OPTIMIZATION IN MES BY IMPLEMENTING SMART ANDON SYSTEM FOR PRODUCTIVITY ENHANCEMENT

Mr. Preetam Patil[1], Prof. G. S. Dhende[2]

[1]M.Tech Scholar, Dept. of Mechanical Engineering, Government College of Engineering, Karad, Maharashtra
[2]Assistant Professor, Dept. of Mechanical Engineering, Government College of Engineering, Karad, Maharashtra

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Abstract - *In today's manufacturing culture, change has to come to be a consistent. Modern assembly systems have to adapt for products, markets, technologies with regulatory requirements. The assembly lines in industry are undergoing tremendous modifications with efficient process control and the rapid improvement in production by automation, information technology and networking. Variant oriented assembly structures were developed to obtain greater flexibility and adaptableness to feature product variety and variations and scaling production. Therefore we introduce Smart assembly systems where embedded network applied for the work stations and system to achieve more communication between entities in the system and establish the smart error detection framework which can analyze the reasons behind the errors in various categories with advanced data like frequency of the error and time loss to enhance the productivity. Where value added implementations inspired by productivity improvement techniques in industrial revolution 2 (mass production) with the digital improvements at present.*

Key Words: *Smart MES, Lean Manufacturing, Smart Andon, OEE, Integrated Control System*

1. INTRODUCTION

In today's competitive world enterprise or organizations manufacturing high quality, defect free products at optimum cost. For this organizations adapting new culture for total quality and productivity management in the manufacturing as well as in addition to service sector gave beginning to new ways to enhance high-quality of products. By using the use of various tools of TQM. In India, Automobile Industry rapidly growing, developing to increase productivity in both commercial and passenger vehicle segment. As per the customer demands for high product variety lead a higher degree of individualization and increase competition among manufacturers which favor new developments like suitable assembly line, fitment stations, and sub-assembly stations. Well-established assembly lines need to be adapt changes to enhance the productivity. Production planning process is most important factor in the manufacturing industry. Assembly line is plays important role in the production planning and process. Assembly lines are designed to be cost efficient and suitable for mass production that uses highly specialized workflow analysis. Where the number of variants require flexible method for the assembly process which means to make assembly line more proactive by reducing the downtime of the assembly lines. It can be possible by enhancement in the error detection system as well as enhancing the response to the defect or error occurred.

1.1 Background

TATA Motors Ltd. (PVBU), Chikhli, Pune is the automobile manufacturing plant for passenger vehicle segment currently developing reference architecture base for Industry 4.0 platform. As per the RAMI 4.0 in TCF (Trim Chassis Fitment) Shop where the work done by adapting digitalization for the manufacturing execution system with ensuring the zero defect and error analysis framework development with implementing root cause for errors occurring to reduce downtime in production. Previous Andon system had seven-segmented LED display only showing simple data like actual and target production along with total downtime for the shift. Pull cord signals, DC tool interlocks, Audit check station interlocks, breakdown alerts and safety locks integrated through PLC for framework development for IIOT which leads to data acquisition of the system by using RSLinks software for data transfer PLC to the Excel. This gathered data.

1.2 Andon- Meaning, History, Benefits in lean manufacturing

The operator to hold the production process on assembly line if there any quality issue or breakdown arises and assistance is needed. The andon system is a set of pull-cords or buttons, lights, hooter laps and andon boards installed in assembly lines. If the operator stops the assembly line by activation of pull cord then light gets turn on at his station which indicate the supervisor which process is responsible for the stoppage. The supervisor then goes immediately to that workstation to investigate the problem and take necessary corrective action in order to start the assembly line. The andon system includes a means to pause production so that the issue can be solved. It is lean method that is widely adopted in manufacturing development for detection and removal of errors.

In manufacturing industry, andon system introduced in mid-part of 20th century about end of the World War2 which largely accepted by automobile industries in Japan. The commercial concept was to allow the operators or supervisors to suspend the production if there are any quality or safety issues. It is introduced as part of Jidoka Quality Control method which taken by Toyota as the part of Toyota Production System from then it is a part of the Lean

Production Approach. The concept of andon system and this technique mainly attributed to William Edwards Deming, an American engineer who worked on betterment in mass production along with quality product with most of the Japanese manufacturers in 1950's.

At first andon system developed and used in industry was simple light that indicate supervisor to signal line status based on colours. Nowadays, more sophisticated and complicated visual displays are often used in the Andon system. Apart from Andon lights the Andon system normally also include an Andon board which has the purpose of distributing other key information regarding the manufacturing status which the Andon light cannot provide. According to Lean Manufacturing Andon is an effective communication tool.

Benefits in lean manufacturing by using andon system:

Andon system provides both short and long term benefits in manufacturing which directly improves the productivity of the shop.

