is a very important cost factor to any manufacturer. It not only is limited to machines but also extends to areas such as cost of idleness of operators, cost of utilities and organization. It is very important to quantify the downtime as it is indicator of availability and helps to understand the scope of improvement in saving Opex.

To understand the same, there are several types of downtimes that are configured in the system of the manufacturer in this case study as mentioned below.

Table 1: Downtimes

AUXILIARY WATER/AIR
BARREL HEATING
COLOR CHANGE
CRANE PROBLEM
DIE CLEANING/BARREL CLEANING
ENTRIB COMUNICATION ERROR
HRS HEATING TIME
Insert /Punch Change For Production
INSERT SHORTAGE
LUNCH
M/C BREAK DN - HYDROLICS
M/C BREAK DN -ELECTRICALS
M/C BREAK DOWN(ELECTRONICS)
M/C PREVENTIVE MAINTENANCE
M/CBREAK DN-MECHANICAL
MACHINE CLEANING
MACHINE STARTUP TIME
MAN POWER SHORTAGE
MATERIAL PREHEAT
MATERIAL TRIAL
MOULD BREAK DOWN
MOULD PREVENTIVE MAINTENANCE
MOULD TRIAL
NO PLAN
NOZZLE BLOCK
OIL PREHEATING
OPRATER INACTIVE

Table 2: Breakdowns

INSERT SHORTAGE
M/C BREAK DN - HYDROLICS
M/C BREAK DN -ELECTRICALS
M/C BREAK DOWN(ELECTRONICS)
M/CBREAK DN-MECHANICAL
MAN POWER SHORTAGE
MOULD BREAK DOWN
NOZZLE BLOCK
QUALITY PROBLEM DURING PRODUCTION
R/M CONVEYING SYSTEM PROBLEM
R/M SHORTAGE
ROBOT PART GRIPING PROBLEM
RUNNER/SPRUE/GATE STICKING
SPRUE PICKER PART GRIPING PROBLEM

This basically encompasses various ad hoc failures**.**

Table 3: Process Delays:

AUXILIARY WATER/AIR
BARREL HEATING
COLOR CHANGE
HRS HEATING TIME
Insert /Punch Change For Production
MACHINE STARTUP TIME
MATERIAL PREHEAT
MATERIAL TRIAL
MOULD TRIAL
OIL PREHEATING
PROCESS SETTING
QUALITY FIRST OFF APPROVAL

Contains various pre- requisite processes before starting production**.**

Table 4: Maintenance:

DIE CLEANING/BARREL CLEANING
M/C PREVENTIVE MAINTENANCE
MACHINE CLEANING
MOULD PREVENTIVE MAINTENANCE

Contains the various planned and unplanned maintenance activities

Table 5: Management Loss

NO PLAN
OPRATER INACTIVE

This basically is the downtime because of No plan upload in the system i.e. the machine is ideal as the marketing team or senior management were not able to generate sufficient orders to run the machines. It also includes the inactivity of operators which is due to lack of controls

Table 6: Lunch Breaks

LUNCH

Considering the excess time taken after the stipulated time to start production by the workers.

Table 7: Others: Downtime reasons which are due to any unknown reason apart from production.

	Downtime (In Minutes)							
Reason	April	March	February	January	December	Total	Hours	Approx Loss
AUXILIARY WATER/AIR	16.95	2488.716667	5704.2	3818.9	5191.933333	17220.7	287.011667	143505.833
BARREL HEATING	60.95	1511.5	2967.883333	2857.083333	1742.116667	9139.533333	152.325556	76162.7778
COLOR CHANGE	0	266.7333333	189.8166667	194.5333333	94.53333333	745.6166667	12.4269444	6213.47222
CRANE PROBLEM	0	0	0	28.28333333	0	28.28333333	0.47138889	235.694444
DIE CLEANING/BARREL CLEANING	0	665.45	555.0333333	1739.15	1626.016667	4585.65	76.4275	38213.75
ENTRIB COMUNICATION ERROR	0	0	1307.383333	0	0	1307.383333	21.7897222	10894.8611
HRS HEATING TIME	0	15.38333333	311.3333333	47.18333333	29.2	403.1	6.71833333	3359.16667
Insert /Punch Change For Production	13.15	1816.433333	3405.116667	1596.483333	0	6831.183333	113.853056	56926.5278

