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PLANT LAYOUT OPTIMIZATION THROUGH EVALUATION OF PLANT CAPABILITY USING DMAIC METHODOLOGY

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Abstract

In the present scenario manufacturing capability is maximum output that an industry can produce in a given period with available resources. The important parameters which affect the capacity in negative way are increase in break time, downtime, repair time and many other minor factors. A case study is done in an automotive industry with the objective of evaluating production capacity of a plant to find the factors which constitute a major part of total breakdown. Efforts are made to reduce the idle time in the assembly shop. The causes for breakdown are identified and analyzed through DMAIC methodology, so that no idle time is required due to breakdown or for repair work. During primary investigation, rework time required to remove scratches and dents of door due to flaws in door hanger fixture constituted a major part of total breakdown. The idle time at transfer area also play an important role in restricting productivity. This research work is carried out at Nissan Motor India Pvt. Ltd, Chennai with a view of optimizing the production to achieve set target. The results revealed a remarkable improvement in productivity and also a new door hanger fixture has been designed, developed and implemented to reduce scratches and dents on doors.

Keywords: Optimization, Plant layout, DMAIC, Cycle time, Defects, Productivity

INTRODUCTION

In several manufacturing areas at present, real challenges are arising for the improvements such as downtime reduction, quality improvement, efficiency improvements, cycle time reduction etc. Six Sigma's most common and well-known methodology is its problem-solving DMAIC (Define-Measure-Analyze- Improve- Control) approach. Six sigma is structured methodology that focuses on reducing variation, measuring defects and improving the quality of products, processes and services. The six sigma process has a 99.99966% defect free rate. This is equivalent to 3.4 DPMO (defects per million opportunities) or single defect for every 294000 units. It has been on an incredible run over 25 years, producing significant savings to the bottom line to the bottom line of many large and small organizations. The visualized DPMO by using six sigma 3.4 is shown in following Figure 1. Motorola implemented Six Sigma companywide in 1987~1997, and this practice has caused its stock price grown more 21% every year, and it also records as high as 17 billion in saving.

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Many more companies have also had positive results with Six Sigma. At the Schaumburg, Illinois facility, ten years after implanting Six-Sigma, great successes were seen. Though Fredrick Taylor, Walter Stewart and Henry Ford played a great role in the evolution of Six-Sigma in the early twentieth century, it is Bill Smith, Vice President of Motorola Corporation, who is considered as the Father of Six sigma.