In the short-term, it provides benefits as:

a. Visibility as well as transparency in the manufacturing processes

b. Reduce in the waste

c. Increase in the productivity and overall efficiency

In the long-term, it provides benefits as:

a. Enhance the quality of products in manufacturing

b. Responsible operators who are accountable for the line running as efficiently and effectively as possible, empowering them to act when problems arise, rather than waiting for management

c. Reduce the cost and downtime by error analysis

d. Long term improvements for production process.

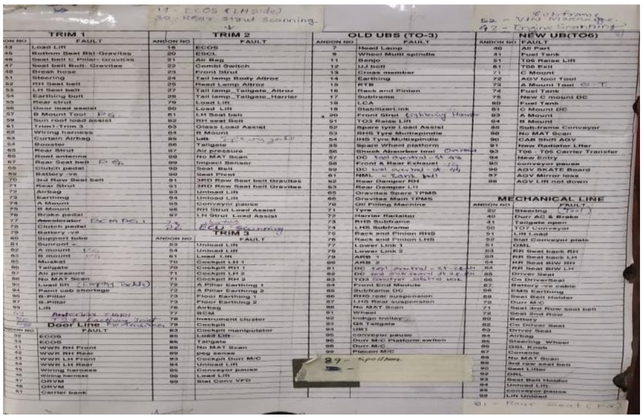
1.3 Andon System at TCF Shop in Tata Motors

In TCF Shop there are total 178 operating stations in main 8 assembly lines where all lines are in series for production. At every station there are two pull cords to stop the assembly line at that station, one is for if the material is short or wrong and second one is for if the operation is incomplete. Also the system consist of automatic stopping for conveyors, lifts by the safety means or the wrong operation performed or incomplete operation by operator by DC torque tools at the workstations. Previous in-use andon system have seven segment LED display for andon dashboard where it consist of information about actual and targeted production, total part short stoppages, pull cord stoppages and time loss (in minutes) as per shift A, B & C.

(a) Main Andon Dashboard

(b) Andon Board at assembly line at TCF Shop

(c) HMI display: Line Stoppage



(d) Andon code chart sheet

Fig.1: Old Andon Dashboard

As the no. of stations in the shop and the no. of errors in operations can be seen therefore to simplify this numbers are used for displaying error occurrence on the Andon dashboard and supervisor use the chart displayed at monitoring system to identify the operation where the error occurred and take remedial action on it. Every assembly line have LED display where line engineer and team leaders can see the Andon No. if the conveyor stopped by any error or external issue.

1.4 Need for Andon improvement

As per current scenario organization looking for improvement in the production system by tracking the assembly operation process for enhancement in productivity with maintaining quality of product. This can be done by optimizing the operation process which means by reducing the downtime of the assembly line. For reducing downtime error analysis framework required which contains real time error detection with detailed information of error, which can be achieved by development of Andon system and optimization in error classification along with data acquisition where error classified in different categories, type of error, sub-type, location of the error with reason along with the frequency of the error and the time loss for particular error. By analyzing that data it is possible to take remedial actions.