The system captures the downtime based on the configured downtime reasons as we discussed above. These downtimes were analyzed for months and the monetary loss was also calculated (According to the manufacturer the average Opex is Rs. 500.) as mentioned Table 7:

Based on this report, we try to find out the major contributors to the downtime as mentioned in Fig 3 below:

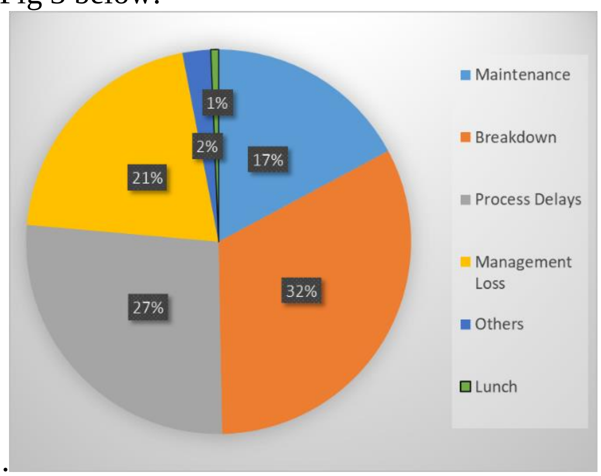

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Figure 3: Major contributors to downtime

5.2 Inferences

- Breakdowns are the main reasons for downtime followed by Process Delays.
- Management Loss consist 21% of downtime which reinforces the fact that sufficient orders were not generated.

5.3 Insights Derived

- 6.5L rupees was incurred due to unavailability of operators, excess lunch time and no plan. Here the management needs to generate more orders. However due to the visibility of IIOT solution excess lunch time was decreased by 90%.
- 1.3L rupees was incurred due to downtimes caused on not getting timely approvals and setting process parameters. So, strict timelines should be followed on getting the approvals and setting process parameters.
- 1.5L rupees was incurred due to Oil Preheating. However, according to the

reports, it has decreased by 92% which infers the scope of improvement in process delays.

- 4.5L rupees was incurred in maintenance downtimes. If proper scheduling is done apart from business hours, then a major chunk of Opex can be saved.

5.4 Rejection Analysis:

Rejection is an indicator of productivity and quality of any production facility. The number of rejected parts or weight of wastage depicts how well the raw materials are converted to acceptable finished products. It also is an indication how meticulously are the manufacturing processes are followed in the production facility and expertise of operators in handling raw materials as well as machines.

Just like Downtime, there are several rejection reasons that are configured in the system. The report below shows the total rejections from November 2019 to March 2020 based on rejection reasons. (See Table 8)

Table 8: Top Rejection Categories from Nov-March

Top rejection categories from Nov-March	
Reason	**Rejected Quantity**
SHORT SHOT	16248
PROCESS SETUP	10534
PART STICKING IN MOULD	9914
INPROCESS PRODUCT TESTING	7685
SILVER STREAKS	6406
Purge Shot Rejection	4828
BREAK DOWN	4551
MOULD TRIAL Rejection	3912
FLASH	3728
POWER CUT ANG D.G CHANGEOVER	3618
CRACKING	3608
BLACK POTS/APECS	3166
Machine Startup Rejection	2775
SHRINKAGE	1771

Based on these categories and products, Top 5 analysis was done for 4 months as we can find in Table 9 below:

Table 9: number of rejected parts based on Product name and reason of rejection.