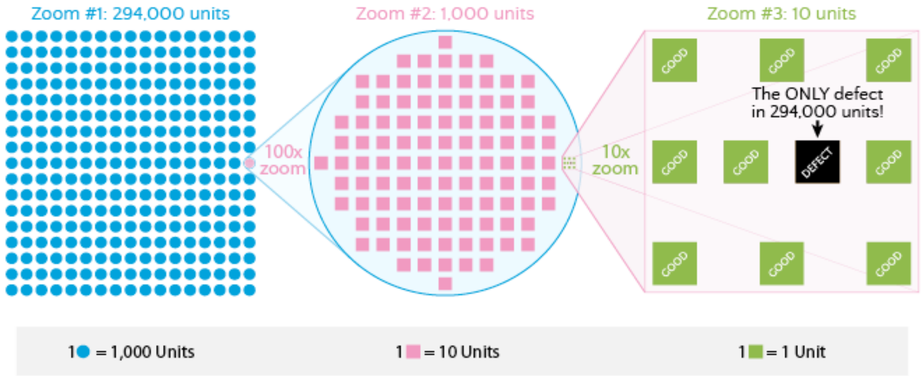

Figure 1. DPMO Visualized by Six Sigma 3.4

LITERATURE REVIEW

As per Toyota's production system, lean manufacturing can be defined as 'A systematic approach to identifying and eliminating wastes through continuous improvement by making the product at the pull of the customer in pursuit of perfection'. Waste can be eliminated and lean development can be achieved by various tools such as 5S, Kanban, Kaizen, Value stream mapping and Work standardization [1-5]. VSM is a process for analyzing the current scenario and to design a future scenario for framing the sequence of activities that takes a product from its beginning through to the consumer. VSM is used as a main tool to identify the opportunities for various lean techniques. Different research articles have discussed the various applications of VSM technique like aircraft, supply chain, logistics, healthcare, service related industries and information flow analysis in different manufacturing industries [6-10]. A supply chain model was to achieve success in agile supply chain where the system should adapt to changes immediately and the stakeholder should possess knowledge about the various stages of the supply chain and share the information at the right time to sustain the agility in the supply chain was proposed [11-15]. Multi objective mixed-integer linear program with total cost, total flow time, and total lost sales as key objectives was developed for addressing production, distribution, and capacity planning of global supply chains by considering cost, responsiveness, and customer service levels simultaneously [16-20]. A customized Artificial Neural Network (ANN) model that allows changes for the decision-making process was proposed. The model employed with fuzzy analytics hierarchy process (FAHP) for determining the relative weights of the attributes used posteriorly in the ANN model with back propagation learning [21-24]. The inventory management practices of various companies and institutions were studied and compared with necessary suggestions for improvement using the ABC analysis inventory management method. The ABC analysis was found to be useful to most of the companies already in usage of this tool either manually or with an enterprise resource planning system [25-29]. Projects were undertaken to identify areas in the process where extra expenses did exist and introduced appropriate measurement system, which reduced expenses on production times. The variables influencing the chosen characteristics and then optimized the process in a robust and repeatable way were represented and focused on what six sigma is today and its roots in both Japan and in the west and what Six-Sigma offers the world today. A distinct methodology for integrating lean

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manufacturing and Six –Sigma philosophies in manufacturing facilities were highlighted [30-32]. Based on the above literature a study was made on optimization of plant layout using DMAIC methodology in an automotive industry.

METHODOLOGY

To implement Six-Sigma, it must follow DMAIC approach step-by step is shown in Figure 2. This approach is briefly described for the concerned organization. Lack of proper analysis may lead to the process to a wrong way, which will deviate from the main function of improvement. Every successful work goes on some specific sequence. This work also completes some specific step. After completing each successful step, it is necessary to move next step. Methodologically the total process of the work is divided into two basic stages, Measurements and Improvements. The DMAIC is a basic component of Six-Sigma methodology- a better way to improve work process by eliminating the defects rate in the final product.