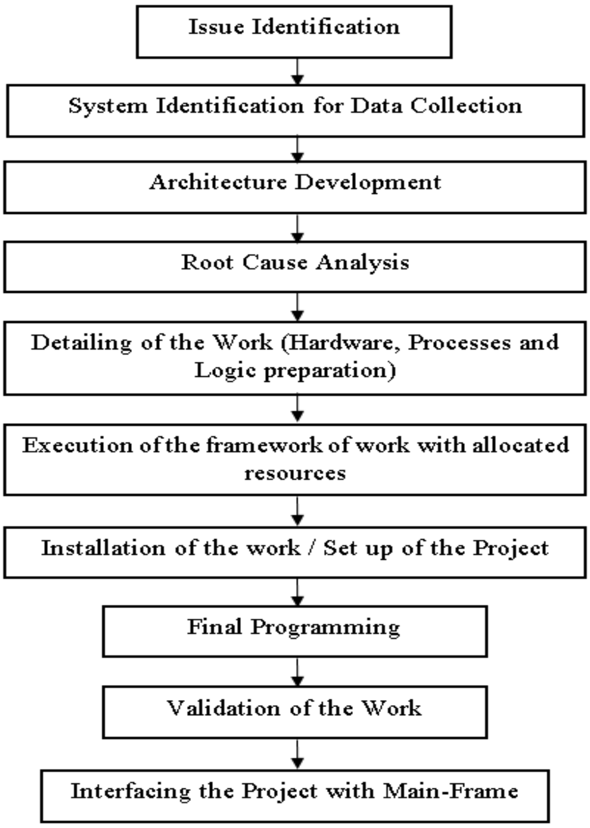


Fig.2: Flowchart of the Methodology

The flowchart represents the methodology flowchart and steps followed to complete this project. At first the observation have to be done for problems in assembly line, kitting area, logistics and overall working background in TCF Shop for issue identification. As per the observations and checking old system and software feasibility to adapt desired changes for development after identifying issues. Then as per our requirement for real time error detection and data analysis system, architecture has to be develop by data acquisition from PLC system to excel. By collecting data from newly developed architecture, have to find operations in which frequency of error is high and operations which have huge downtime. After finding those, root cause analysis have to be done to reduce or eliminate the error by taking remedial actions by applying various lean techniques which developed in early years of 19th century for mass production and quality management with today's digital automation technology which leads to reduction in downtime and frequency of the error.

2. SMART ANDON DASHBOARD DEVELOPMENT

In excel as per requirement digital dashboards developed by gathered data, for this first data sheet prepared considering all andon codes as per the assembly lines with their respective occurring locations, reason of occurrence, those errors are categorized into several types as responsible department which have to take action on. Also for supportive interaction detailed data analysis types again differentiated into sub-categories or sub-types. For live tracking as error occurred in any assembly line on informational dashboard the andon code displayed along with the reason of error, location, frequency of occurrence of particular error with the exact downtime due to that error.

Table -1: Sheet preparation for Data Collection

Shift Name	Andon Code	Side (RH/ LH)	Station No.	Type	Sub-Type	Description
Name of Assembly Line	Andon No. of Error	Details about Location of the Error Occurred		Classification of Error as per Responsible Department to take action on		

Also for detailed real time data analysis operational dashboards and made which contains station wise classification of data about error occurred in a particular shift. By which remedial action plan can be made to enhance assembly line.

The errors or issues categorized as:

I. **Material:**

Error indicating shortage of the part/parts in assembly line.

II. **Breakdown:**

Error indicating function failure of a tool in assembly line or malfunction or conveyor or lift or any equipment.

III. Process:

Error indicating delay in operation by operator by pull cord stoppages.

IV. Starved:

Indication for Conveyor stopped of moving assembly line due to not received partial assembled body from previous assembly line.

V. Blocked:

Indication for Conveyor stopped of moving assembly line due to inability to send partial assembled body in next assembly line as next line filled with maximum capacity and stopped.

VI. Interlock:

Error indicating incomplete operation, wrong operation at semi-automatic tools and critical stations which directly affects quality and safety of the product. It is the mechanism which prevents undesired operations as preventing machine harming operators or damaging itself by preventing one element from changing its state. For this assembly lines conveyor stoppage treated as preventive element.

Sub-types are as:

a. DC tools

b. Over Travel

c. Part Genealogy

d. Pick to light

e. Machines

VII. Quality:

It indicates the conveyor stoppage at the audit stations as defect found in the partial assembled body. It can be wrong part assembled, faulty part or any observed defect in fitment in quality inspection on lineside.

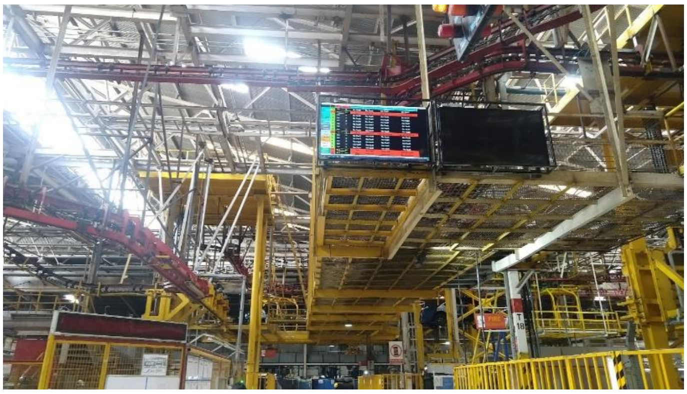
VIII. Safety:

Indication for assembly line stoppage due to safety protocol not been followed at risky operations or maintenance while breakdown.

For constant monitoring of the operations and error occurrence Operational dashboard is developed which mainly focused on activities that are constantly changing and might require attention and response to resolve error. This dashboard displays live data from PLC also stored for counting frequency of particular error and downtime due to that error.

Along with the self-diagnostic error detection Andon system for betterment in production and reducing those error analysis of occurred errors is required, therefore analytical dashboard developed by excel tools by using gathered data which acquired by PLC for individual assembly lines for detailed analysis and collective analysis of all assembly lines for interdependency and for finding root cause for downtime in production.

As shown in Figure below developed live dashboard tracks real time errors and displays stoppages in conveyors in different assembly lines due error occurrence with detailed description about error. Which helps to instruct the person who's responsible to take action on which reduces the time for resolution of error.