January				
Parts based			Reason Based	
Part	Rejected Parts		Reason	Rejected Parts
12490199 FILTER DISC 120 MESS, RED TAIWAN	1546		PROCESS SETUP	2245
12470001 CAP 32 MM - CF	741		SHORT SHOT	2060
12510004 2inch DIAL GUAGE	710		PART STICKING IN MOULD	1909
12510002 2inch PC COVER PRESSUER GUAGE-RIB	683		INPROCESS PRODUCT TESTING	1853
12510009 2inch DIAL CASE COVER - PRESSURE GUAG	679		SILVER STREAKS	1547

February				
Parts based			Reason Based	
Part	Rejected Parts		Reason	Rejected Quantity
M22 TUBE GRIPPER	3206		SHORT SHOT	5716
12490199 FILTER DISC 120 MESS, RED TAIWAN	2820		PROCESS SETUP	4039
12490220 131Y/132Y FILTER DISC	2466		Purge Shot Rejection	3105
12510002 2inch PC COVER PRESSUER GUAGE-RI	1650		SILVER STREAKS	2274
12490199 FILTER DISC 120MESH RED	1114		PART STICKING IN MOULD	2197

December				
Parts based			Reason Based	
Part	Rejected Parts		Reason	Rejected Quantity
12490199 FILTER DISC 120 MESS, RED TAIWAN	1744		SHORT SHOT	2029
12510002 2inch PC COVER PRESSUER GUAGE-RIB	1382		SILVER STREAKS	1762
12510012 2.5 INCH PC COVER	1136		PROCESS SETUP	1494
12270018 2.5inch DIAL GUAGE	834		INPROCESS PRODUCT TESTING	1477
12510009 2inch DIAL CASE COVER - PRESSURE GUAG	603		BLACK POTS/APECS	1276

November				
Parts based			Reason Based	
Part	Rejected Parts		Reason	Rejected Quantity
12490199 FILTER DISC 120 MESS, RED TAIWAN	4969		SHORT SHOT	4318
12490247 1.5inch FILTER DISC	1900		PART STICKING IN MOULD	3786
12490199 FILTER DISC 120MESH RED	1835		PROCESS SETUP	1329
12510009 2inch DIAL CASE COVER - PRESSURE (	561		INPROCESS PRODUCT TES	1297
12490220 131Y/132Y FILTER DISC	491		CRACKING	1165

From the above report we can see the number of rejected parts based on Product name and reason of rejection.

Inferences

- Certain products highlighted in Green have the greatest number of rejections every month. Using this information, the plant heads can try to understand the reasons for facing high number of rejections for specific products.
- The Reasons highlighted in light Red have a high share of rejections every month.
- One Rejection reason from one month is getting carried forward to feature in top 5 rejections reasons of the succeeding month. So, this pattern gives the manufacturer a visibility to predict the kind of rejections he may see the next month.

5.5 Mapping Downtime and Rejections*:*

According to experts of Plastic manufacturing field, a lot of rejections can be minimized by controlling the related reasons of downtime. Based on the Downtime analysis and Rejection analysis, a mapping was prepared which specifies controlling which downtime can result in reduced rejections.

Table 10: Based on Mold Maintenance

Mould Maintenance	
MOULD BREAK DOWN	PART STICKING IN MOULD
ROBOT PART GRIPING PROBLEM	MOULD TRIAL Rejection
RUNNER/SPRUE/GATE STICKING	FLASH
SPRUE PICKER PART GRIPING PROBLEM	CRACKING
	BLACK POTS/APECS
	BURN MARK
	SCRATCH/DENT
	THREAD CUTTING DURING UNSCREAW
	GATE POINT (SPLAY,DULL,CUT) MARK.
	SHORT MOULDING NEAR GATE POINT
	WELD LINE
	WEAK PARTS
	BLOW HOLE
	FITMENT FEDECT
	EJECTOR MARKS

Mold is the heart of any plastic product manufacturing process. If the mold maintenance is properly done and as per standards, the downtime will reduce, leading to reduction in rejections also.