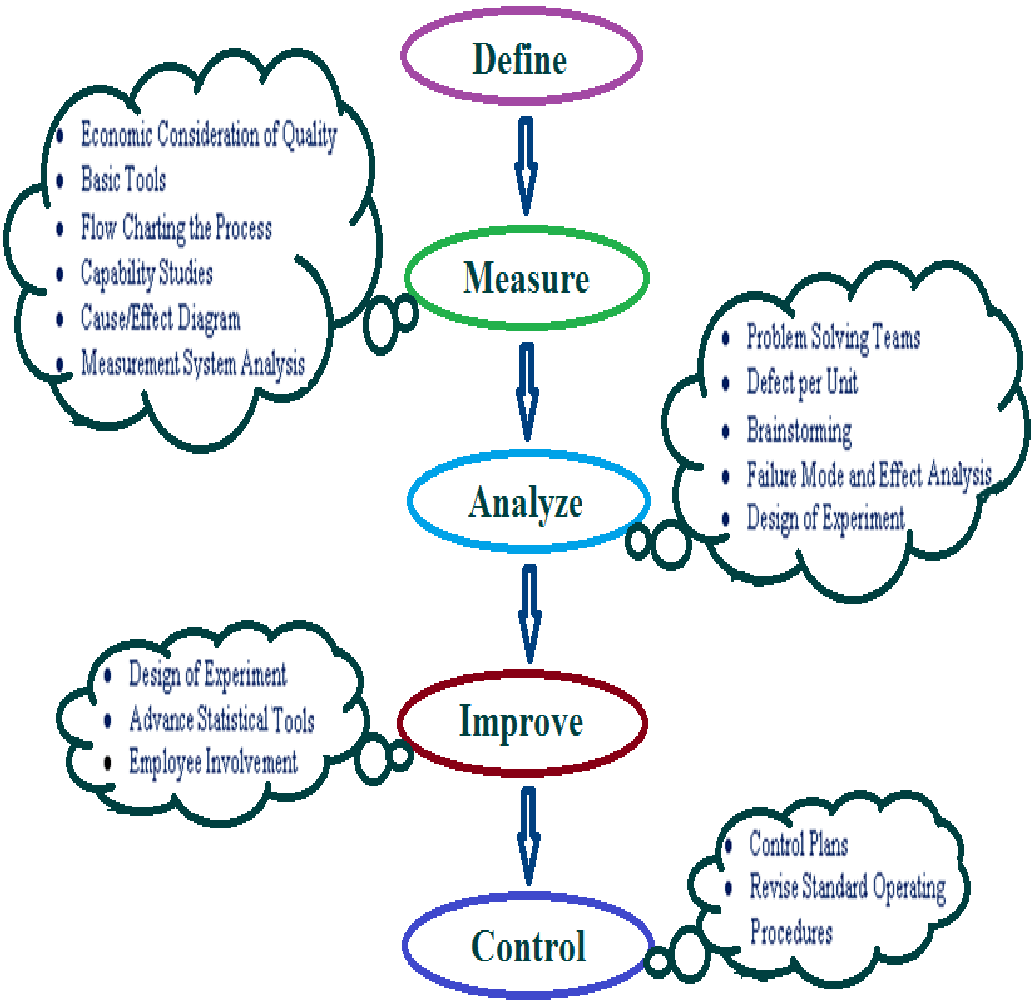

Figure 2. DMAIC Methodology for Operation Six Sigma Scheme

DATA COLLECTION AND ANALYSIS

Case study is performed at Nissan Motor India Pvt. Ltd., Pune. It has Tact/TAKT time of 115 seconds which indirectly means capacity of producing 31 JPH (Jobs per Hour). To check whether production is as per set target or not, a plant capacity evaluation was done in the assembly shop of the automobile pioneer, Nissan Plant, Chennai. The overall assembly

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section layout of the plant is shown in Figure 3. Capacity evaluation focused over TAKT times, transfer times, lifter times. This calculated time is compared with ideal timings. The comparison brought various takts, defects under light which lead to breakdowns or increase in repair time.

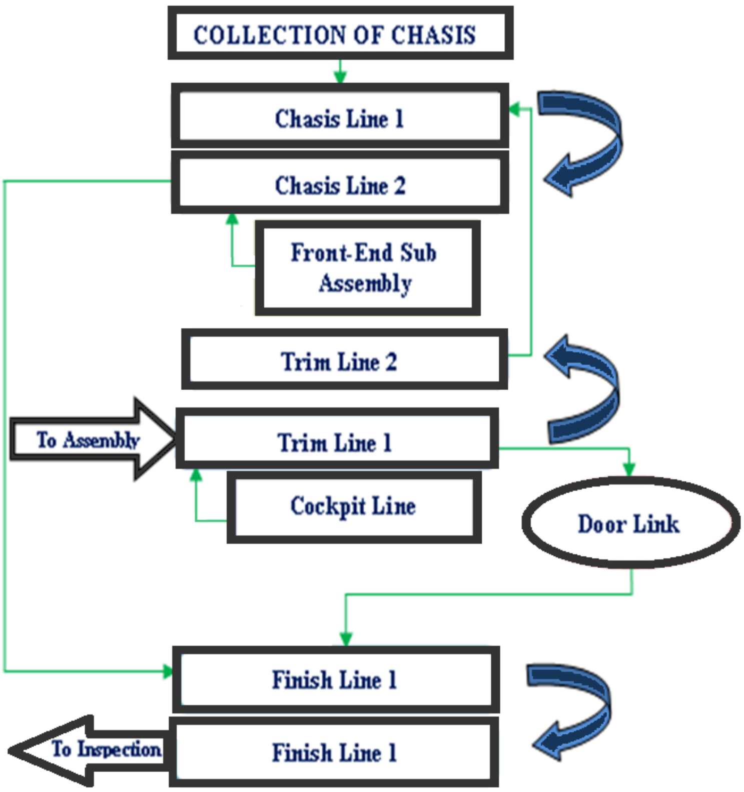

Figure 3. Over View of Assembly Shop Layout

TAKT TIME ANALYSIS

TAKT demonstrates the rate at which the customer buys the product. TAKT reflects the frequency at which the product has to come out of the manufacturer to meet the customer demand. TAKT time is calculated by dividing available working time per shift (in min) with the customer demand per shift.