	ANDON NO	TIMELOSS	FREQUENCY	STATION	CONDITION	CATEGORY	DETAILS
TRIM 1 LH	34	12.0	6	T34	Quality	Pull cord	LH_Stn34
TRIM 1 RH	54	0.0	0	T12	Interlock	DC tool	Earthing bolt
TRIM 2 LH	94	20.0	4	Unload Lift	Starved	Bank Empty	Unload Lift
TRIM 2 RH	0	0.0	0	No Fault	No Fault	No Fault	No Fault
TRIM 3 LH	48	5.0	2	T48	Quality	Pull cord	LH_Stn48
TRIM 3 RH	0	0.0	0	No Fault	No Fault	No Fault	No Fault
NUB LH	83	13.5	20	UB14	Interlock	DC Tool	A Mount
NUB RH	85	0.0	0	UB16	Breakdown	Fault	Sub-frame Conveyor
OUB LH	61	89.9	44	NML	Blocked	Bank full	NML
OUB RH	0	0.0	0	No Fault	No Fault	No Fault	No Fault
NML LH	0	0.0	0	No Fault	No Fault	No Fault	No Fault
NML RH	12	34.3	12	NML12	Material	Pull cord	RH_Stn12
OML LH	0	0.0	0	No fault	No fault	No fault	No fault
OML RH	31	87.0	129	OML21	Interlock	Over travel	RH Door Load Assist
DOOR LH	16	36.2	58	D16	Process	Pull cord	Stn16
DOOR RH	16	46.0	76	D16	Process	Pull cord	Stn16

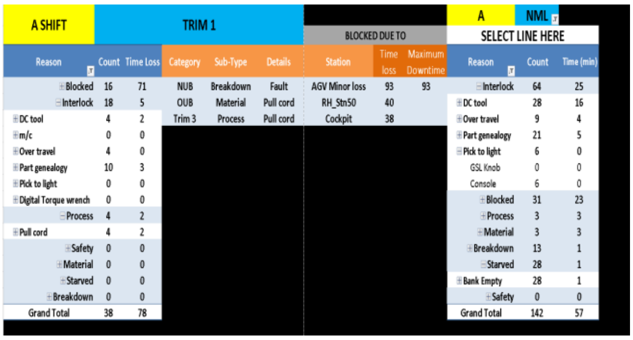
(a)Error Detection live Andon Dashboard

Actual(min)	A								
Type	OUB	NML	Trim 3	Trim 2	NUB	Trim 1	OML	DOOR	Grand Total
Blocked	65	40	41	58	16	84		38	341
Process	0	5	26	0	4	2	60	17	113
Interlock	17	43	5	3	4	6	11	19	109
Breakdown	0	3	6	1	47	0	0		57
Material	22	4	7	2	16	0	5		56
Starved	0	2	0	27	6	0			35
Quality			10	4		0			14
Safety	0	0	0	0		0	0		0
Grand Total	105	97	95	94	93	92	76	74	726

(b) Down-time data analysis dashboard assembly lines

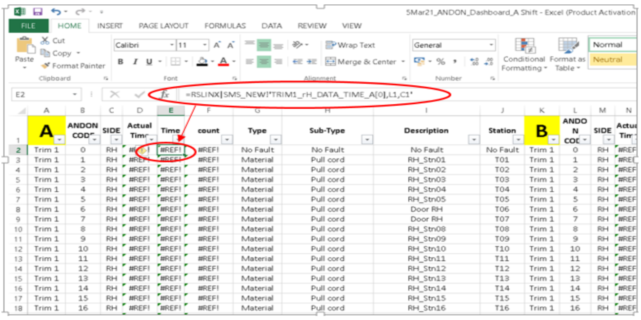
Type	Interlock														
	Column Labels														
	NML		OUB		OML		Trim 1		Trim 3		NUB		Trim 2	Total min	Total nos
Reason	min	nos	min	nos	min	nos	min	nos	min	nos	min	nos	min		
DC tool	27	28	7	15	0	0	2	4	4	13	4	7	1	6	44	73
Over travel	7	9	8	36	11	23	0	4	0	0	0	1	0	0	26	73
Part genealogy	9	21	3	8			4	10	1	1	1	2	2	6	20	48
Pick to light																
Muskat							0	0							0	0
GSL Knob	0	0													0	0
Console	0	6													0	6
Digital Torque wrench							0	0							0	0
m/c																
B-Pillar							0	0							0	0
Oil Filling Machine			0	0											0	0
Grand Total	43	64	17	59	11	23	6	18	5	14	4	10	3	12	90	200

(c) Data analysis dashboard by types of errors



(d) Root cause analysis dashboard for downtime

(e) Line-wise error classification dashboard



(f) Data acquisition from PLC to Excel Sheet

Fig.3: Analytical & Operational Andon Dashboards

As shown in Figure analytical and operational dashboards developed for tracking the error occurred as per data acquisition sheet by using excel tools as pivot table, V-lookup, add-in counter, timer along with formulation-calculation in excel.