Table 11: Based on Protocol

Protocol Related	
BARREL HEATING	INPROCESS PRODUCT TESTING
COLOR CHANGE	SILVER STREAKS
DIE CLEANING/BARREL CLEANING	Purge Shot Rejection
HRS HEATING TIME	POWER CUT ANG D.G CHANGEOVER
MACHINE CLEANING	Machine Startup Rejection
MACHINE STARTUP TIME	COLOUR DEFECTS(VARIATION)
MATERIAL PREHEAT	COLOR CHANGE
NOZZLE BLOCK	FLOW MARK
OIL PREHEATING	MATERIAL TRIAL
	OIL/GREASE MARK

Similarly, certain Downtime can be reduced by following certain SOPs, checklists and protocols and hence will lead to subsequent reduction of rejections

5.6 Performance Analysis

In simple terms, performance of a machine can be explained as the number of parts produced in a specific time interval with respect to an ideal level. In this case study, three broader angles have been presented to view performance of the machines.

Table 12: Performance based on production quantity

Top 5 Analysis											
January				February				March			
Machine	Produced Qty	Accepted Qty	Rejection%	Machine	Produced Qty	Accepted	Rejection%	Machine	Produced Qty	Accepted Qty	Rejection%
06-FM-61-80T	152452	152275	0.12%	05-FM-76-80T	621498	619517	0.32%	03-TOS-60-100T	582572	582351	0.04%
23-TOS-59-150T	135556	135068	0.36%	02-FM-177-125T	342876	341550	0.39%	07-NB-132-110T	416588	415692	0.22%
04-FM-118-80T	123168	122722	0.36%	06-FM-61-80T	317782	316962	0.26%	02-FM-177-125T	276572	276006	0.20%
17-OIMA-91-180T	94596	94369	0.24%	07-NB-132-110T	314500	310613	1.24%	06-FM-61-80T	260022	259310	0.27%
02-FM-177-125T	83578	83428	0.18%	04-FM-118-80T	261501	259454	0.78%	04-FM-118-80T	253944	253298	0.25%
Bottom 5 Analysis											
January				February				March			
Machine	Produced Qty	Accepted Qty	Rejection%	Machine	Produced Qty	Accepted	Rejection%	Machine	Produced Qty	Accepted Qty	Rejection%
03-LNT-53-350T	3117	3016	3.24%	07-FM-151-350T	7637	7337	3.93%	06-FM-148-350T	5859	5679	3.07%
05-FM-128-350T	2910	2850	2.06%	01-FM-51-660T	7095	6916	2.52%	01-FM-51-660T	5306	5181	2.36%
02-FM-52-450T	2500	2472	1.12%	06-FM-148-350T	6758	6582	2.60%	04-TOS-54-350T	5304	5086	4.11%
06-FM-148-350T	2642	2427	8.14%	05-FM-128-350T	6359	6171	2.96%	05-FM-128-350T	4849	4731	2.43%
01-FM-51-660T	1574	1535	2.48%	27-FM-171-775T	5455	5332	2.25%	27-FM-171-775T	3345	3227	3.53%

The most basic level of analysis of performance is to find out the machines producing the greatest number of parts. Through Top 5 and Bottom 5 analysis approach, following points of visibility were derived:

- Finding out the most consistent performing machines: In the Top 5 Analysis part, we can see the most consistent performing machines highlighted in green as they feature among Top 5 best performing machines every month. So, the performance parameters of these machines can be studied and used as a reference.
- Finding out the non-performing machines: In the Bottom 5 Analysis, we can find out the machines with consistently low contribution to the production volume. As we can see the machines highlighted in red feature in the Bottom 5 for every month. By getting this visibility, the plant heads can investigate the reason for such performance which can be attributed to lack of maintenance, technical failures, or lack of orders. This visibility further helps to find out the scope of availability of machines for producing other parts which they are not assigned to produce.
- Significant Rejection % between Top 5 and Bottom 5 machines: As we can see the Top 5 machines have a rejection% less than 1 whereas it is always greater than 1 for Bottom 5 machines. This again calls for investigation for plant heads to find out the reasons as it exceeds more than just the start up rejections.