Working shift per day	= 1
Working hours per shift	= 8 hours (480 minutes)
Tea break per shift	= 1 breaks * 10 minutes = 10 minutes
Lunch break per shift	= 50 minutes
Net Available time per shift	= [available time-(breaks+break down)]
	= 480-60 = 420 minutes
Customer demand per day	= 32 No's
TAKT time	= (Valuable Production Time)/(Customer Demand)
	= 420/256 = 1.640 minutes = 98 seconds

The TAKT time require to meet the customer demand is calculated and found to be 98 seconds.

Rework Statistics: Number of scratches for January 2016 to December 2016 is shown in following chart. The chart concludes that the total number of scratches were around 1480 for the past calendar year. A company of Nissan Motor India Pvt. Ltd. reputation are not

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habituated for frequent rework, also cannot compromise with quality. What does 1 scratch mean? It means increase in cost as well as increase in repair time for an industry which produces a car every 115 sec. The month wise total no. of defects for the year of 2016 is shown in Figure 4.

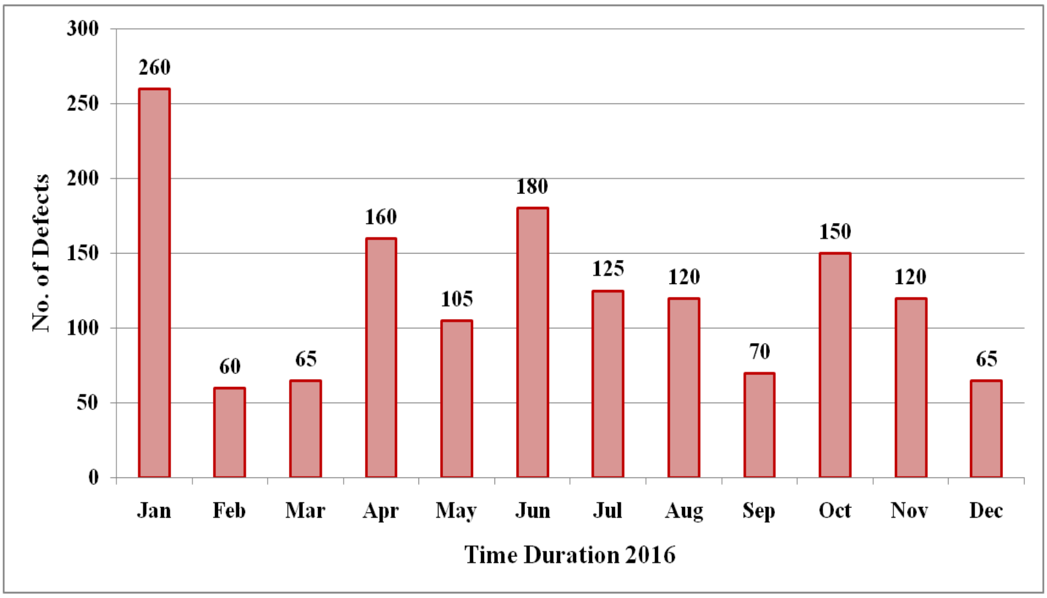

Figure 4. Month Wise Number of Defects in 2016

A fishbone diagram is developed which shows the cause-and effects chains that affect the variation in cycle time Figure 5. Based on surveys and interviews with engineers and field supervisors, we found that the resource buffer size has the most critical influence on the cycle time variation of assembly work. In other words, the buffer size optimization will increase the sigma level through Critical to Quality (CTQ) improvement. Accordingly, the sigma level improvement will increase the process performance as well.