As per root cause detected by system feasibility has been checked for elimination of errors or reducing its frequency.

3. COMPARISON BETWEEN OLD ANDON SYSTEM AND NEW ANDON SYSTEM

Table -2: Comparison between old Andon system and new Andon system

Sr. No.	Old Andon System	New Smart Andon System
1.	In old andon system stoppages due to quality wasn't included.	All type of stoppages are included in new andon system along with respective reasons.
2.	It is traditional type of andon system having seven-segment LED screen as information dashboard.	It is digital andon system consist of digital LED display as a dashboard with detailed information.
3.	Old andon system only used for error detection for real time.	New andon system capable of error detection as well as it shows detailed description for the error.
4.	No local (Shop floor) system which provides real time analysis for time loss	Excel based system which provides real time analysis for time loss with historical data
5.	It does not have such type of dashboards.	New andon system consist line-wise analytical dashboards for categorization of errors and calculating downtime and frequency.
6.	Main dashboard only shows target production and the actual production with total time loss for the shift.	This system can arrange root cause for the time loss in the shift to take remedial actions for reducing downtime.

4. TECHNIQUES USED FOR PRODUCTIVITY ENHANCEMENT

Productivity enhancement can be achieved by 'Time Study' which also called as work measurement technique which essential for betterment in both planning and controlling operations. By A. B. Segur, "Time required for all experts to perform the fundamental motions (processes of work) is constant". Where as per the British Standard Institute the time study is defined as, "The application of techniques designed to establish time for qualified worker to carry out a specified job at a defined level of performance".

There are two major contributions or techniques which used in industry for productivity enhancement are Taylor's method and Gilbreth's method.

Taylor's method is the method in which mainly focused for achieving efficiency in production through the quickness of the operation being done. It is method to reduce operation time by completing steps in the operation less time by training the operator for the task by scientific time studies. Where Gilbreth's method which focused on reducing the number of motions for the operation by eliminating unnecessary steps in the operation process or motion of the operator in the process by scientific motion studies. As Taylor was focused on reducing process time, where Gilbreth tried to make the overall process more efficient. Gilbreth's approach for productivity enhancement is concerned with quality improvement and worker's welfare where in Taylorism workers are less relevant than the profits by increase in productivity.

4.1 Value added Implementations for Downtime Reduction

1. As per feedback given by experts in department of Quality, Maintenance and Operations some modifications proposed and made for maintaining quality by zero defect in operations introducing part picking techniques for operators in assembly line as well as for kitting line for part complexity management.
2. Audit checkpoint divided with assembly lines to reduce response time for reassembly and fitment for defective parts.
3. Also by digitalization and automation introduced in the manufacturing processes with reference to Gilbreth's Therbling manual supervising replaced with the feedback looping for the operations where time loss might be due to work delay by operator. Where hooters added in assembly lines at those operations which gets activated if operator not started operation till half operation time passed.

4.2 Part Complexity Management

About 10 to 13% of partial assembled body goes for rework at audit point due to wrong parts, as different variants of same product have huge verity in colour-code, design and features which results to wrong fitment on body by operator. This complexity can be avoided by introducing picking indication system for the operators where part complexity management required.

Smart Part Complexity Management is achieved by Order Processing System, where it is the process or work-flow associated to the picking, packing and transport of the packed gadgets to assembly line and is a key detail of order achievement. Which can possible by using Pick-to-light system at kitting Area and Assembly line side, where for kitting area the operator have to scan the barrel code of the variant which is generated by MES system for the detection for the parts needed in kitting area and after picking the parts have to give confirmation feedback by pressing push-button. As for line side Pick-to-light integrated with the conveyor system where parts of different variants organized where LED lamp is attached for different parts of variants of the product. And specific lamp gets turn on for specific variant when variant enters in process zone and after picking the parts have to give confirmation feedback by pressing push-button.

(1)

(2)

(3)

(4)

Fig.4: Pick-to-light System at line side and kitting area

4.3 Feedback Looping

With reference to the Gilbreth's Therbling, hooters added in assembly lines to moderate the activities which linked with PLC System as tools, scanners, etc. of operators while working condition, as if operator haven't started working till half of operation time passed away then hooters get activated which notifies the supervisor and the team leader of assembly line. By this automated system looking after the operators is reduced and necessary working gets more time. Also it reduced the frequency of the operation delay by the operators which directly affect as reduce in downtime.