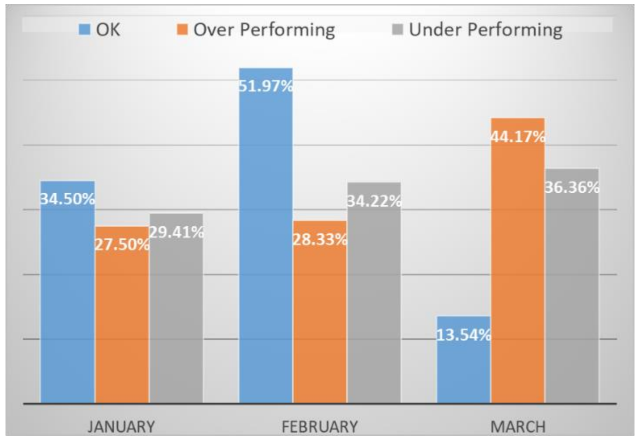

Figure 4: Performance Based on Cycle Time:

Based on this summary reports were generated on performance classification as mentioned in Figure 4 above

Here the visibility is produced based on the cycle time trends to produce certain parts. Cycle time can be explained as the time required to produce a single part of plastic through a cycle to a finished product. This time includes injection of plastic into the mold to the start of production of next plastic part.

Every part which is produced in a plastic manufacturing plant has a specific Ideal / Standard cycle time which is configured in the system. The system also captures the Average Cycle time for each part. A tolerance time is also taken due to various external factors such as Operator delay. So, the theory behind this is:

- If Standard Cycle Time > Average Cycle Time, then more parts are produced in less time which means machine is Over Performing.
- If Standard Cycle Time < Average Cycle Time, then less parts are produced in the stipulated time which means machine is Under Performing.

In this research we have considered three parameters namely Standard Cycle Time, Average Cycle Time, Deviation (Standard Cycle Time - Average Cycle Time), Tolerance (2 secs as per manufacturer's norms) to classify the performance of machines into 3 broader categories as mentioned below:

- OK : Deviation [-2,2] secs
- Over Performing: Deviation > 2 secs
- Under Performing: Deviation < - 2 secs

Inferences

- There has been a healthy increase in Over Performing category from January to March due to the visibility provided by IIOT solution and the steps taken towards better performance such as maintaining correct parameters.
- There has been a steady increase in Under Performing machines. The plant heads and managers need to check for such machines and find ways increase performance by maintaining correct parameters, selecting the correct machine for a specific product to increase performance.

5.7 Selecting Suitable Optimized Machine

This is an important inference based, data driven visibility which the IIOT solution provided to the manufacturer. Based on performance analysis of cycle time and energy consumption, the Suitable Optimized Machine was found out for parts being produced in two or more machines.

Table 13: Suitable Optimized Machine:

Part Name	Produced in	Based on cycle time	Dev/ Cycle Time	Based on energy	Suitable Optimized Machine
12490117 126TL FILTER BRREL	01-FM-51-660T, 02-FM-52-450T	01-FM-51-660T	Deviation	02-FM-52-450T	To be decided by user requirements
12550002 2inch /2.5inch HCF CONE	01-FM-51-660T, 27-FM-171-775T	01-FM-51-660T	Cycle Time	27-FM-171-775T	To be decided by user requirements
12550006 3INCH HCF CONE NEW	01-FM-51-660T, 27-FM-171-775T	01-FM-51-660T	Cycle Time	27-FM-171-775T	To be decided by user requirements
12470001 CAP 32 MM - CF	01-NB-136-130T, 05-FM-76-80T	01-NB-136-130T	Cycle Time	05-FM-76-80T	To be decided by user requirements
12490199 FILTER DISC 120 MESS, RED TAIWAN	02-FM-177-125T, 04-FM-118-80T, 05-FM-76-80T	05-FM-76-80T	Cycle Time	05-FM-76-80T	05-FM-76-80T
12490001 3inch FILTER BODY PLAIN BSP ,OPEN	03-LNT-53-350T, 07-FM-151-350T	07-FM-151-350T	Cycle Time	03-LNT-53-350T	To be decided by user requirements
12490077 2.5inch FILTER BODY PLAIN BSP ,OPEN	03-LNT-53-350T, 08-FM-169-350T	08-FM-169-350T	Deviation	03-LNT-53-350T	To be decided by user requirements
12490300 3inch SURE CLEAN FILTER BODY BSP	03-LNT-53-350T, 07-FM-151-350T	03-LNT-53-350T	Deviation	07-FM-151-350T	To be decided by user requirements
12490302 2.5inch SURE CLEAN BARREL	03-LNT-53-350T, 04-TOS-54-350T	03-LNT-53-350T	Cycle Time	03-LNT-53-350T	03-LNT-53-350T
12530030 2.5inch HU BACK BSP 3/4inch OPEN ,2inch OPEN	03-LNT-53-350T, 09-FM-114-300T	09-FM-114-300T	Deviation	09-FM-114-300T	09-FM-114-300T
12490047 121Y/122Y FILTER JALLI 120MESH	03-TOS-60-100T, 05-FM-76-80T	05-FM-76-80T	Cycle Time	05-FM-76-80T	05-FM-76-80T
12510004 2inch DIAL GUAGE	04-FM-118-80T ,05-FM-76-80T	05-FM-76-80T	Cycle Time	05-FM-76-80T	05-FM-76-80T
12550057 2inch HCF BODY BSP , PPGF	06-FM-148-350T, 07-FM-151-350T	06-FM-148-350T	Deviation	06-FM-148-350T	06-FM-148-350T
12540027 2.5 /3inch TV CAP, GREEN, PPCP	08-FM-77-200T, 25-TOS-58-150T, 26-TOS-74-150T	26-TOS-74-150T	Deviation	26-TOS-74-150T	26-TOS-74-150T
12550009 2.5inch SILIPON FLANGE PPGF	08-FM-77-200T, 16-FM-105-200T	08-FM-77-200T	Deviation	08-FM-77-200T	08-FM-77-200T
12490116 126T FILTER BARREL	09-FM-114-300T, 10-FM-55-275T	09-FM-114-300T	Deviation	09-FM-114-300T	09-FM-114-300T
12490064 123YM/124YS FILTER JALLI 120 MESH	09-FM-179-200T, 18-FM-104-150T , 25-TOS-58-150T	25-TOS-58-150T	Deviation	25-TOS-58-150T	25-TOS-58-150T
12490232 2inch ECO FILTER BODY BSP	09-FM-179-200T, 16-FM-105-200T	09-FM-179-200T	Deviation	09-FM-179-200T	09-FM-179-200T
12530021 2inch HU BACK BSP 3/4inch OPEN	09-FM-179-200T, 15-FM-56-200T	09-FM-179-200T	Deviation	09-FM-179-200T	09-FM-179-200T

The rows marked green are the parts (in Table 13) for which a Suitable Optimized Machine was found out. For ex. 12490199 FILTER DISC 120 MESS, RED TAIWAN is being produced in three machines namely 02-FM-177-125T, 04-FM-118-80T, 05-FM-76-80T. Out of these three machines, 05-FM-76-80T produced the part in less time and consumed less energy than others.

Now, the manufacturer has the visibility and liberty to decide how he can produce the product optimally. Moreover, for other parts in white, the manufacturer needs to decide the priority for production (cycle time or energy) and can select the machine accordingly. In this way the IIOT solution helps the user to build a plan based on machine performance on various parameters**.**

6. Results And Findings

Figure 5: Year-wise performance chart

Due to the visibility provided and optimization strategies suggested and derived from the IIOT solution, we can find:

- Availability has increased by **7.07%** M-O-M.
- Performance and Quality has remained on higher 90s which is very good.
- OEE has increased by **8.19%** M-O-M.
- Surpassed World Class OEE of 85% in March i.e. 86.18%.
- Provided visibility on optimizable hidden cost of around **15L** INR.