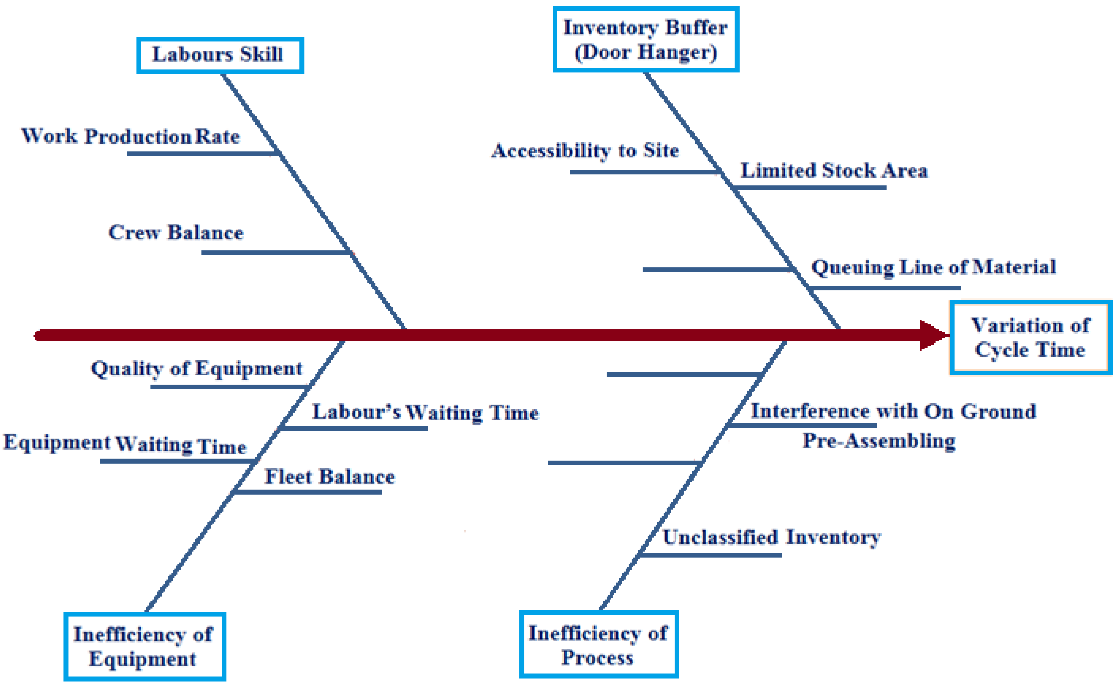

Figure 5. Factors Influencing Cycle Time Variation

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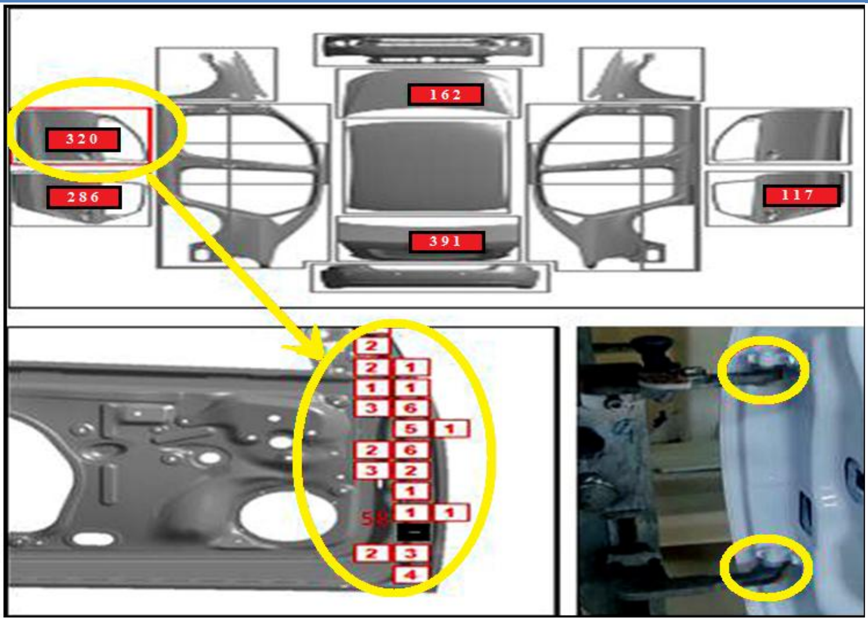

Figure 6. Number of Scratches during Jan 2016 to July 2016 Door Wise

The door wise number of scratches during January 2016 to July 2016 is shown in Figure 6. The results revealed that the time for rework of doors constituted a major part of total down time. The problems identified were:

- Scratches were induced in bottom half of doors.
- Frequent wearing of protective caps
- Difficulties in loading and unloading of doors

Heavy investigation was performed to root out causes of door hanger arm which led to scratches and difficulties for mounting and unmounting of doors on hangers. The root causes were as follows:

- Frequent wearing of protective caps exposed metallic nuts to bottom half of door which led to scratches on vibration.
- The gap between door hanger's arm and door was less enough to cause an issue during locking and unlocking of doors shown in Figure 7.