4.4 Energy Management

It is planned as preventive measure for major breakdown of heavy machinery such as motors of the belt conveyors, lifts and chain conveyors. Where power consumption and parameters like actual current, voltage are driven from equipment like motor drive and smart energy meter to the system for data formation for condition monitoring.

5. OBSERVATIONS

As per the gathered data from the smart andon system the feasibility checked for enhancement the process with minor change in the sequence of the operations, training to the operator or introducing new operational way for particular operation.

5.1 Investigation for reduction in downtime as per feasibility

By field survey in TCF Shop error occurred arranged with respective frequency of occurrence as per priority order to reduce downtime and frequency for all stations. Priority decided by operation having high downtime, high frequency of occurrence and simplicity to adapt modifications without disturbing other operations. Work-stations chosen for modifications identified for possible root cause for errors.

Table -3: Prioritized workstations with possible causes for error occurred

Station No.	Operation	Description	Potential cause
T 49	Front Strut fitment	Part genealogy	1. Wrong Colour-code part delivered 2. Scanner malfunction 3. Barcode Error
T 53	Front Airbag fitment	Part genealogy	1. Operation Delay 2. Scanner malfunction 3. Barcode Error
T 56	Tail lamp Body Altroz	Part genealogy	Faulty/ Wrong Colour-code part delivered
UB 23	UJ bolt tightening	DC Tool	Bolt slippage while tightening
UB 22	Banjo bolt tightening	DC Tool	1. Bolt slippage while tightening 2. Under-tightening/Over-tightening due to wrong program selection
UB 48	LHS Tyre Multi-spindle	DC tool	1. Operation delay 2. Tool malfunction
UB 48	RHS Tyre Multi-spindle	DC tool	1. Operation delay 2. Tool malfunction
NML 11	Seat 2nd Row fitment	DC tool	1. Wrong Part 2. Operation Delay
NML 02	Console fitment	Pick to light	Operation Delay
NML 04	GSL Knob assembly	Pick to light	Operation Delay
OML 21	RH Door Load Assist tool	Over travel	1. Tool breakdown 2. Operation Delay 3. Fitment stoppage
OML 21	LH Door Load Assist tool	Over travel	1. Tool breakdown 2. Operation Delay

Table -4: Workstations chosen for reduce frequency of error

Assembly line	Operation	Description	Operation time (T sec)	Practical Operation time ($T+t$ sec)
Trim 1	A Mount fitment	DC tool	100	135
	B Mount fitment	DC tool	100	128
	Battery –ve cable fitment and tightening	Part genealogy	105	113
	Booster fitment	Part genealogy	90	105
	Clutch pedal scanning and fitment	Part genealogy	105	150
Trim 2	Front Airbag fitment	Part genealogy	100	130
	Combi Switch fitment	Part genealogy	100	112
	Front Strut scanning	Part genealogy	70	75
	Head Lamp Altroz	Part genealogy	105	150
	Tail lamp Body Altroz	Part genealogy	105	140
Trim 3	Rear Airbag fitment	Part genealogy	80	100
UB 1	Fuel Tank tightening	DC Tool	105	112
UB 2	Tyre scanning	Part genealogy	90	95
Door	WWR tightening LH Front	DC tool	75	80
	WWR tightening RH Front	DC tool	90	92
NML	Steering Airbag fitment	Part genealogy	90	98
	Co-driver Seat fitment	Part genealogy	105	145
	Console fitment	Pick to light	105	107
	Driver Seat fitment	Part genealogy	105	133
	GSL Knob assembly	Pick to light	90	128
	Steering Wheel scanning and fitment	Part genealogy	90	96

Where, T = Actual Operation Time

t = Time Delay by operator during operation

Stations with higher downtime and frequency of interlock activation selected of remedial actions where the observations shown in graphs below.