Scope of Improvement

6.1.1 Transition into Cloud based architecture

Cloud based architecture is a must in place of on-premise server-based architecture. It is because with increase in size and data produced in a plant, the on-premise server may not support it for longer run. Since the cloud architecture provides highly scalable infrastructure, provides disaster recovery facilities, better security features, better availability than on premise server architecture, it is a must in embarking the digital journey.

Use of Wireless sensors

Transition to wireless sensor is important as it saves the set up and maintenance cost of wiring. Wires make the set up messy and makes troubleshooting difficult.

Operator Performance Analysis

Operators are the main component in any industrial set up and their skill, expertise and discipline help to provide better results. So, the integration of Operator Performance Analysis system helps to extract Operators' data from ERP and monitors their performance based on delays, accepted products in the assigned machines. So, integration of this module is important.

Challenges:

6.2.1 Low understanding of Industry 4.0 [15]

There is a need of perception creation among SME (Small and Medium Scale Enterprises) on the importance of IIOT services and the concept of Industry 4.0. It should be viewed as an investment for the future rather than a cost in present.

6.2.2. Lack of capability to apply new business model. [15]

The business model as well as the organizational structure should be flexible enough to adapt digital strategy in the current model without disturbing the existing system.

6.2.3 Security concerns [16]

IOT still being in developing stage, security has been a question. Though various protocols for secure transmission has been developed, the reliability is still a question among potential adopters.

6.2.4 Industrial automation and monitoring systems replacing low cost labor. [17]

In a developing country like India, industrial automation can lead to replacement of several unskilled labor in manufacturing plants.

6.2.5 Poor digital operation strategy and vision. [18]

Several companies fail to envisage a proper vision of what they expect to see themselves after adoption. The greater issue is staying digital rather than adopting digital strategies. Deriving value out of Industrial IOT service remains a challenge.

7. Future Scope of Research:

Integration of Digital Twin Technology in IIOT solution: Digital Twin has been the buzzword in this era of smart manufacturing where companies such as IBM have made strides in. Digital Twin has the potential of creating a new evolution in manufacturing to achieve super optimized performance by creating a digital equivalent of the physical machine and carrying out simulations **[19].** This will again help to optimize the machine performance and will help to increase efficiency to a larger extent.

8. Conclusion

From this research it was understood that visibility of the industrial processes plays a vital part in taking steps to increase OEE. The IIOT solution if visibility which helped to derive certain issues which can cost company a huge fortune without its knowledge. The derived information and reports helped to decide the areas of focus to achieve accepted efficiency levels. Technology and manpower need to work in tandem to create profits by increasing OEE and IIOT plays a major role in providing the digital eye to any firm to achieve this.

References

L. Columbus, “86% Of Enterprises Increasing IoT Spending in 2019,” Forbes, Nov. 2018. Accessed on: 10.05.2020. Retrieved from: https://www.forbes.com/sites/louiscolumbus/2018/11/23/86-of-enterprises-increasing-iot-spending-in-2019/#1be703d1384d

S. Malhotra, “IoT Landscape and NASSCOM Initiatives”. May. 2017. Accessed on: 12.05.2020. Retrieved from: https://www.wfeo.org/wp-content/uploads/stc-information/L3-IoT_Landscape-by-S_Malhotra.pdf

R. Dhawan, S. Gupta, N. Huddar, B. Iyer, R. Mangaleswaran, and A. Padhi, “The auto component industry in India: Preparing for the future,” McKinsey & Company, Sep. 2018. Accessed on: 15.05.2020. Retrieved from: https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Asia%20Pacific/The%20auto%20component%20industry%20in%20India%20preparing%20for%20the%20future/ACMA%20Vertical_Onscreen_Final.ashx

A, “Increasing OEE of an assembly line using the Industrial Internet of Things,” Journal of Mechanics of Continua and Mathematical Sciences, vol. 1, no. 3, 2019.