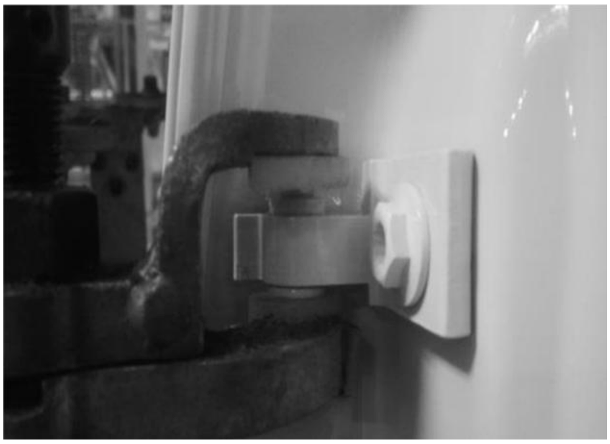

Figure 7. Gap between Door and Locking Nut

Proposed Improvements: After thorough research through plant capacity evaluation, it was decided to redesign the fixture. The points covered were

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- Protective cap were replaced by PU coating which has excellent chemical resistance, reduced chances of wearing and hence, exposing nuts to doors is shown I the Figure 8.
- Collar of bushes were to be reduced by 2 mm to 6 mm. this increased the gap between doors and door holding arms.
- Metallic nuts were replaced by Nylon-6 nuts which completely eliminates possibility of scratches.

Figure 8. Increased Gap between Door and Locking Nut

A fishbone diagram Figure 9 shows the items that cause the variations of the employee working time. Based on the surveys and interviews with engineers and field supervisors, and from the analysis of the crew balance chart, we found that the moving direction of door hanger and balanced rations of workers are the major areas that mostly affect the variation of labor working time.

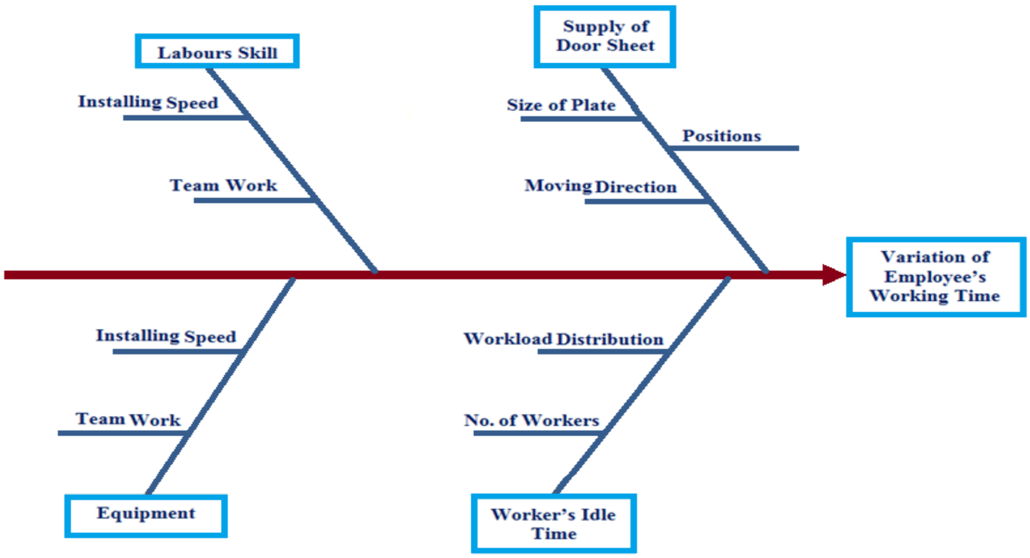

Figure 9. Factors Influencing Changes of Employees Working Time

Finalized Process Sheet: The comparison of bracket fixture before and after milling and plating operations is shown in Figure 10. The different processes are hinge bracket up and down are dissembled from door hangers, protective caps are removed and forwarded for milling, in milling thickness is reduced to 1.6 mm from 3.5 mm. and then undergoes chemical plating to get even surface and better corrosion resistance, after plating, the brackets are

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forwarded to moulding where small nylon-6 balls with color powder are heated, melted and poured in the mould, to get desired PU coating and moulded brackets fixture are then assembled and checked for ease of mounting and unmounting of doors from hangers during locking and unlocking respectively.