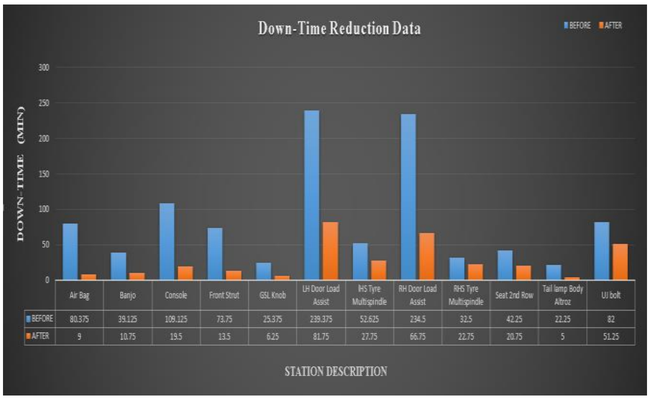


Fig.-5: Downtime comparison before and after implementation

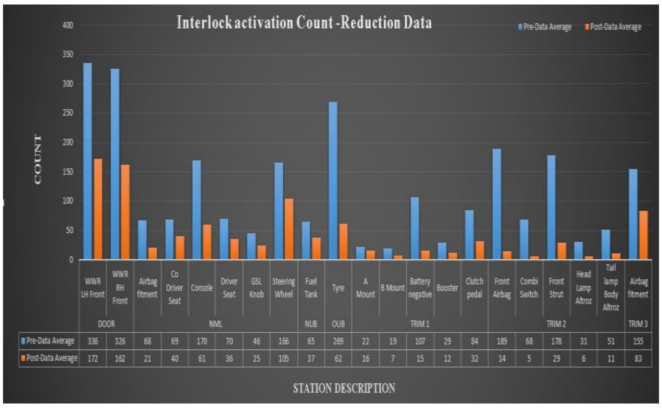


Fig.-6: Comparison of frequency of error occurrence comparison before and after implementation

Table -5: Pre-implementation and Post-implementation Production data

Production data	No of Units Produced			
	Average -Shift A	Average-Shift B	Total	Efficiency
Pre-implementation	184	175	359	71.8%
Post-implementation	216	195	411	82.2%

6. CALCULATIONS:

Overall Equipment Effectiveness:

Overall Equipment Effectiveness is an indicator for how efficient the operation process is.

OEE = Availability x Performance efficiency x Quantitative efficiency

$$\textbf{Availability} = \frac{\text{Net Production time} - \text{Downtime per shift}}{\text{Total time available}}$$

$$= \frac{440 - \frac{\text{Downtime}}{2}}{450}$$

$$\textbf{Performance efficiency} = \frac{\text{Actual Production}}{\text{Maximum Production Possible}}$$

$$= \frac{\text{Actual Production}}{275}$$

$$\textbf{Quantitative efficiency} = \frac{\text{Actual Production}}{\text{Target production}}$$

$$= \frac{\text{Actual Production}}{275}$$

$$\text{Ideal OEE} = \frac{440 - \frac{\text{Downtime}}{2}}{450} \times \frac{\text{Actual Production}}{275} \times \frac{\text{Actual Production}}{250}$$

$$= \frac{440 - 0}{450} \times \frac{250}{275} \times \frac{250}{250} = 0.88$$

Ideal OEE = 88%

Net Production time available = 440 min.

Target for the production = 250 units.

The total time available = 450 min per shift.

Actual Production (before implementation) = 359/2 units

= 180 units.

Actual Production (after implementation) = 411/2 units

= 206 units.

$$\text{Performance Efficiency (before implementation)} = \frac{180}{275}$$

= 0.654

= 65.4%

$$\text{Performance Efficiency (after implementation)} = \frac{206}{275}$$

= 0.749

= 74.9%

$$\text{Quantitative Efficiency (before implementation)} = \frac{180}{250}$$

= 0.72

= 72%

$$\text{Quantitative Efficiency (after implementation)} = \frac{206}{250}$$

= 0.824

= 82.4%

Table -6: Calculated Availability for operations

Operation	Availability	
	before Implementation	After Implementation
Front Strut fitment	0.81	0.95
Front Airbag fitment	0.80	0.96
Tail lamp Body Altroz	0.93	0.97
UJ bolt tightening	0.80	0.86
Banjo bolt tightening	0.89	0.95
LHS Tyre Multi-spindle	0.86	0.92
RHS Tyre Multi-spindle	0.91	0.93
Seat 2nd Row fitment	0.88	0.93
Console fitment	0.74	0.93
GSL Knob assembly	0.92	0.96
RH Door Load Assist tool	0.46	0.83
LH Door Load Assist tool	0.45	0.80

Table 7 Calculated OEE for work-station

Operation	Overall Equipment Effectiveness	
	before Implementation	After Implementation
Front Strut fitment	0.383244	0.584945698
Front Airbag fitment	0.3763116	0.591117458
Tail lamp Body Altroz	0.4371336	0.596603467
UJ bolt tightening	0.3746112	0.533171489
Banjo bolt tightening	0.4194756	0.588717329
LHS Tyre Multi-spindle	0.4053492	0.565401791
RHS Tyre Multi-spindle	0.426408	0.572259302
Seat 2nd Row fitment	0.4162056	0.575002307
Console fitment	0.3462276	0.576716684
GSL Knob assembly	0.4338636	0.594889089
RH Door Load Assist tool	0.21513984	0.511913204
LH Door Load Assist tool	0.209934	0.491340671
AVERAGE	0.37032532	0.565173207
	37.03%	56.52%

7. CONCLUSIONS

- Excel Based system to provide real-time analysis of time-loss with the error detection established and validated in TCF.
- Audit Check 'OK' has been increased by 5-10% which was requirement of quality.
- The rise in Production clearly seen as for Shift A is 13% and for Shift B is 09%
- 100% Energy Consumption data for sub-stations can be moderate through MES.
- Average overall equipment effectiveness increased by 19.49%

8. Scope for future work

- Results as per the expectations ensures the proposed architecture development which further continued with Industry 4.0 Megaproject in the organization.
- Development for the Alternative of HMI Screen can be possible through referencing this work as it allows to customisation as per requirement of user with scope of development without dependency.
- Data transfer to excel through PLC can increase scope of condition monitoring of different appliances with communication to drive & parameter monitoring is possible of the appliances.