S. Wang, J. Wan, D. Li, and C. Zhang, “Implementing Smart Factory of Industrie 4.0: An Outlook,” International Journal of Distributed Sensor Networks, vol. 12, no. 1, p. 3159805, 2016.

F. Wortmann and K. Flüchter, “Internet of Things,” Business & Information Systems Engineering, vol. 57, no. 3, pp. 221–224, 2015.

M. C. Jena, S. K. Mishra, and H. S. Moharana, “Application of Industry 4.0 to enhance sustainable manufacturing,” Environmental Progress & Sustainable Energy, vol. 39, no. 1, p. 13360, 2019.

C. Cronin, A. Conway, and J. Walsh, “Flexible manufacturing systems using IIoT in the automotive sector,” Procedia Manufacturing, vol. 38, pp. 1652–1659, 2019.

C. Cronin, A. Conway, and J. Walsh, “Flexible manufacturing systems using IIoT in the automotive sector,” Procedia Manufacturing, vol. 38, pp. 1652–1659, 2019.

J. Cheng, W. Chen, F. Tao, and C.-L. Lin, “Industrial IoT in 5G environment towards smart manufacturing,” Journal of Industrial Information Integration, vol. 10, pp. 10–19, 2018.

J. Heilala, P. Järvinen, P. Siltanen, J. Montonen, M. Hentula, and M. Haag, “Interactive Visual Analytics of Production Data - Predictive Manufacturing,” Proceedings of The 9th EUROSIM Congress on Modelling and Simulation, EUROSIM 2016, The 57th SIMS Conference on Simulation and Modelling SIMS 2016, 2018.

M. Pertselakis, F. Lampathaki, and P. Petrali, “Predictive Maintenance in a Digital Factory Shop-Floor: Data Mining on Historical and Operational Data Coming from Manufacturers’ Information Systems,” Lecture Notes in Business Information Processing Advanced Information Systems Engineering Workshops, pp. 120–131, 2019.

W. H. W. Mahmood, I. Abdullah, and M. H. F. M. Fauadi, “Translating OEE Measure into Manufacturing Sustainability,” Applied Mechanics and Materials, vol. 761, pp. 555–559, 2015.

C. Bamber, P. Castka, J. Sharp, and Y. Motara, “Cross- functional team working for overall equipment effectiveness (OEE),” Journal of Quality in Maintenance Engineering, vol. 9, no. 3, pp. 223–238, 2003.

S. Luthra and S. K. Mangla, “Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies,” Process Safety and Environmental Protection, vol. 117, pp. 168–179, 2018.

M. Lezzi, M. Lazoi, and A. Corallo, “Cybersecurity for Industry 4.0 in the current literature: A reference framework,” Computers in Industry, vol. 103, pp. 97–110, 2018.

L. Li, “Chinas manufacturing locus in 2025: With a comparison of ‘Made-in-China 2025’ and ‘Industry 4.0,’” Technological Forecasting and Social Change, vol. 135, pp. 66–74, 2018.

S. Erol, Schumacher, A. and Sihn, W,” Strategic guidance towards Industry 4.0–A three-stage process model. In International Conference on Competitive Manufacturing”. https://www.researchgate.net /profile/Selim_Erol/publication/286937652_Strategic_guidance_towards_Industry_40_-_a_three-stage_process_ model/links/5671898308ae90f7843f2d27/Strategic-guidance-towards-Industry-40-a-three-stage-processmodel.pdf

Q. Qi and F. Tao, "Digital Twin and Big Data Towards Smart Manufacturing and Industry 4.0: 360 Degree Comparison," IEEE Access, vol. 6, pp. 3585–3593, 2018.