Figure 10. Bracket Fixture Comparison after and before Milling and Plating

Cost Analysis: The maintenance cost for temporary repair work, removal of scratches and labour was around EUR 4760 per month and rework cost for each hanger costs EUR 234.9 and has payback period of 7.4 months. The implementation cost, rework cost and expenditure cost are given in Table 1, Table 2 and Table 3 respectively.

Table 1. Implementation Cost

Sl. No.	Nature of Work	Cost (Rs.)
1	Door Hanger Fixture Rework Cost	17,408/-
2	Total Coat for 150 Hangers Development	26,11,206/-

Table 2. Rework Cost

Sl. No.	Type of Cost	Labor Cost (Rs.)	Total Cost (Rs.)
1	Maintenance Cost per Month	43,520/-	3,55,602/-
2	Rework Cost	0	0
Total			3,55,602/-

Table 3. Payback Period

Sl. No.	Expenditures	Cost (Rs.)
1	Investment	26,40,745/-
2	Expenses	0
3	Total	26,40,745/-
Payback		6.9 Months

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RESULTS

The door wise number of scratches November 2017 to February 2018 is given in Figure 11 and the major benefits achieved like elimination of door scratches, elimination of continuous replacement of door hanger parts and reduction in maintenance cost. The observed results of the modified door hanger fixture implementation are given in the Table 4.

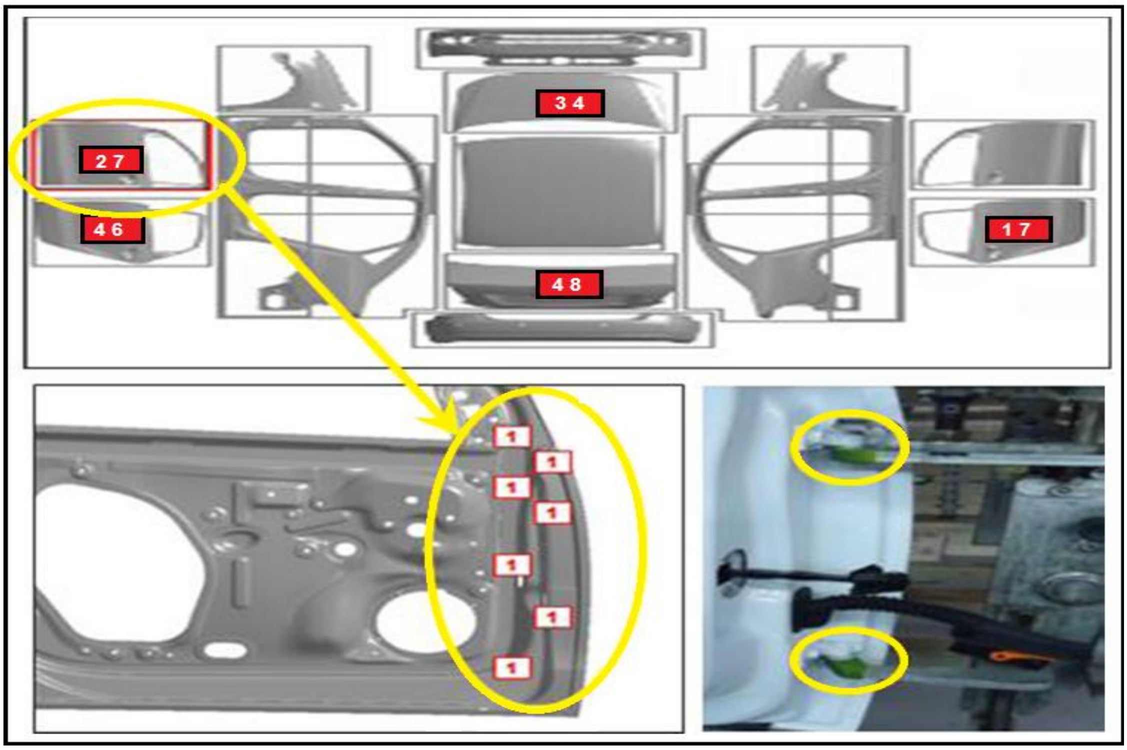

Figure 11. Number of Scratches Oct 2017 to Jan 2018 Door wise

Table 4. Results after Modified Door Hanger Fixture Implementation

Week No.	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13
Total No. of Defects	4	4	6	9	SD	11	12	12	14	12	15	10	9
Cumulative Defects	4	8	14	23	23	34	46	58	72	84	99	109	118