9. REFERENCES

1. Susana G. Azevedoa, Kannan Govindan, Helena Carvalho (2011) "An integrated model to assess the leanness and agility of the automotive industry", Resources, Conservation and Recycling 66 (2012) 85–94
2. Amir Azizi (2015) "Evaluation Improvement of Production Productivity Performance using Statistical Process Control, Overall Equipment Efficiency, and Autonomous Maintenance", 2nd International Materials, Industrial, and Manufacturing Engineering Conference, MIMEC2015, 4-6 February 2015, Bali Indonesia
3. Enrico Franza, Felix Erlerb , Tino Langera , Andreas Schlegela and Johannes Stold (2017) "Requirements and tasks for active energy management systems in automotive industry", 14th Global Conference on Sustainable Manufacturing, GCSM 3-5 October 2016, Stellenbosch, South Africa, Procedia Manufacturing 8 (2017) 175 – 182
4. Patrik Fager , Robin Hanson, Lars Medbo, Mats I. Johansson (2019) "Kit preparation for mixed model assembly – Efficiency impact of the picking information system", Computers & Industrial Engineering 129 (2019) 169–178
5. Shohin Aheleroffa, Xun Xua, Yuqian Lua and Mauricio Aristizabal (2020) "IOT-enabled smart appliances under industry 4.0: A case study", Advanced Engineering Informatics 2020 Computers and Electrical Engineering 87 (2020) 106772
6. Yasir Shahzada, Huma Javeda, Haleem Farmanb, Jamil Ahmad (2020) "Internet of Energy: Opportunities, applications, architectures and challenges in smart

industries", Computers and Electrical Engineering 86 (2020) 106739
7. Zhang, X., Ming, X. (2020) "An implementation for Smart Manufacturing Information System (SMIS) from an industrial practice survey", Computers & Industrial Engineering, 2020.106938
8. Xue-Feng Shaoa, Wei Liua, Yi Lia, Hassan Rauf Chaudhryb and Xiao-Guang Yue (2020) "Multistage implementation framework for smart supply chain management under industry 4.0", Technological Forecasting & Social Change 162 (2021) 120354
9. Mahak Sharma, Sachin Kamble, Mani Venkatesh, Rajat Sehrawat, Amine Belhadi, Vardaan Sharma (2020) "Industry 4.0 adoption for sustainability in multi-tier manufacturing supply chain in emerging economies", Journal of Cleaner Production 2020.125013
10. Abdur Rahim, Arafatur Rahman, M.M. Rahman, A. Taufiq Asyhari, Zakirul Alam Bhuiyan, D. Ramasamy (2020) "Evolution of IOT-enabled connectivity and applications in automotive industry: A review", Vehicular Communications, 2020.100285
11. Daniel Ibaseta, Andrés García, Martín Álvarez, Belén Garzón, Fidel Díez and Julio Molleda(2020) "Monitoring and control of energy consumption in buildings using WOT: A novel approach for smart retrofit", Sustainable Cities and Society 65 (2021) 102637
12. Shishir Muralidhara, Niharika Hegde, Rekha PM (2020) "An internet of things based smart energy meter for monitoring device-level consumption of energy", Computers and Electrical Engineering, 87 (2020) 106772
13. Alok Mathur, G. S. Dangayach, M. L. Mittal and Milind Sharma (2011) " Performance measurement in automotive manufacturing", Measuring Business Excellence, Vol. 15 Iss 1 pp. 77-91
14. Damilare T. Onawoga and Olasunkanmi O. Akinyemi (2013) "Minimizing Incident Stoppages on Critical Equipment by Inspections and Planning", The Pacific Journal of Science and Technology, Volume 14, 280804004
15. P. Muchiri A. and L. Pintelon (2008) "Performance measurement using overall equipment effectiveness (OEE): literature review and practical application discussion", International Journal of Production Research, Vol. 46, No. 13, 1 July 2008, 3517–3535
16. Madhav Prasad Nepal and Moonseo Park (2004) "Downtime model development for construction equipment management", Engineering, Construction and Architectural Management Volume 11 · Number 3 · 2004 · pp. 199–210