The number of defects for the period of May 2017 to January 2018 was calculated after implementing the modified door hanger fixture. Especially in October 2017 only 8 hangers were modified but subsequently in January 2018 the number of modified hangers are 112. The graphical representation of modified door hanger during 2017-18 is shown in the following Figure 12. An attempt has been made to improve the productivity and profitability of the industry. The key to any successful project is to meet both budget and schedule requirements. Also, in order for project plan to be reliable, it needs to follow a control mechanism to achieve project goals. This research work demonstrated the applications of plant capacity evaluation in order to find defects, problems, its causes and remedies for productivity enhancement. The objective of case study done at Nissan Motor India Pvt Ltd, Chennai was to eliminate rework required due to the improper design of door hanger arm. The case study resulted in cost saving of Rs. 3, 55, 602/- per month. Also the implementation of improved door arm fixture reduces the motion waste and monotonous efforts of the labors

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which further enhances the labors job satisfaction and goodwill of the organization.

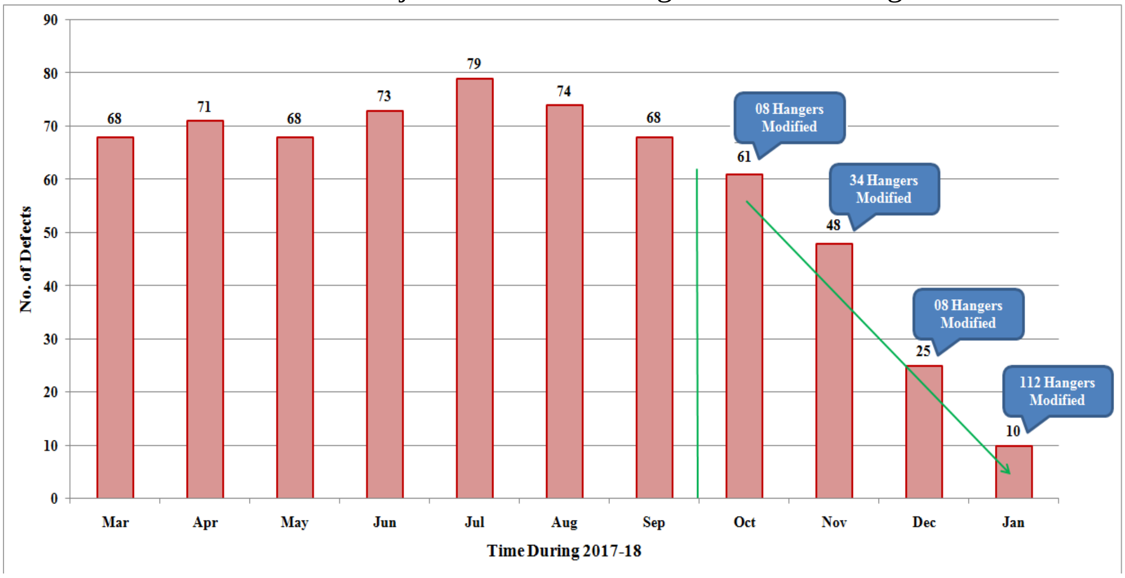

Figure 12. Defects on Door Hanger Protection Customized during 2017-2018

CONCLUSION

A study was carried out in an automotive industry with the objective of evaluating the plant production capacity to find the factors which constitute a major part of total breakdown. Efforts were made to reduce the idle time in the assembly shop. The causes for breakdown were identified and analyzed through DMAIC methodology hence no idle time is required due to breakdown or for repair work. Based on the observed results the following conclusions and recommendations were listed as follows:

- Implementation of modified door hanger is reduced the number of defects in the door from 58 to 7 during October 2017 to January 2018.
- Implementation of TAKT time will improve overall work in progress efficiency to a good value. It helps to decrease the work in progress between the stages and finished goods inventory.
- TAKT time policy has no significant impact on the overall equipment effectiveness as it is primarily depends on quality and system reliability.
- The plant capacity evaluation reveals that there is scope for improvement in transfer time between trim lines. It has contributed second largest to the total downtime with 2163 minutes of break time.
- With objective of producing 32 Jobs per hour, industry need to focus on various TAKT's and transfer times which are consuming unnecessary or exceeding TAKT time of 98 seconds.

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